TELEHEALTH IN PEDIATRICS

EDITED BY: Tzielan Lee and Mark Lo
PUBLISHED IN: Frontiers in Pediatrics

frontiers Research Topics

ISSN 1664-8714
ISBN 978-2-88976-448-8
DOI 10.3389/978-2-88976-448-8

About Frontiers

Frontiers is more than just an open-access publisher of scholarly articles: it is a pioneering approach to the world of academia, radically improving the way scholarly research is managed. The grand vision of Frontiers is a world where all people have an equal opportunity to seek, share and generate knowledge. Frontiers provides immediate and permanent online open access to all its publications, but this alone is not enough to realize our grand goals.

Frontiers Journal Series

The Frontiers Journal Series is a multi-tier and interdisciplinary set of open-access, online journals, promising a paradigm shift from the current review, selection and dissemination processes in academic publishing. All Frontiers journals are driven by researchers for researchers; therefore, they constitute a service to the scholarly community. At the same time, the Frontiers Journal Series operates on a revolutionary invention, the tiered publishing system, initially addressing specific communities of scholars, and gradually climbing up to broader public understanding, thus serving the interests of the lay society, too.

Dedication to Quality

Each Frontiers article is a landmark of the highest quality, thanks to genuinely collaborative interactions between authors and review editors, who include some of the world's best academicians. Research must be certified by peers before entering a stream of knowledge that may eventually reach the public - and shape society; therefore, Frontiers only applies the most rigorous and unbiased reviews.
Frontiers revolutionizes research publishing by freely delivering the most outstanding research, evaluated with no bias from both the academic and social point of view. By applying the most advanced information technologies, Frontiers is catapulting scholarly publishing into a new generation.

What are Frontiers Research Topics?

Frontiers Research Topics are very popular trademarks of the Frontiers Journals Series: they are collections of at least ten articles, all centered on a particular subject. With their unique mix of varied contributions from Original Research to Review Articles, Frontiers Research Topics unify the most influential researchers, the latest key findings and historical advances in a hot research area! Find out more on how to host your own Frontiers Research Topic or contribute to one as an author by contacting the Frontiers Editorial Office: frontiersin.org/about/contact

TELEHEALTH IN PEDIATRICS

Topic Editors:
Tzielan Lee, Stanford University, United States
Mark Lo, University of Washington, United States

Citation: Lee, T., Lo, M., eds. (2022). Telehealth in Pediatrics.
Lausanne: Frontiers Media SA. doi: 10.3389/978-2-88976-448-8

Table of Contents

frontiers in Pediatrics

ORIGINAL RESEARCH
published: 03 March 2021
doi: 10.3389/fped.2021.642369

Evaluating Patients' and Neonatologists' Satisfaction With the Use of Telemedicine for Neonatology Prenatal Consultations During the COVID-19 Pandemic

*Maria C. Lapadula[1], Shanna Rolfs[2], Edgardo G. Szyld[1], Gene Hallford[1], Tracie Clark[1], Mike McCoy[1], Stephanie McKnight[1] and Abhishek Makkar[1]**

[1] *Division of Newborn Medicine, Department of Pediatrics, University of Oklahoma Health Sciences Center, Oklahoma City, OK, United States,* [2] *University of Oklahoma College of Medicine, Oklahoma City, OK, United States*

Background: During the COVID-19 pandemic, telemedicine plays a critical role in providing safe, effective healthcare services, while reinforcing social distancing and optimizing the use of personal protective equipment. In this context, the Oklahoma Children's Hospital implemented virtual neonatology prenatal visits for pregnant women with a diagnosis of fetal anomalies. While tele-consultations have been broadly used with a high degree of acceptance in rural and remote areas, satisfaction has not been assessed in this particular scenario, where patients and physicians discussing sensitive healthcare information had to rapidly adjust to this new modality.

Objectives: To evaluate patients' and neonatologists' satisfaction with virtual prenatal consultations in the context of the COVID-19 pandemic and to compare satisfaction levels of patients receiving virtual consultation with those receiving in-person consults.

Methods: This cross-sectional study evaluated patients' and neonatologists' satisfaction with virtual consultations. Participants included pregnant women with diagnosis of fetal anomalies who received neonatology prenatal consultations at Oklahoma Children's Hospital, either in-person or through telemedicine, from May to mid-November 2020, and neonatologists providing virtual prenatal consultations in the same period. Virtual visits were delivered via Zoom Pro^{TM}. Patients and physicians who agreed to participate rated acceptability completing an anonymous 5-point Likert scale survey. Item frequencies and means for categories of items were computed by group (video-consult patients, in-person patients, physicians) and analyzed, using Welch's t for unequal sample size.

Results: Overall consultation quality was rated good or excellent by 35 (100%) video-consult patients and 12 (100%) in-person patients. Patient group means computed on six 5-point Likert items about patient-physician communication did not differ significantly, video-consult: $M = 28.71$ (2.22); in-person consult: $M = 28.92$ (1.78) ($p = 0.753263$). All eight physicians (100%) agreed or strongly agreed that telemedicine was effective, using a 5-point Likert scale, and their combined consultation quality score computed on 10 survey questions was high: $M = 46.4$ (3.11).

OPEN ACCESS

Edited by:
Mark Lo, University of Washington, United States

Reviewed by:
Daniele Trevisanuto, University Hospital of Padua, Italy
Silvia Salvatore, University of Insubria, Italy

***Correspondence:**
Abhishek Makkar
abhishek-makkar@ouhsc.edu

Specialty section:
This article was submitted to Neonatology, a section of the journal Frontiers in Pediatrics

Received: *15 December 2020*
Accepted: *10 February 2021*
Published: *03 March 2021*

Citation:
Lapadula MC, Rolfs S, Szyld EG, Hallford G, Clark T, McCoy M, McKnight S and Makkar A (2021) Evaluating Patients' and Neonatologists' Satisfaction With the Use of Telemedicine for Neonatology Prenatal Consultations During the COVID-19 Pandemic. Front. Pediatr. 9:642369. doi: 10.3389/fped.2021.642369

Conclusion: Despite patient inexperience with tele-consultations, the quick implementation of telemedicine, and the sensitive reason for the visit, patients and physicians were highly satisfied with virtual visits. Telemedicine is a safe, effective alternative for providing neonatology prenatal consultations for pregnant women with diagnosis of fetal anomalies during the pandemic.

Keywords: telemedecine, neonatology prenatal consultation, satisfaction survey, virtual prenatal visits, COVID-19 pandemic

INTRODUCTION

The use of telecommunication technologies for medical purposes in the US date to the late 1950s (1). In the last three decades, with the proliferation of personal computers in the 1990s and more recently with smartphones, telemedicine became more popular. Research has found a high degree of acceptance among patients and providers, especially in rural and remote areas where access to specialists is limited (2–5). Virtual consultations have already been applied across different medical fields and have been shown to be effective and safe when used in appropriate clinical scenarios (6, 7).

The emergence of the novel coronavirus pandemic led to rapid and substantial changes in the way ambulatory care is delivered. The scope of telehealth abruptly grew worldwide (8) as a strategy for preventing patients' and providers' viral exposure and preserving personal protective equipment (PPE) while continuing to provide outpatient services. In April 2020, 43.5% of Medicare primary care visits were performed via telemedicine, compared with 0.1% reported in February same year, before the arrival of the COVID-19 pandemic (9). With unprecedented rapidity, all medical specialties adopted telehealth services, which have been shown to be a safe and effective solution to assure continuity of outpatient care, in a massive transition from in-person to virtual visits (10).

On these bases, the Section of Neonatal and Perinatal Medicine at Oklahoma Children's Hospital in Oklahoma City initiated virtual neonatology prenatal consultations for pregnant women with diagnosis of fetal anomalies, beginning in March 2020 (**Figure 1**). In ideal conditions, establishing a valid patient-physician relationship before the provision of telemedicine services is recommended (11). However, the current circumstances make this difficult. The transition to teleconsultations has been particularly challenging for neonatologists since the prenatal consult is typically the first encounter with these patients, and the reason for the visit is to communicate the diagnosis and prognosis of a congenital anomaly.

Delivering bad news is one of a physician's hardest tasks, and empathy and communication skills are essential (12). Since this was our first experience using telemedicine for these complex and sensitive consults and satisfaction has not been addressed in this context, we developed a survey to explore acceptability among users and providers. The purpose of this study was to assess patients' and neonatologists' satisfaction with virtual prenatal consultations during the COVID-19 pandemic.

Abbreviations: PPE, personal protective equipment; PDC, prenatal diagnostic clinic; IRB, institutional review board; CQ, consultation quality.

METHODS

This cross-sectional study assessed satisfaction levels of patients and physicians using telemedicine for prenatal consultations during the COVID-19 pandemic in the Prenatal Diagnostic Clinic (PDC) at Oklahoma Children's Hospital in Oklahoma City. Prior to the project initiation, our research team submitted a plan of study to the Institutional Review Board (IRB) at the University of Oklahoma Medical Center. It was approved and granted a waiver of informed consent (IRB#12187), since no personal identifiers or medical information were to be collected as part of the study. Participation of both patients and professionals was anonymous and voluntary.

Pregnant patients with prenatally diagnosed fetal anomalies and who were seen at the PDC were offered and provided prenatal consultations by neonatologists concerning their baby's diagnosis and anticipated plan of care. Due to the COVID-19 pandemic, neonatologists had the option to provide the visits virtually, using the Zoom Pro^{TM} platform, beginning in March 2020. Physicians received online training on how to use the platform before providing the service. In addition to familiarizing themselves with technology use, physicians were educated about specific requirements with virtual consultations, such as including verbal consent and platform used for the consultation in documentation and using modifier codes for billing. Of the 26 neonatologists within the Section of Neonatal and Perinatal Medicine, eight provided prenatal outpatient consultation service during the study period, having the majority of them performed both virtual and in-person visits. The decision whether or not to participate in virtual, was a matter of individual preference. Although we coordinated efforts for patients to be evaluated by the whole multidisciplinary team on the day they had their regularly-scheduled ultrasound, other specialists (neurosurgeons, obstetricians, pediatric cardiologists, etc.) provided consultation in person at the PDC as they have not implemented tele-consultations at the moment.

Inclusion Criteria

The patient population included pregnant women with fetal anomalies who received prenatal visits with a neonatologist at Oklahoma Children's Hospital from May 1st to November 15th of 2020. Participating providers included neonatologists who

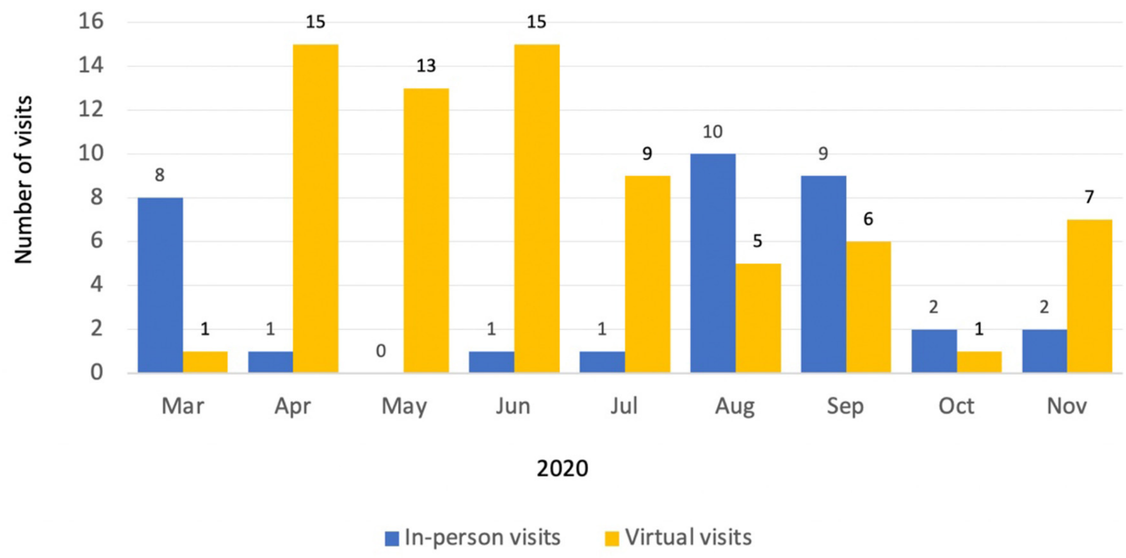

FIGURE 1 | Neonatology prenatal consultations provided at Oklahoma Children's Hospital from March to mid-November 2020.

delivered virtual prenatal consultations in the same time frame. Patients who received in-person consults were considered eligible to participate as a control group.

Virtual Consultation Procedure

Tele-consultations were provided in a dedicated room ensuring patients' privacy and confidentiality via Zoom Pro™. After a patient's regularly-scheduled prenatal ultrasonography imaging, the patient was guided to the consultation room where she and the accompanying spouse or guest were requested to wait. At the time of the consultation, the PDC nurse navigator initiated a Zoom session with the consulting neonatologist and introduced the patient to her/him. Once the communication was established, the nurse navigator provided patients with a plain white envelope containing the anonymous satisfaction survey (**Supplementary Figure A**). Those willing to participate were asked to place the completed survey in a sealed envelope and leave it in a designated drop-box inside the room. At this time, the nurse navigator exited the room. Upon beginning the consultation, the neonatologist verbally consented for the virtual visit via Zoom. At the end of the consultation, the consulting physician notified the nurse navigator via text message that the appointment was over and instructed the patient to return to the waiting room. Then, the PDC nurse navigator wiped down the room and the computer and let the clinic staff know that the patient had returned to the waiting room.

In a similar fashion, patients receiving in-person consultations were given a questionnaire (**Supplementary Figure B**), identical to the one offered to virtual patients but without the questions relating to the telemedicine equipment and experience. This survey was provided to them in a plain white envelope and they were given the opportunity to complete the form and leave it in a designated drop-box in the consultation room. Physicians who provided virtual consultation during the study period received a survey (**Supplementary Figure C**) to be voluntarily filled and placed in a designated drop box.

All patients who received outpatient consultation got to meet their baby's neonatologist as inpatient once they were admitted to the hospital before delivery. At that time, the plan of care that was given to them during their outpatient prenatal consultation visit was reviewed and discussed.

Satisfaction Survey

To address patients' satisfaction, we developed a survey using 5-point Likert scale items addressing perceived quality of care, physician's professional and communication skills, and the technology involved in the consultation. Physicians' satisfaction was measured on 5-point Likert scale items assessing previous experience with telemedicine, overall perception of the quality of healthcare provided, and technical aspects of the communication. Due to the anonymous nature of our survey and the small sample involved, we were not able to identify those physicians, if any, who solely provided virtual consultations or determine the overall demographic characteristics of the physician sample as a whole. We collected surveys from patients and providers involved in virtual visits from May 1st to November 15th of 2020. We obtained surveys from a convenience sample of patients who received in-person prenatal visits in the same time frame. Although no questions were asked about participants' ethnicity, a Spanish language version of the survey, translated by a certified translator, was available.

Statistical Analysis

Frequencies and percentages were computed on all responses from virtual and in-person patients and providers. A composite consultation quality (CQ) score was created by summing participant responses from questions related to patient-physician

TABLE 1 | Patients' demographic variables.

Parameter	In-person $N = 12$ n (%)	Telemedicine $N = 35$ n (%)	P-value
Age in Years			0.261547
Under 20	0	1 (2.86)	
20 to 39	10 (100)	32 (91.42)	
Over 40	0	1 (2.86)	
Did not answer	2	1 (2.86)	
Education			0.618918
Some school	4 (40)	4 (11.43)	
High school graduate	4 (40)	17 (48.57)	
Advanced education	2 (20)	12 (34.26)	
Did not answer	2	2 (5.71)	
English Fluency			0.171628
Yes	8 (66.67)	31 (88.57)	
No (Spanish-speakers)	4 (33.33)	4 (11.43)	

communication. The CQ score included the six questions common to both the virtual and in-person surveys (Questions 2, 3, 4, 5, 6 and 7. See **Supplementary Figure A**). Each question had a possible range of 1 to 5, creating a possible composite score range of 1 to 30. A CQ score was also calculated for physicians; however, it was not statistically compared with the patients' CQ score as the physician survey consisted of different questions. The combined CQ score for physicians was calculated on ten 5-point Likert scale survey questions. Between-group comparisons were made on individual question responses and the composite CQ scores where appropriate, using Welch's t for unequal sample size.

RESULTS

Participants

From May to mid-November, 81 patients received outpatient neonatology prenatal consultations. During that period, 50 patients completed and returned the satisfaction survey, being the overall response rate 61.7% (50/81). As the surveys were anonymous, we do not know the reasons why 31 patients decided not to participate. We speculate that after receiving unfavorable news, the willingness to participate in the study was understandably diminished. Of the 50 patients who completed the survey, 38 received virtual visits and 12 in-person visits. Three of the virtual patients' surveys were incomplete so only 35 were included in the final analysis. As this was a cross-sectional study using an anonymous questionnaire, participant demographic information was limited to age and level of education (**Table 1**). Eight consults were conducted in Spanish by a certified, Spanish-speaking physician. Four (11.43%) virtual consultation respondents and four in-person controls (33.33%) completed the survey in Spanish. English-speaking and Spanish-speaking participants were compared in both virtual and in-person patient groups on all survey questions and the composite CQ score. No statistically significant differences were found on any of these measures (**Tables 2**, **3**).

TABLE 2 | Comparison of English-speaking vs. Spanish-speaking virtual patients (Welch's t-test for unequal N's).

Comparison of English-speaking vs. Spanish-speaking virtual patients				
	English $N = 31$	Spanish $N = 4$	t value	P-value
Question 1	Mean = 4.65	Mean =4.75	0.389950	0.716434
Question 2	Mean = 4.65	Mean =4.50	−0.475708	0.660722
Question 3	Mean = 4.84	Mean = 4.75	−0.342693	0.751686
Question 4	Mean = 4.77	Mean = 4.75	−0.0925573	0.931196
Question 5	Mean = 4.867	Mean = 4.75	−0.452467	0.678318
Question 6	Mean = 4.84	Mean = 4.50	−1.142815	0.328521
Question 7	Mean = 4.84	Mean = 4.75	−0.342693	0.751686
Question 8	Mean = 4.84	Mean = 4.75	−0.321251	0.766393
Question 9	Mean = 4.77	Mean = 4.75	−0.0925573	0.931196
Question 10	Mean = 4.71	Mean = 4.50	−0.689967	0.531244
Question 11	Mean = 4.84	Mean = 4.50	−1.12907	0.330325
Satisfaction score	Mean = 28.81	Mean = 28.25	−0.373977	0.730217

TABLE 3 | Comparison of English-speaking vs. Spanish-speaking in-person patients (Welch's t-test for unequal N's).

Comparison of English-speaking vs. Spanish-speaking in-person patients				
	English $N = 8$	Spanish $N = 4$	T-value	P-value
Question 2	Mean = 4.75	Mean =4.75	0.000000	1.000
Question 3	Mean = 4.88	Mean = 5.00	1.000001	0.350616
Question 4	Mean = 4.88	Mean = 5.00	1.000001	0.350616
Question 5	Mean = 4.75	Mean = 5.00	1.527525	0.170471
Question 6	Mean = 4.63	Mean = 4.50	−0.320061	0.757371
Question 7	Mean = 4.88	Mean = 5.00	1.000001	0.350616
Question 8	Mean = 4.88	Mean = 4.75	−0.447214	0.675132
Satisfaction score	Mean = 29.00	Mean = 29.75	0.941979	0.94197

Over the study period, eight neonatologists provided virtual prenatal consultations, and all completed and returned the anonymous survey. No demographic information was collected as the small sample size would have likely identified participants.

Telemedicine-Related Issues

For 24 of the 35 patients who participated in tele-consultations, it was the first time they had received a virtual doctor's visit. All but one (97.14%) agreed or strongly agreed that they had been told in advance that the meeting with their doctor would take place through a videocall. One survey respondent was unsure whether or not they had been told before the visit. Thirty-four survey respondents (97.14%) reported feeling satisfied about talking with their baby's doctor through a videocall, with one survey completer reporting feeling neutral about the videocall.

All eight physicians agreed or strongly agreed that they had received adequate training in use of the telemedicine system for providing virtual neonatal visits ($N = 8$, 100%). All strongly agreed that the telemedicine system was both reliable and adequate for providing neonatal consults. Further, all agreed and strongly agreed that telemedicine is an effective way of delivering healthcare information to patients, and most agreed or strongly agreed that it is comparable in quality with in-person care ($N = 7$, 87.5%). The physician who felt neutral in that response explained in the comments' section that it would have been nice to be able to hand a tissue to the patient after communicating the news. All agreed or strongly agreed that they felt comfortable providing advice to patients *via* telemedicine, and all believed that it allowed for good patient interaction. As the primary reason for moving to virtual prenatal consults was due to the emergent COVID-19 pandemic, doctors were asked and all agreed or strongly agreed with feeling relieved delivering consults through telemedicine

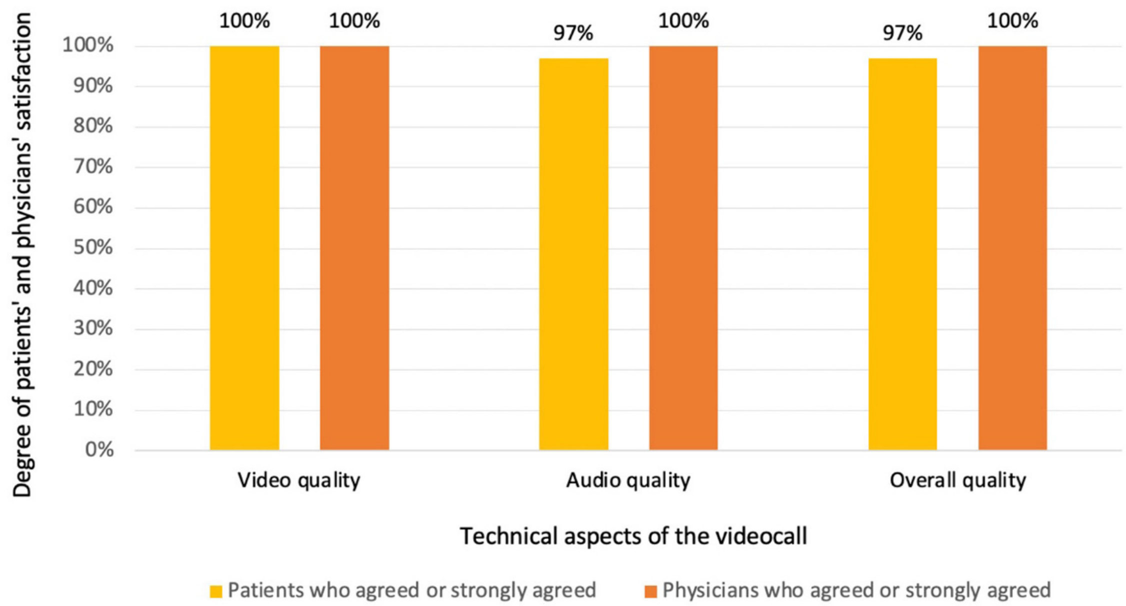

FIGURE 2 | Patients' and physicians' satisfaction with the videocall quality.

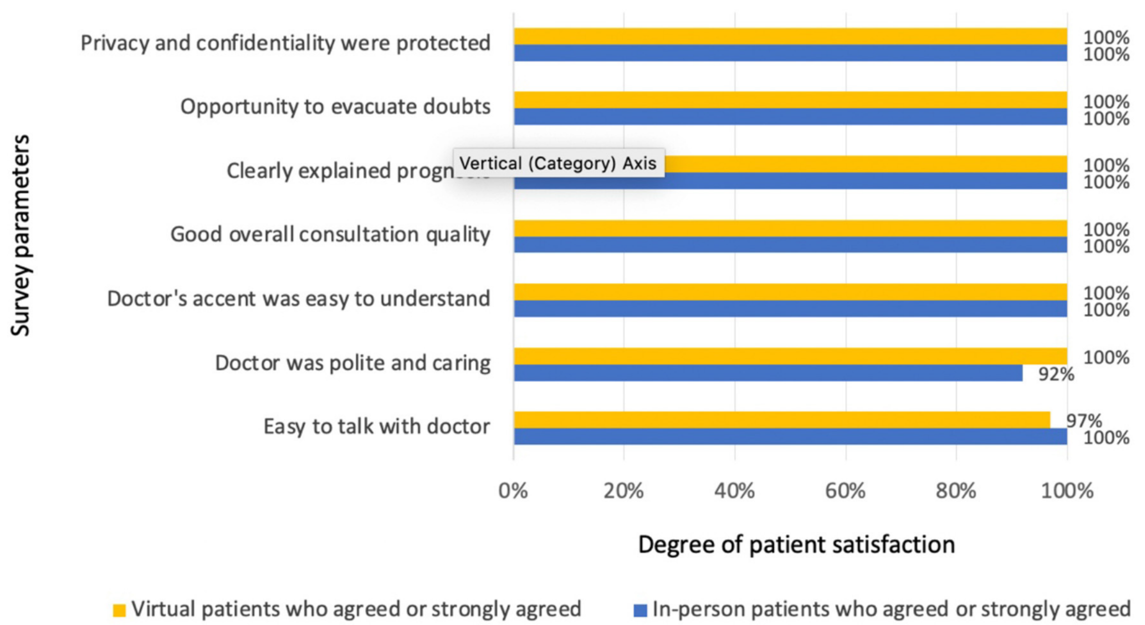

FIGURE 3 | Patients' satisfaction with prenatal consultations in both groups (virtual and in-person visits).

because it protected themselves and their patients from COVID-19 exposure. Finally, all eight neonatologists agreed or strongly agreed that their overall feeling about the use of telemedicine for prenatal consultations was good.

When inquiring about the technological aspects of the communication, both patients and physicians reported a high level of satisfaction with the audio, video and overall quality of the videocall (**Figure 2**). Among survey respondents who answered the question, 98.7% indicated that they would participate in virtual doctor visits in the future.

Prenatal Consultation Quality of Care Questions

The overall quality of the consultation, as well as satisfaction with individual components of the visit regarding physicians' professional and communicational skills, were highly rated among patients in both groups. The items included in the satisfaction survey and the percentage of patients who agreed and strongly agreed in their responses are represented in **Figure 3**. Virtual patients agreed or strongly agreed that it was easy to talk to their baby's doctor through the videocall ($N = 34$, 97.14%), while all (100%) control patients agreed or strongly agreed that it was easy to talk to their baby's doctor during the in-person visit. Similarly, all 35 virtual and 11 of 12 (91.68%) in-person patients agreed or strongly agreed that their baby's doctor was polite and caring. All virtual ($N = 35$) and in-person ($N = 12$) patients agreed or strongly agreed that their baby's doctor's accent was easy to understand.

Consultation Quality Scores

Statistical comparison of virtual vs. in-person groups on the survey question rating overall consultation quality and the combined CQ score revealed no significant difference on either measure (**Table 4**). The combined CQ score for physicians showed a high mean across all items ($M = 46.4 \pm 3.11$) (**Table 5**).

TABLE 4 | Patients' perceptions of the overall consult quality and composite CQ score group means computed on six 5-point Likert items about patient-doctor communication.

	Virtual ($N = 35$)	In-person ($N = 12$)	P-value
Overall consult quality	Mean = 4.83 SD = 0.38	Mean = 4.83 SD = 0.40	0.971083
Composite CQ score	Mean = 28.71 SD = 2.22	Mean = 28.92 SD = 1.78	0.753263

TABLE 5 | Physicians' perceptions of the overall consult quality and composite CQ score group means computed on ten 5-point Likert scale survey questions.

	Mean (SD)	Lowest	Highest
Overall consult quality	4.63 (0.52)	4	5
Composite CQ score	46.38 (3.11)	42	50

DISCUSSION

After evaluating different components of satisfaction among patients and neonatologists with the use of telemedicine for prenatal consultations, we found a similar degree of fulfillment with virtual visits when compared with in-person consultation. Despite the rapid implementation of telemedicine and the limited training physicians received, virtual consultations met users' and providers' expectations. A reasonable interpretation of the results is that these consults do not require physical examination and the success depends on good patient-physician communication.

The ability to listen and empathize with patients while providing information in a lay language is important in any medical consultation (13), but is essential when delivering bad news. It was our concern that the use of telemedicine would make it more difficult for patients and physicians to understand each other due to differences in regional dialects and cultures. Patients receiving virtual visits, regardless of the language they spoke, agreed that talking to the doctor was easy, the accent was understandable and that they felt content (the doctor was polite and caring). Ironically, in pandemic days, non-verbal cues are easier to detect through a videocall where patients and physicians are allowed to remove their face masks than in "traditional" visits in which masks and a six-foot-distance are required.

Although all physicians agreed that telemedicine was a reliable, effective tool for providing prenatal consultations, one was not sure about its quality being equal to in-person visits, arguing that it would have been nice to be able to hand a tissue to the patient. That is not a minor comment; as virtual visits rise in number, so does the need to develop new techniques to emotionally support our patients through distance technologies (14).

Even though two thirds of virtual patients were participating in a tele-consultation for the first time, most were satisfied about talking to their baby's doctor through telemedicine and would participate in a virtual visit in the future. Based on these results, we are considering providing virtual visits to patients in their homes, respecting patients' times and reducing transport costs while allowing them to connect more frequently and easily. Bishop et al. recently demonstrated the feasibility of providing prenatal consultation where the patient was located at home, but they did not evaluate patient and provider satisfaction with telemedicine use (15).

To our knowledge, this is the first study showing the satisfaction component of prenatal consultations for patients with fetal anomalies. In accordance with previous studies conducted in related fields, telemedicine was shown to be a safe and effective tool with which to provide ambulatory consultations with a high satisfaction rate among users and providers (16–18).

Our study may have important economic implications. Although we did not calculate the reduction in healthcare costs, we optimized the use of PPE and reduced potential exposures of both patients and staff, since some neonatologists provided the visits from their homes. Also, telemedicine consultations during the pandemic have allowed us to efficiently manage our workforce, which was reduced due to staff illness and quarantine requirements.

Limitations include the small sample size, the fact that patients' acceptability of tele-consultations could have been influenced by the COVID-19 pandemic context, and that participating physicians had elected to conduct virtual visits. While physicians had the option to provide virtual or in-person visits, patients did not have the opportunity to choose. However, none refused to receive a virtual visit, and all reported a high-quality perception of the visit. Because of the anonymous nature of the survey, we did not attempt to link diagnosis with degree of satisfaction reported by patients. However, we do not believe that this variable influenced their responses as the overall parental satisfaction, either with virtual or in-person prenatal consultations, was very high.

Prior to the pandemic, telemedicine was mostly used in rural and remote areas for patients with limited access to specialized care (19, 20). With the outbreak of COVID-19, the flexibilization of federal and state regulations and reimbursement policies allowed for telemedicine expansion. We are experiencing an unprecedented shift in the way we deliver outpatient care. While face-to-face visits are the best-known model with which to provide healthcare and are irreplaceable in many cases, new technologies emerged and are changing the paradigm of outpatient care delivery. The pandemic brought the opportunity to implement telemedicine in almost all medical fields and was shown to be safe, efficient and cost-effective when appropriately used. Once the COVID-19 restrictions are released, video-consultations may be a suitable option for selected patients, reducing the need for face-to-face visits without decreasing healthcare quality or patient satisfaction. Additionally, offering a consultation with the whole multidisciplinary team in same room, either virtual or in-person, would result in a significant improvement in the quality of care provided to these patients.

In conclusion, after exploring satisfaction with the use of telemedicine for prenatal consultations during the current pandemic, we found a high degree of acceptance from both patients and neonatologists. When comparing satisfaction levels of patients receiving virtual visits with those receiving in-person visits, we found telemedicine to be non-inferior to traditional consultations in terms of perceived quality of care. Despite the rapid implementation of the new platform and the scarce training neonatologists received, they were able to establish a good patient-physician communication, clarify patients concerns, and convey empathy, which is particularly important in these sensitive consults. Based on our findings, we anticipate that telemedicine could be effectively used in the future to provide neonatology prenatal consultations to patients not only within the hospital, but also in their homes.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

ML contributed to study design, data analysis and manuscript preparation. AM contributed to study design, data analysis and manuscript preparation. SR contributed to data collection and manuscript preparation. ES contributed to study design and manuscript preparation. GH contributed to data analysis and manuscript preparation. TC contributed to study design and manuscript preparation. MM contributed to data collection. SM contributed to data collection. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

ACKNOWLEDGMENTS

We would like to thank Lise DeShea for statistical support and Kathy Kyler for editorial support.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fped.2021.642369/full#supplementary-material

REFERENCES

1. Higgins C, Dunn E, Conrath D. Telemedicine: an historical perspective. *Telecomm Policy*. (1984) 8:307–13. doi: 10.1016/0308-5961(84)90044-2
2. Brown-Connolly NE. Patient satisfaction with telemedical access to specialty services in rural California. *J Telemed Telecare*. (2002) 8(2_suppl):7–10. doi: 10.1177/1357633X020080S204
3. Marcin JP, Ellis J, Mawis R, Nagrampa E, Nesbitt TS, Dimand RJ. Using telemedicine to provide pediatric subspecialty care to children with special health care needs in an underserved rural community. *Pediatrics*. (2004 113:1–6. doi: 10.1542/peds.113.1.1
4. Marcin JP, Shaikh U, Steinhorn RH. Addressing health disparities in rural communities using telehealth. *Pediatr Res*. (2016) 79:169–76. doi: 10.1038/pr.2015.192
5. Orlando JF, Beard M, Kumar S. Systematic review of patient and caregivers' satisfaction with telehealth videoconferencing as a mode of service delivery in managing patients' health. *PLoS ONE*. (2019) 14:e0221848. doi: 10.1371/journal.pone.0221848
6. Di Cerbo A, Morales-Medina JC, Palmieri B, Iannitti T. Narrative review of telemedicine consultation in medical practice. *Patient Prefer Adherence*. (2015) 9:65–75. doi: 10.2147/ppa.S61617
7. O'Cathail M, Sivanandan MA, Diver C, Patel P, Christian J. The use of patient-facing teleconsultations in the national health service: scoping review. *JMIR Med Inform*. (2020) 8:e15380. doi: 10.2196/15380
8. Webster P. Virtual health care in the era of COVID-19. *Lancet*. (2020) 395:1180–1. doi: 10.1016/S0140-6736(20)30818-7
9. Bosworth A ea. Medicare beneficiary use of telehealth visits: early data from the start of COVID-19 pandemic Washington, DC: Office of the Assistant Secretary for Planning and Evaluation, U.S. Department of Health and Human Services.: Office of the Assistant Secretary for Planning and Evaluation, U.S. Department of Health and Human Services.; 2020 [cited 2020 09/01/2020]. Available online at: https://aspe.hhs.gov/system/files/pdf/263866/HP_IssueBrief_MedicareTelehealth_final7.29.20.pdf (accessed July 28, 2020).
10. Wosik J, Fudim M, Cameron B, Gellad ZF, Cho A, Phinney D, et al. Telehealth transformation: COVID-19 and the rise of virtual

care. *J Am Med Inform Assoc*. (2020) 27:957–62. doi: 10.1093/jamia/ocaa067
11. AMA. 50-state survey: Establishment of a patient-physician relationship via telemedicine: American Medical Association; 2018 [updated 2018; cited 2020]. Available online at: https://www.ama-assn.org/system/files/2018-10/ama-chart-telemedicine-patient-physician-relationship.pdf (accessed December 21, 2020).
12. VandeKieft GK. Breaking bad news. *Am Fam Physician*. (2001) 64:1975–8.
13. Gask L, Usherwood T. ABC of psychological medicine. The consultation. *BMJ*. (2002) 324:1567–9. doi: 10.1136/bmj.324.7353.1567
14. Mehta SJ. Telemedicine's potential ethical pitfalls. *AMA J Ethics*. (2014) 16:1014–7. doi: 10.1001/virtualmentor.2014.16.12.msoc1-1412
15. Bishop CE, Jackson LE, Vats KR, Azzuqa AA. Prenatal neonatology telemedicine consultation for patients with fetal anomalies during the COVID-19 pandemic era: rapid implementation and lessons learned. *J Perinatol*. (2020) 40:1451–2. doi: 10.1038/s41372-020-00787-9
16. Bhandari NR, Payakachat N, Fletcher DA, Sung Y-S, Eswaran H, Benton T, et al. Validation of newly developed surveys to evaluate patients' and providers' satisfaction with telehealth obstetric services. *Telemedicine e-Health*. (2020) 26:879–88. doi: 10.1089/tmj.2019.0156
17. Futterman I, Rosenfeld E, Toaff M, Boucher T, Golden-Espinal S, Evans K, et al. Addressing disparities in prenatal care via telehealth during COVID-19: prenatal satisfaction survey in east harlem. *Am J Perinatol*. (2020). doi: 10.1055/s-0040-1718695
18. Pflugeisen BM, Mou J. Patient satisfaction with virtual obstetric care. *Matern Child Health J*. (2017) 21:1544–51. doi: 10.1007/s10995-017-2284-1
19. Makkar A, McCoy M, Hallford G, Escobedo M, Szyld E. A hybrid form of telemedicine: a unique way to extend intensive care service to neonates in medically underserved areas. *Telemed J E Health*. (2018) 24:717–21. doi: 10.1089/tmj.2017.0155
20. Hoffman AM, Lapcharoensap W, Huynh T, Lund K. Historical perspectives: telemedicine in neonatology. *Neoreviews*. (2019) 20:e113–e23. doi: 10.1542/neo.20-3-e113

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Pediatrics

ORIGINAL RESEARCH
published: 04 March 2021
doi: 10.3389/fped.2021.642460

Exploring Pediatric Tele-Rheumatology Practices During COVID-19: A Survey of the PRCOIN Network

Y. Ingrid Goh[1,2], Danielle R. Bullock[3], Janalee Taylor[4], Rajdeep Pooni[5], Tzielan C. Lee[5], Sheetal S. Vora[6], Cagri Yildirim-Toruner[7,8], Esi M. Morgan[4], Nancy Pan[9], Julia G. Harris[10], Andrew Warmin[11], Kendra Wiegand[11], Jon M. Burnham[12] and Fatima Barbar-Smiley[13] for the Pediatric Rheumatology Care Outcomes Improvement Network (PR-COIN)*

[1] Division of Rheumatology, The Hospital for Sick Children, Toronto, ON, Canada, [2] Child Health Evaluative Sciences, SickKids Research Institute, Toronto, ON, Canada, [3] Division of Rheumatology, Department of Pediatrics, University of Minnesota, Minneapolis, MN, United States, [4] Division of Rheumatology, Cincinnati Children's Hospital Medical Center, Cincinnati, OH, United States, [5] Division of Allergy, Immunology and Rheumatology, Stanford Children's Health, Palo Alto, CA, United States, [6] Division of Pediatric Rheumatology, Atrium Health Levine Children's Hospital, Charlotte, NC, United States, [7] Department of Rheumatology, Baylor College of Medicine, Houston, TX, United States, [8] Department of Rheumatology, Texas Children's Hospital, Houston, TX, United States, [9] Division of Pediatric Rheumatology, Hospital for Special Surgery, Weill Medical College of Cornell University, New York, NY, United States, [10] Division of Pediatric Rheumatology, Children's Mercy Kansas City, Kansas City, MO, United States, [11] Cincinnati Children's Hospital Medical Center, Cincinnati, OH, United States, [12] Division of Rheumatology, Children's Hospital of Philadelphia, Philadelphia, PA, United States, [13] Division of Rheumatology, Nationwide Children's Hospital, Columbus, OH, United States

OPEN ACCESS

Edited by:
Jordi Anton, Hospital Sant Joan de Déu Barcelona, Spain

Reviewed by:
Sharmila Jandial, Newcastle upon Tyne Hospitals NHS Foundation Trust, United Kingdom
Jaime De Inocencio, University Hospital 12 de Octubre, Spain

***Correspondence:**
Y. Ingrid Goh
ingrid goh@utoronto.ca

Specialty section:
This article was submitted to Pediatric Rheumatology, a section of the journal Frontiers in Pediatrics

Received: 16 December 2020
Accepted: 13 January 2021
Published: 04 March 2021

Citation:
Goh YI, Bullock DR, Taylor J, Pooni R, Lee TC, Vora SS, Yildirim-Toruner C, Morgan EM, Pan N, Harris JG, Warmin A, Wiegand K, Burnham JM and Barbar-Smiley F (2021) Exploring Pediatric Tele-Rheumatology Practices During COVID-19: A Survey of the PRCOIN Network. Front. Pediatr. 9:642460. doi: 10.3389/fped.2021.642460

Healthcare providers were rapidly forced to modify the way they practiced medicine during the coronavirus disease 2019 (COVID-19) pandemic. Many providers transitioned from seeing their patients in person to virtually using telemedicine platforms with limited training and experience using this medium. In pediatric rheumatology, this was further complicated as musculoskeletal exams typically require hands-on assessment of patients. The objective of this study was to examine the adoption of telemedicine into pediatric rheumatology practices, to assess its benefits and challenges, and to gather opinions on its continued use. A survey was sent to the lead representatives of each Pediatric Rheumatology Care and Outcomes Improvement Network (PR-COIN) site to collect data about their center's experience with telemedicine during the COVID-19 pandemic. Quantitative data were analyzed using descriptive statistics, and qualitative data were thematically analyzed. Responses were received from the majority [19/21 (90%)] of PR-COIN sites. All respondents reported transitioning from in-person to primarily virtual patient visits during the COVID-19 pandemic. All centers reported seeing both new consultations and follow-up patients over telemedicine. Most centers reported using both audio and video conferencing systems to conduct their telemedicine visits. The majority of respondents [13/19 (68%)] indicated that at least 50% of their site's providers consistently used pediatric Gait Arms Legs and Spine (pGALS) to perform active joint count assessments over telemedicine. Over half of the centers [11/19 (58%)] reported collecting patient-reported outcomes (PROs), but the rate of reliably documenting clinical components varied. A few sites [7/19 (37%)] reported performing research-related activity during telemedicine visits. All centers thought that telemedicine visits were able to meet providers' needs and support their continued use when the pandemic ends. Benefits reported with telemedicine visits included convenience and continuity of care for families. Conversely, challenges included limited ability to perform physical exams and varying access to technology. Pediatric rheumatology providers were able to transition to conducting virtual visits during the COVID-19 pandemic. Healthcare providers recognize how telemedicine can enhance their practice, but challenges need to be overcome in order to ensure equitable, sustainable delivery of quality and patient-centered care.

Keywords: telemedicine, pediatric rheumatology, telehealth, COVID-19, virtual platform, digital health (eHealth), health services research, virtual care

INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic triggered an international call for physical distancing, which limited patients' access to healthcare. As a result, healthcare providers explored telemedicine as an alternative or complementary method of delivering medical care (1, 2). The pediatric population, specifically those with chronic diseases, have higher medical needs, necessitating frequent visits to their medical provider (3). Due to the nature of their underlying diseases and treatment with immunosuppressive medications, children with rheumatic conditions require ongoing medical care for both physical exam assessment and laboratory studies (3).

Limited access to pediatric rheumatology care is an established issue, which is further exacerbated by the shortage of providers (4). Although there was little infrastructure to support virtual visits, telemedicine was proposed as a solution to improving access to pediatric rheumatologists prior to the COVID-19 pandemic (5–7). While previous telemedicine studies in other areas of medicine including adult rheumatology have shown promise, there are limited published reports regarding its use in the pediatric rheumatology setting (8–12). Piga et al.'s (13) systematic review on feasibility, effectiveness, and patient satisfaction with telemedicine for patients with rheumatic disease identified three studies involving patients with juvenile idiopathic arthritis (JIA). Two of the studies were self-management studies and one was an education study; therefore, remote disease activity assessment was not performed on these studies (14–16). An abstract published in 2014 surveying 77 pediatric rheumatology practices reported that seven sites had telemedicine capabilities, but only three sites actively used telemedicine to see patients (17). Another study at one center reported that families preferred in-person to telemedicine visits, though most of the respondents were unfamiliar with telemedicine (9). The rate of telemedicine acceptance appeared to increase with greater familiarity with this medium (9). Despite the evidence suggesting telemedicine could result in potential cost savings, the adoption of telemedicine remained low for the reasons mentioned above (8). An abstract published in 2018 reported on the experience of providing pediatric rheumatology care over telemedicine using a mixed model (10). Patients traveled to a site close to their home with telemedicine capabilities, where they connected virtually with their pediatric rheumatologist while having a hands-on joint disease activity assessment performed by their local Advanced Clinician Practitioner in Arthritis Care (ACPAC) practitioner (10, 18). Decreased cost and burden associated with travel, as well as increased access to care and patient satisfaction, were noted (10).

The COVID-19 pandemic forced healthcare providers, including pediatric rheumatology providers, to rapidly shift to virtual care. Many of the previous barriers to telemedicine, such as reimbursement and regulatory concerns, were abruptly lifted to allow for its accelerated adoption (19). The practice of telemedicine facilitated uninterrupted medical care while abiding by physical distancing requirements. The forced, expedited adoption of telemedicine across pediatric rheumatology clinics came with its challenges. The recognition of these challenges and barriers prompts the identification of potential solutions that will improve future delivery of care over telemedicine. The objective of this study was to examine the adoption of telemedicine into pediatric rheumatology practices during the COVID-19 pandemic, to assess its benefits and challenges, and to gather opinions on its continued use.

MATERIALS AND METHODS

The Pediatric Rheumatology Care and Outcomes Improvement Network (PR-COIN) is a quality improvement collaborative learning network of 21 pediatric rheumatology medical centers and parent/patient stakeholders across the United States and Canada (20). Together, they partner to identify and close gaps in healthcare for children with rheumatic diseases by leveraging quality improvement science and to bring research discoveries to patient care promptly (20). In addition, the Network strives to disseminate the knowledge gained to the wider community through education and publication of results (21). Participating sites are focused on improving the outcomes of care for children with rheumatic diseases (21).

In light of the rapid adoption of telemedicine in pediatric rheumatology, members of the PR-COIN Tele-Rheumatology Workgroup conducted an electronic survey. The main goal of this survey was to gather information reflecting each center's experiences during the COVID-19 pandemic, specifically related to telemedicine, including their rates of adoption, how visits were being conducted, and their opinions of seeing patients using this medium (see **Supplementary Material** for survey).

TABLE 1 | Composition of Healthcare Team at PR-COIN Sites.

Type of Members on Healthcare Team	Number of Sites
Pediatric rheumatologists, trainees, nurses, practitioners (nurse/ACPAC)	3
Pediatric rheumatologists	2
Pediatric rheumatologists, trainees, nurses, allied health (medical assistants)	2
Pediatric rheumatologists, nurses, practitioners (nurse/ACPAC), allied health (medical assistants)	2
Pediatric rheumatologists, nurses, allied health (physical therapist/practical nurse/social worker)	2
Pediatric rheumatologists, trainees, nurses	2
Pediatric rheumatologists, nurses	1
Pediatric rheumatologists, trainees	1
Pediatric rheumatologists, nurses, allied health (social worker, physical therapist), specialists from other departments	1
Pediatric rheumatologists, trainees, practitioners (nurse/ACPAC), allied health (medical assistant)	1
Pediatric rheumatologists, trainees, nurses, practitioners (nurse/ACPAC), allied health (medical assistant/physical therapist/occupational therapist/social worker)	1
Pediatric rheumatologists, trainees, practitioners (nurse/ACPAC), nurses, allied health (physical therapist/social worker/dietitian), specialists from other departments	1

ACPAC, Advanced Clinician Practitioner in Arthritis Care; PR-COIN, Pediatric Rheumatology Care and Outcomes Improvement Network.

The survey was sent to the lead investigator at each PR-COIN center. They were requested to complete the survey within a 1 week period during June 2020. Survey data were collected and managed using REDCap® electronic data capture tool (22, 23). REDCap® is a secure, web-based software platform designed to support data capture for research studies, providing (1) an intuitive interface for validated data capture, (2) audit trails for tracking data manipulation and export procedures, (3) automated export procedures for seamless data downloads to common statistical packages, and (4) procedures for data integration and interoperability with external sources (22, 23).

Quantitative data were analyzed using descriptive statistics. Two independent reviewers analyzed the qualitative data using grounded theory to provide understanding of concepts and ideas emerging from the survey.

PR-COIN collaborative activities are covered under an umbrella Institutional Review Board (IRB) protocol, including member surveys that are used as part of continuing quality improvement.

RESULTS

Center Demographics

The survey was completed by 19 of 21 (90%) PR-COIN centers, but only 18 of the surveys had complete responses. Centers varied in the size and composition of their team (range: 4–33 members at each site) (**Table 1**). Teams included pediatric rheumatologists, trainees, nurses, practitioners (nurse/ACPAC), allied health professionals (e.g., medical assistant, social workers, dietitian, physical therapist, occupational therapist), and physicians from other subspecialties such as adolescent medicine and dermatology. The smallest site was composed of four pediatric rheumatologists, whereas the largest site was composed of 11 pediatric rheumatologists, one nurse practitioner, two medical assistants, six nurses, six fellows, four physical therapists, two occupational therapists, and one social worker.

Telemedicine Adoption and Utilization

Of the 18 centers with completed responses, only four centers (21%) reported conducting telemedicine visits prior to the COVID-19 pandemic. However, telemedicine was previously utilized to service <10% of the four center's population. All 18 responding sites indicated that they were able to successfully adopt telemedicine visits during the COVID-19 pandemic. The switch from in-person to telemedicine services occurred mid-March for 10/18 (55%) of the centers, while the remaining centers switched mid to late March (**Figure 1**). At its peak, 16/18 (89%) reported seeing 75–100% of visits were conducted using telemedicine. As some sites began phased reopening (seeing patients in person) during late spring of 2020, the use of telemedicine subsequently decreased. All sites reported using telemedicine to see both new referrals and follow-up patients.

Telemedicine Platforms

The most commonly reported platform used to conduct telemedicine visits was Zoom (7/19), followed by American Well (5/19). Sites also indicated that they used Microsoft Teams, FaceTime, Doximity, and Ontario Telemedicine Network (OTN) (2/19). Other rarely reported platforms included Jabber, WhatsApp, SBR Health, Bluejeans, and WebEx (1/19). The majority of sites (11/19) reported using MyChart as their patient portal. This was followed by HealthELife (3/19), FollowMyHealth (2/19), and one unspecified patient portal.

Type of Telemedicine Visits

All sites reported their ability to conduct virtual visits with both audio and visual features (**Figure 2**). Here, 12/19 (63%) sites reported using videoconferencing systems, 5/19 (26%) reported using a combination of both videoconferencing systems and electronic health record (EHR) patient portals, while 2/19 (11%) sites reported using only their EHR patient portal. Moreover, 13/19 (68%) sites reported also conducting audio-only visits. Also, 3/19 (16%) sites reported using mixed models where patients traveled to a site close to their home with audio and video telemedicine capabilities. These three sites were using this mixed model prior to the COVID-19 pandemic.

In-Person vs. Telemedicine Visit

When providers were asked about reasons to see a patient in person vs. using telemedicine, respondents indicated a patient having active or worsening disease and requiring additional medical care such as hospitalization or joint

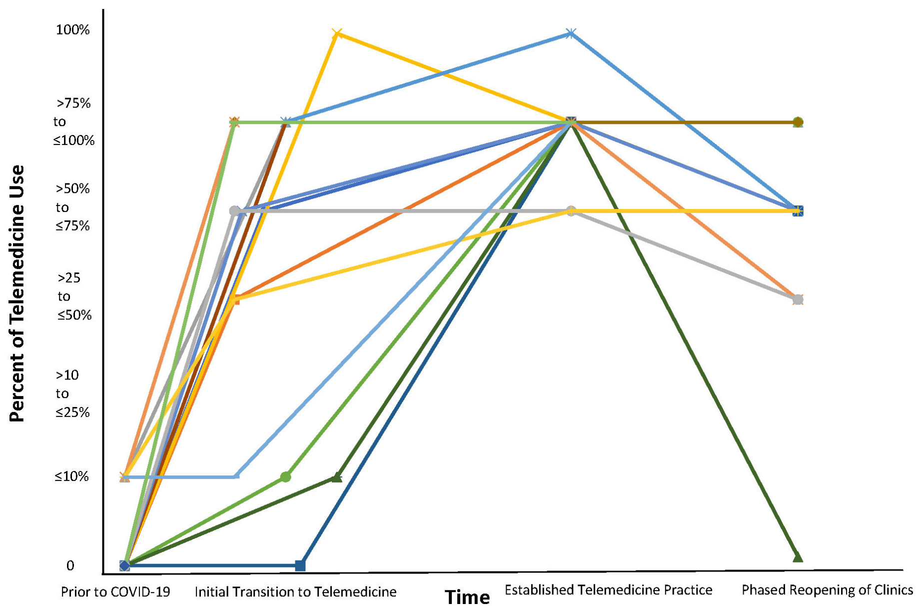

FIGURE 1 | Use of Telemedicine Prior to and During the COVID-19 Pandemic. Each color represents a different center.

injections, coordinating collaborative care, or upon patient request (**Table 2**).

Effect on Patient Volume

The majority of centers [14/19 (74%)] reported that their patient volumes had decreased as a result of switching to telemedicine during COVID-19, while 4/19 (21%) reported that their volumes were about the same. One site was not certain about whether their patient volumes had been affected.

Assessment of Joint Disease Activity

Most centers [13/19 (68%)] reported that at least 50% of their providers consistently used the pediatric Gait, Arms, Legs, Spine tool (pGALS) to perform joint activity assessments in patients with JIA (**Figure 3**). The pGALS is a structured musculoskeletal exam that has been used and validated in multiple languages to identify musculoskeletal abnormalities in children during in-person assessments (24).

Patient-Reported Outcomes

Patient-reported outcomes (PROs) were collected by most sites (**Table 3**). Here, 15/19 (79%) sites reported collecting duration of morning stiffness. Multi-item PROs questionnaires, e.g., Child Health Assessment Questionnaire (CHAQ), or Patient-Reported Outcomes Measurement Information System (PROMIS) measures were collected by a small minority of centers (5–11%). The majority of sites reported verbally collecting PROs during the telemedicine appointment [16/19 (84%)]. In addition, 3/19 (16%) sites reported collecting PROs using their patient portals, 2/19 (11%) sites reported collecting PROs using e-mail, and 1/19 (5%) sites indicated they also had a custom system built during the COVID-19 pandemic to collect PROs. The PRO completion rate varied widely, with 5/19 (26%) sites reporting <50% completion, 5/19 (26%) sites reporting 50–75% completion, 5/19 (25%) sites reporting 76–100% completion, and the four remaining sites did not respond to this question. PROs that were able to be obtained verbally, such as morning stiffness or patient global assessment, were more reliably collected than Patient-Reported Outcome Measures (PROMs), which are generally longer validated questionnaires.

Documentation

The reliability of providers documenting items is described in **Table 4**. Medication reconciliation, medication refills, and date of last eye examination were the items that were the most frequently documented. Conversely, height and weight were the least documented items.

Items Patients Received Prior to the Telemedicine Visit

The instructions provided to patients to prepare for their telemedicine visit varied from site to site. Consent was also obtained by some sites prior to their appointment. Patient instructions were e-mailed, mailed, or provided verbally. Patients would receive an e-mail link for the telemedicine appointment or notification by their patient portal. Two sites offered mock visits to ensure that patients knew how to connect. Some nurses and medical assistants are connected with patients prior to their visit to gather pre-visit information.

Items Patient Received After the Telemedicine Visit

The majority of respondents indicated that patients received prescriptions 18/19 (95%), referrals 16/19 (84%), and after-visit summary 13/19 (68%) at the end of their telemedicine

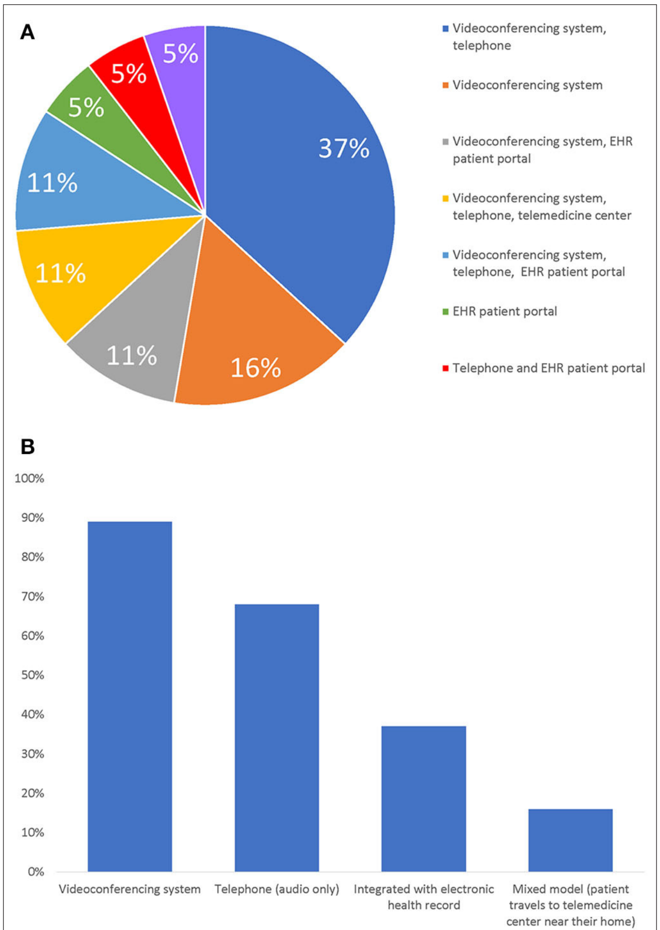

FIGURE 2 | Mediums Used to Perform Telemedicine Visits. **(A)** Medium Usage by Sites. **(B)** Sites Usage of Mediums. Note: Bar graph answers are not mutually exclusive.

TABLE 2 | Reasons for In-Person Visit Preferred Over Telemedicine Visit.

Joint injection	89%
Anticipate hospitalization	74%
Worsening condition	68%
Evidence of new rheumatic disease	63%
Active disease	58%
Parent request/desire	53%
New patient	47%
Other	16%
Need for laboratory visits	5%

appointment. Additional items that were provided included requisitions for external labs [4/19 (21%)], physiotherapy resources [2/19 (11%)], requisition for external diagnostic imaging [1/19 (5%)], and disease-specific information [1/19 (5%)].

Patients generally received these materials through their patient portal [12/19 (63%)] or by mail [12/19 (63%)]. Also, 8/19 (42%) sites reported sending this information by e-mail, and 3/19 (16%) indicated that they provided it by fax. One respondent indicated that pertinent items were faxed directly to the recipient, e.g., pharmacy or other clinics.

Research During Telemedicine Visits

With respect to conduct of research activities over telemedicine, 7/19 (36%) sites reported conducting research activity during this period, while 8/19 (42%) reported that they were unable to conduct research. Of the sites reporting the ability to conduct research during the COVID-19 pandemic, only 2/7 (14%) sites reported being able to obtain consent over telemedicine. Most of the research that continued was follow-up visits for registries where information could be abstracted from charts or clinical personnel were able to assist with a portion of the research process. Coordinating research during this time relied more heavily on communication with the clinical team and the clinical team's willingness to assist with activities.

Benefits and Challenges to Use of Telemedicine

Benefits noted with telemedicine included improved convenience, no need to travel, continuity of care for families who were hesitant to have in-person appointments, and the ability to see patients in their natural environment (**Table 5**). Challenges noted with telemedicine included limited ability to perform physical exams, difficulties assessing disease activity, and difficulties accessing and utilizing technology (**Table 6**).

All respondents agreed telemedicine visits met both provider and patient needs. All respondents also indicated that they believed that the use of telemedicine visits should continue following the resolution of the COVID-19 state of emergency. At the time of survey, most centers 14/19 (74%) felt that <50% of established patients and 15/19 (79%) new patients could be safely and effectively seen over telemedicine moving forward.

DISCUSSION

Telemedicine has facilitated the continuity of care to pediatric rheumatology patients while reducing the risk of transmission of COVID-19 among healthcare providers, patients, and caregivers. To our knowledge, this is the first survey assessing the change in telemedicine practices in pediatric rheumatology due to the COVID-19 pandemic. Not only has telemedicine facilitated the continuity of care in pediatric rheumatology, but it has also been successfully adapted by other pediatric subspecialties including adolescent medicine, otolaryngology, and sleep medicine (25–27).

In light of the need to quickly respond during the pandemic, a variety of platforms were used to conduct telemedicine visits. With the adaptation and normalization of telemedicine into clinical practice, healthcare teams have since moved toward ensuring that telemedicine visits are conducted using private and secure [e.g., Health Insurance Portability and Accountability Act (HIPAA)/Personal Health Information Protection Act (PHIPA) compliant] healthcare information exchange platforms. Some institutions have invested in infrastructure to conduct these visits such as webcams and software that integrate virtual visits

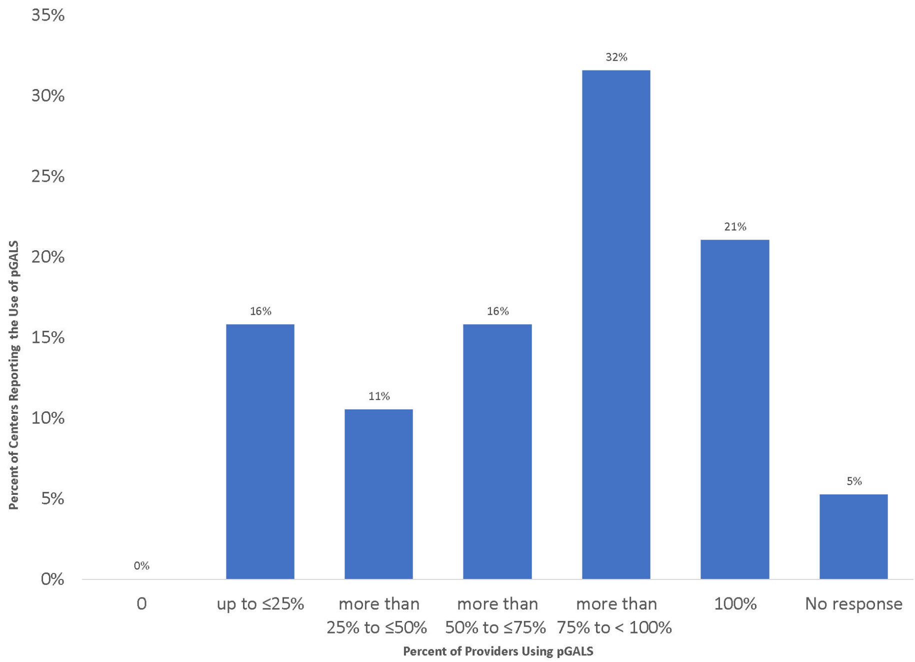

FIGURE 3 | Percentage of Providers from Each Site Using pGALS to Assess Joint Disease Activity during Telemedicine Visits.

TABLE 3 | Patient-Reported Outcomes Documented During Telemedicine Visit.

Morning stiffness	79%
Patient global assessment	68%
Pain intensity	58%
Patient self-reported joint count	26%
Do not collect any patient-reported outcomes (PROs)	11%
Child Health Assessment Questionnaire (CHAQ)	11%
Other	11%
Patient-Reported Outcomes Measurement Information System (PROMIS)	5%
Juvenile Arthritis Multidimensional Assessment Report (JAMAR)	5%
Pediatric Quality of Life Inventory^{TM} (PedsQL)	0%

TABLE 4 | Items Documented During a Telemedicine Visit.

Medication reconciliation	95%
Medication refills	95%
Date of last eye examination	95%
Visit conducted using telemedicine	79%
Allergy review	79%
Laboratory results	79%
Physician Global Assessment	74%
Patient Global Assessment	74%
Joint count	68%
Patient-Reported Outcomes	53%
Disease activity (e.g., JADAS)	42%
Treatment target(s)	37%
Weight	26%
Height	0%

into patients' EHRs. Although the enactment of the National Emergencies Act in the United States and telehealth expansion in Canada helped overcome some barriers of reimbursement and HIPAA, it did not address the issue of reimbursement and providing telemedicine services to patients residing in another state (interstate licensure) or another country (28, 29).

Although our results indicated that all sites had the ability to conduct visits with audio and video capability, we do not know what proportion of visits were conducted audio-only consultations vs. audio and video consults.

Despite the availability of telemedicine, providers recognized circumstances where patients should be seen in person, suggesting that there may be a need to systematically triage patients to determine whether they should be seen in person or over telemedicine. This process may require additional time and preparation of the healthcare and administrative team. To our knowledge, there currently are no recommendations or guidelines on how to best triage pediatric rheumatology patients, which may warrant future investigations.

The reasons for changes in patient volumes during the COVID-19 pandemic are not specifically known. Possible explanations for decreased volumes include family reluctance to leave home during the pandemic, declined visit bookings, limited access or resources of families to conduct telemedicine visits, and caregiver's occupation and changes in work schedule. It is also not clear whether telemedicine visits are longer in

TABLE 5 | Benefit of Telemedicine Visits.

No travel	95%
More convenient	84%
Continuity of care for families who are hesitant to come for in-person visits	84%
Less cancellations/no shows	58%
Decreased patient wait times (i.e., shorter time to schedule an appointment)	53%
Decreased clinic visit length (i.e., time spent with healthcare provider)	42%
Other (e.g., opportunity to observe a patient's home environment)	5%

TABLE 6 | Challenges of Telemedicine Visits.

Limited ability to perform physical exams	89%
Assessing disease activity	84%
Access to technology	68%
Safety labs being performed at recommended interval	53%
Adequate Internet bandwidth	47%
Providing multidisciplinary care	42%
Patient education	32%
Communicating after-visit instructions/making follow-up visits	26%
Licensure	11%
Reimbursement	5%
Other-Miscellaneous technological issues for the patients/providers	5%

duration or if the learning curve of conducting telemedicine visits affected scheduling volumes. Furthermore, patients may have limited ability to be seen over telemedicine because they might not have the bandwidth, resources, or knowledge of how to access telemedicine visits. We do not know how many new referrals each site receives annually or how many patients with JIA are serviced annually, therefore we cannot predict how large of a clinical volume is seen by healthcare providers at each site, which may affect their comfort level with using telemedicine.

Although most centers reported that some of their providers used the pGALS to assess joint activity, this tool has not been validated for use over telemedicine. As a result, healthcare providers may not be confident in the accuracy of active joint activity assessment when utilizing this tool over this telemedicine. The instrument also may not be able to identify small effusions or detect active joints in young children when used over telemedicine. Recently, Shenoi et al. (30) proposed the Video-pGALS (an adapted version of the pGALS), but this has not been validated and was created using input from a small group of pediatric rheumatologists. Additional research needs to be undertaken to determine whether this tool can accurately assess joint disease activity in a virtual setting. If it is determined that this tool is valid, it could enable the standardization of care over telemedicine. Conversely, if it is not valid, pediatric healthcare providers will need to seek other means of performing accurate joint disease activity assessments.

Given that our survey found that about half of the sites' teams used pGALS to assess their patients over telemedicine, it is possible that not all healthcare providers are aware of or trained in the use of the pGALS joint activity assessment tool. As such, there is an opportunity to train providers so they are aware of tools that may assist them during their physical assessment of patients. Similarly, should a tool be validated for performing assessment over telemedicine, it is important that the knowledge be disseminated to educate providers, which will, in turn, standardize care among pediatric rheumatology patients over telemedicine.

PROs are an integral part of routine clinical practice and contribute to a myriad of studies (31). The documentation of patient global assessments was reportedly low. This may be due to several factors including the reliance of the healthcare provider to ask the patients to rank the state of their rheumatic condition on a scale of 0–10 and then documenting the response. During the initial adoption of telemedicine, healthcare providers may have prioritized learning how to provide care using this medium and, therefore, may have elected to focus on completing items that they deemed to be a higher priority. With increased familiarity of delivering care over telemedicine platforms, it is possible that PRO collection and documentation have increased. Furthermore, as a proportion of patients will continue being seen over telemedicine after the pandemic is over, it would be worthwhile to implement a method to reliably collect PROMs for these visits.

The variability in the documentation of items during telemedicine visits compared to in-person visits may be due to several factors. Some variations may be accounted for by local billing, compliance, and/or institutional requirements. It appeared that information that the providers had more ease and control of obtaining, such as medication reconciliation, was more reliably documented, whereas other pieces of information that required some effort of patients and their caregivers (e.g., measuring height) or other measuring tools (e.g., weight scale) were less reliably documented. As telemedicine will continue to serve a proportion of patients, healthcare providers should consider how to equip families that may not have a scale or, less commonly, a stadiometer, on how to reliably collect these measurements. Providing educational resources to patients and families as well as communicating alternative methods to accomplish these measurements might be a feasible option. Most families have access to smartphones where they could download applications that may help them perform measurements or access websites, such as the Centers for Disease Control and Prevention (CDC), which have instructional guidelines (32, 33). Clinical support tools (such as Smart Phrases, note templates, and billing templates) embedded in the EHR may assist in reminding healthcare providers to document exam elements during telemedicine visits.

Given that everyone was expected to adapt to telemedicine rapidly and the lack of guidance documents at the outset of the pandemic, instructions provided to patients (if any were provided) varied in everyone's practice (even within sites). Since then, some guidance documents have been developed, but there are none specific to pediatric rheumatology (34). It would be worthwhile to look at the current practices among different sites to collectively learn from each other and create a best practice document. Surprisingly, some caregivers do not realize that patients needed to be present for telemedicine appointments or understand the importance of creating an environment to conduct the visit. The development of a best practice document with unified expectations and instructions may assist patients and caregivers to better prepare for their appointment.

Providing requisitions for external laboratory and diagnostic testing after the telemedicine visit offers patients more convenience as they can maintain continuity of care while not traveling too far from their home. Only one site reported providing patients with disease-specific information. It is not clear whether this was because it was an open-ended question and respondents did not think of this answer, or whether other providers did not have digitized resources to send to their patients. With the shift to telemedicine, healthcare teams should consider amassing digital resources that they can provide to their patients and families.

Many institutions limited research activities during the COVID-19 pandemic to reduce the number of staff entering their facilities as well as prioritize the ethical approval of COVID-19-related research activities (35). To ensure that scholarly work continues, it is important to establish mechanisms in which research can be performed over telemedicine (36). This will require developing and operationalizing a plan that is amenable to both healthcare and research teams. In addition, using virtual workflows such as digital consent forms and electronic case report forms will facilitate research activities over telemedicine. Naturally, there will be additional costs associated with these changes, and funders of research will need to avail additional funding to facilitate this transition (35). Researchers will need to include a telemedicine/virtual visit component within their future research budgets. Furthermore, to ensure diversity and inclusiveness, researchers will also need to consider ways to facilitate the participation of individuals who do not have access to technological tools.

Given that patients did not have to travel to attend their telemedicine visit, households saved time and money associated with traveling to see their healthcare provider. Not much is about the cost of pediatric rheumatology telemedicine visits, e.g., Internet data compared to in-person visits, e.g., traveling. It would be worthwhile to explore the economic impacts of these visits. Telemedicine visits offer an alternative solution to overcoming clinician shortages, especially in rural and other underserved populations. In pediatric rheumatology, where there is a clear workforce shortage and states without providers, there is a distinct opportunity to reduce travel-associated costs (8, 37) and ensure regularity of follow-up for patients, which is critical in pediatric chronic care. The convenience of telemedicine could have potentially brought back patients who were not seen in a long time because they were in remission and did not want to lose time and money to travel to their healthcare provider only to be told they were fine. As such, the use of telemedicine can improve the outcomes of patients with pediatric rheumatic conditions, as it increases access to, as well as facilitates, continuity of care.

The challenge of telemedicine is that it may be not be equally accessible to everyone. There remain certain regions with poor bandwidth and minimal Internet services (38). Due to socioeconomic circumstances, some families may not be able to afford the cost associated with these types of appointments. Further work is needed to elucidate the effect of socioeconomic status, language, broadband availability, and technologic literacy on patient access.

Although all respondents indicated that telemedicine met their needs, future work should consider assessing their satisfaction with telemedicine visits. Another item worth assessing is the learning curve associated with telemedicine visits or any additional stress associated with the switch to this medium.

The limitations of our study include that the participants were North American pediatric rheumatologists who were members of PR-COIN, therefore limiting the generalizability of our findings. PR-COIN sites are generally large pediatric research centers that have extensive experience conducting collaborative research. Future studies could be conducted on an international level to assist with the generalizability of the results. In addition, since this was distributed to PR-COIN site leaders, we are uncertain whether the results accurately reflect the opinions of all the providers at their site or whether they were responding based on personal experience. For sites reporting the use of telemedicine prior to the COVID-19 pandemic, we do not know whether this prior experience was equal among all staff members and whether this facilitated a quicker transition to telemedicine for the remainder of their practice. Furthermore, as this survey asked providers to reflect at a single point in time, opinions may have shifted over time with increased experience with the use of telemedicine. We are currently developing a follow-up survey to see whether healthcare providers' opinions have changed with time and experience and identify what novel ideas and tools have emerged $\sim$1 year after mass the adoption of telemedicine. This will enable us to identify best practices. With the identification and implementation of best practices, future studies will be able to observe how disease monitoring over telemedicine changes over time.

Our survey only asked about the use of pGALS as an assessment tool and did not inquire about other tools providers used to assess joint disease activity over telemedicine. We plan to identify other tools that healthcare providers are using to assess joint disease activity, so that if a reliable method is uncovered, the knowledge can be shared with pediatric rheumatology healthcare providers.

Finally, this survey was only administered to healthcare providers and not patients and caregivers. Therefore, we do not have an understanding of telemedicine visits from their perspective. Future projects should include patients' and caregivers' perspectives in order to help understand their needs and barriers and what influences their decisions when selecting appointment mediums. It would also be informative to know how comfortable caregivers would feel if they were asked to actively assist in the physical examination process.

CONCLUSIONS

The COVID-19 pandemic accelerated the change to delivering care over telemedicine. This survey indicates that rapid adaptations occurred to facilitate the implementation of pediatric rheumatology clinical care and research over telemedicine in response to the COVID-19 pandemic. In doing so, they were able to continue providing medical care to pediatric rheumatology patients despite the physical distancing requirements. Given that all sites were able to transition to providing care over telemedicine, the prospect of continuing this practice in the future is highly likely given that most institutions have added resources and infrastructure during the COVID-19 pandemic. We identified specific challenges healthcare providers faced when conducting visits over telemedicine, such as the limited number of available tools to reliably perform assessments, the lack of certainty with these evaluations, and ensuring that patients had access to technology in order to conduct telemedicine visits. Further research is needed to identify and validate tools that can reliably be used to perform assessments over telemedicine, identify mechanisms to improve provider documentation, identify ways to improve the collection of PROs, create standardized instructions to better prepare patients for a successful telemedicine visit, and identify ways to best integrate research visits along with telemedicine visits. Most importantly, we need to ensure that telemedicine can be delivered in a safe, supportive, and accessible way to pediatric rheumatology patients and their families.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors upon request.

ETHICS STATEMENT

PR-COIN collaborative activities are covered under an umbrella Institutional Review Board (IRB) protocol at Cincinnati Children's Hospital Medical Center. Member surveys are used as part of continuing quality improvement. Written informed consent to participate was therefore not required for this study in accordance with the institutional requirements.

AUTHOR CONTRIBUTIONS

YG, NP, FB-S, JH, SV, AW, JB, JT, CY-T, and EM substantially contributed to the conception or design of the work, acquisition, analysis, or interpretation of data for the work. YG, FB-S, DB, JT, RP, and TL drafted the work. YG, FB-S, JT, SV, CY-T, EM, DB, NP, JH, TL, RP, JB, AW, and KW revised the work critically for important intellectual content. All authors approved the final version to be published and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

ACKNOWLEDGMENTS

This research was conducted using data obtained through the Pediatric Rheumatology Care and Outcomes Improvement Network (PR-COIN), collected by the physicians, providers and families participating in this multicenter Quality Improvement Collaborative. https://pr-coin.org/.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fped.2021.642460/full#supplementary-material

REFERENCES

1. Koonin LM, Hoots B, Tsang CA, Leroy Z, Farris K, Jolly B, et al. Trends in the use of telehealth during the emergence of the COVID-19 pandemic — United States, January–March 2020. *Morb Mortal Wkly Rep.* (2020) 69:1595–9. doi: 10.15585/mmwr.mm6943a3
2. Schwamm LH, Erskine A, Licurse A. A digital embrace to blunt the curve of COVID19 pandemic. *NPJ Digit Med.* (2020) 3:64. doi: 10.1038/s41746-020-0279-6
3. Bashshur RL, Shannon GW, Smith BR, Alverson DC, Antoniotti N, Barsan WG, et al. The empirical foundations of telemedicine interventions for chronic disease management. *Telemed E-Health.* (2014) 20:769–800. doi: 10.1089/tmj.2014.9981
4. Foster HE, Rapley T. Access to pediatric rheumatology care - a major challenge to improving outcome in juvenile idiopathic arthritis. *J Rheumatol.* (2010) 37:2199–202. doi: 10.3899/jrheum.100910
5. Duke E. *The Pediatric Rheumatology Workforce: A Study of the Supply and Demand for Pediatric Rheumatologists*. Report to Congress. Health Resources and Services Administration. U.S. Department of Health & Human Services (2007). Available online at: http://bhpr.hrsa.gov/healthworkforce/reports/pedrheumatology.pdf (accessed November 23, 2020).
6. Bolster MB, Bass AR, Hausmann JS, Deal C, Ditmyer M, Greene KL, et al. 2015 American College of Rheumatology Workforce study: the role of graduate medical education in adult rheumatology. *Arthritis Rheumatol.* (2018) 70:817–25. doi: 10.1002/art.40432
7. Henrickson M. Policy challenges for the pediatric rheumatology workforce: part II. Health care system delivery and workforce supply. *Pediatr Rheumatol.* (2011) 9:1–5. doi: 10.1186/1546-0096-9-23
8. Kessler EA, Sherman AK, Becker ML. Decreasing patient cost and travel time through pediatric rheumatology telemedicine visits. *Pediatr Rheumatol.* (2016) 14:54. doi: 10.1186/s12969-016-0116-2
9. Bullock DR, Vehe RK, Zhang L, Correll CK. Telemedicine and other care models in pediatric rheumatology: an exploratory study of parents' perceptions of barriers to care and care preferences. *Pediatr Rheumatol.* (2017) 15:55. doi: 10.1186/s12969-017-0184-y
10. Berard RA, MacQueen S, Diebold M, Goh YI, MacLeod A, Whitney-Mahoney K, et al. A new model of care for pediatric rheumatology in ontario: preliminary results from pilot telemedicine clinics utilizing advanced clinician practitioners in arthritis care. *Arthritis Rheumatol.* (2018) 70. Available online at: https://acrabstracts.org/abstract/a-new-model-of-care-for-pediatric-rheumatology-in-ontario-preliminary-results-from-pilot-telemedicine-clinics-utilizing-advanced-clinician-practitioners-in-arthritis-care/ (accessed February 7, 2021).

11. Leggett PF, Graham L, Steele K, Gilliland A, Stevenson M, O'Reilly D, et al. Telerheumatology - diagnostic accuracy and acceptability to patient, specialist, and general practitioner. *Br J Gen Pract.* (2001) 51:746–8.
12. Ward IM, Schmidt TW, Lappan C, Battafarano DF. How critical is telemedicine to the rheumatology workforce? *Arthritis Care Res.* (2016) 68:1387–9. doi: 10.1002/acr.22853
13. Piga M, Cangemi I, Mathieu A, Cauli A. Telemedicine for patients with rheumatic diseases: systematic review and proposal for research agenda. *Semin Arthritis Rheum.* (2017) 47:121–8. doi: 10.1016/j.semarthrit.2017.03.014
14. Stinson JN, McGrath PJ, Hodnett ED, Feldman BM, Duffy CM, Huber AM, et al. An internet-based self-management program with telephone support for adolescents with arthritis: a pilot randomized controlled trial. *J Rheumatol.* (2010) 37:1944–52. doi: 10.3899/jrheum.091327
15. White M, Stinson JN, Lingley-Pottie P, McGrath PJ, Gill N, Vijenthira A. Exploring therapeutic alliance with an internet-based self-management program with brief telephone support for youth with arthritis: a pilot study. *Telemed e-Health.* (2012) 18:271–6. doi: 10.1089/tmj.2011.0150
16. Armbrust W, Bos JJFJ, Cappon J, van Rossum MAJJ, Sauer PJJ, Wulffraat NM, et al. Design and acceptance of Rheumates@Work, a combined internet-based and in person instruction model, an interactive, educational, and cognitive behavioral program for children with juvenile idiopathic arthritis. *Pediatr Rheumatol.* (2015) 13:31. doi: 10.1186/s12969-015-0029-5
17. Riebschleger MP, Tootoo J, Mroczek A, Clark S. A163: alternative mechanisms of care delivery in pediatric rheumatology: to what extent do they expand the reach of pediatric rheumatologists? *Arthritis Rheumatol.* (2014) 66:S211. doi: 10.1002/art.38589
18. University of Toronto. *ACPAC Program.* (2020) Available online at: https://acpacprogram.ca/ (accessed November 23, 2020).
19. Centers for Medicare & Medicaid Services. *Medicare Telemedicine Health Care Provider Fact Sheet.* (2020). Available online at: https://www.cms.gov/newsroom/fact-sheets/medicare-telemedicine-health-care-provider-fact-sheet (accessed November 23, 2020).
20. PR-COIN. *About Us.* (2020). Available online at: http://www.pr-coin.org/about-network (accessed October 31, 2020).
21. PR-COIN. *Pediatric Rheumatology Care & Outcomes Improvement Network (PR-COIN).* (2020). Available online at: https://www.pr-coin.org/ (accessed October 31, 2020).
22. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)-a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform.* (2009) 42:377–81. doi: 10.1016/j.jbi.2008.08.010
23. Harris PA, Taylor R, Minor BL, Elliott V, Fernandez M, O'Neal L, et al. The REDCap consortium: building an international community of software platform partners. *J Biomed Inform.* (2019) 95:103208. doi: 10.1016/j.jbi.2019.103208
24. Foster HE, Jandial S. PGALS - paediatric gait arms legs and spine: a simple examination of the musculoskeletal system. *Pediatr Rheumatol.* (2013) 11:1–7. doi: 10.1186/1546-0096-11-44
25. Barney A, Buckelew S, Mesheriakova V, Raymond-Flesch M. The COVID-19 pandemic and rapid implementation of adolescent and young adult telemedicine: challenges and opportunities for innovation. *J Adolesc Health.* (2020) 67:164–71. doi: 10.1016/j.jadohealth.2020.05.006
26. Govil N, Raol N, Siong C, Goudy SL. Rapid telemedicine implementation in the context of the COVID-19 pandemic in an academic pediatric otolaryngology practice. *Int J Pediatr Otorhinolaryngol.* (2020) 2020:110447. doi: 10.1016/j.ijporl.2020.110447
27. Johnson C, Taff K, Lee BR, Montalbano A. The rapid increase in telemedicine visits during COVID-19. *Patient Exp J.* (2020) 7:15. doi: 10.35680/2372-0247.1475
28. US Department of Health & Human Services. *Telehealth: Delivering Care Safely During COVID-19.* (2020). Available online at: https://www.hhs.gov/coronavirus/telehealth/index.html (accessed November 23, 2020).
29. Krausz M, Westenberg JN, Vigo D, Spence RT, Ramsey D. Emergency response to COVID-19 in Canada: platform development and implementation for ehealth in crisis management. *JMIR Public Heal Surveill.* (2020) 6:e18995. doi: 10.2196/18995
30. Shenoi S, Hayward K, Curran ML, Kessler E, Mehta JJ, Riebschleger MP, et al. Telemedicine in pediatric rheumatology: this is the time for the community to embrace a new way of clinical practice. *Pediatr Rheumatol.* (2020) 18:85. doi: 10.1186/s12969-020-00476-z
31. Wahl ER, Yazdany J. Challenges and opportunities in using patient-reported outcomes in quality measurement in rheumatology. *Rheum Dis Clin North Am.* (2016) 42:363–75. doi: 10.1016/j.rdc.2016.01.008
32. Centers for Disease Control and Prevention. *Measuring Children's Height and Weight Accurately at Home*. (2020). Available online at: https://www.cdc.gov/healthyweight/assessing/bmi/childrens_bmi/measuring_children.html (accessed November 23, 2020).
33. Pew Research Center. *Mobile Fact Sheet.* (2019). Available online at: https://www.pewresearch.org/internet/fact-sheet/mobile/ (accessed November 23, 2020).
34. American College of Rheumatology. *American College of Rheumatology Position Statement: Telemedicine.* (2020). Available online at: https://www.rheumatology.org/Portals/0/Files/Telemedicine-Position-Statement.pdf (accessed September 25, 2020).
35. Singh JA, Bandewar SVS, Bukusi EA. The impact of the COVID-19 pandemic response on other health research. *Bull World Health Organ.* (2020) 98:625–31. doi: 10.2471/BLT.20.257485
36. Schwamm LH. Telehealth: seven strategies to successfully implement disruptive technology and transform health care. *Health Aff.* (2014) 33:200–6. doi: 10.1377/hlthaff.2013.1021
37. Mayer ML, Mellins ED, Sandborg CI. Access to pediatric rheumatology care in the United States. *Arthritis Care Res.* (2003) 49:759–65. doi: 10.1002/art.11462
38. Drake C, Zhang Y, Chaiyachati KH, Polsky D. The limitations of poor broadband internet access for telemedicine use in rural america: an observational study. *Ann Intern Med.* (2019) 171:382–4. doi: 10.7326/M19-0283

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Pediatrics

SYSTEMATIC REVIEW
published: 17 March 2021
doi: 10.3389/fped.2021.630365

Barriers and Facilitators for Implementing Paediatric Telemedicine: Rapid Review of User Perspectives

Louise Tully[1], Lucinda Case[2], Niamh Arthurs[2], Jan Sorensen[3], James P. Marcin[4] and Grace O'Malley[1,2]*

[1] Obesity Research and Care Group, School of Physiotherapy, RCSI University of Medicine and Health Sciences, Dublin, Ireland, [2] W82GO Child and Adolescent Weight Management Service, Children's Health Ireland at Temple Street, Dublin, Ireland, [3] Healthcare Outcomes Research Centre, Royal College of Surgeons in Ireland, Dublin, Ireland, [4] Department of Pediatrics, University of California Davis School of Medicine, Sacramento, CA, United States

OPEN ACCESS

Edited by:
*Mark Lo,
University of Washington,
United States*

Reviewed by:
*Alexis Rybak,
Assistance Publique Hopitaux De Paris, France
Mark Graeme Coulthard,
Children's Health Queensland, Australia*

***Correspondence:**
*Louise Tully
louisetully@rcsi.com*

Specialty section:
This article was submitted to General Pediatrics and Pediatric Emergency Care, a section of the journal Frontiers in Pediatrics

Received: *17 November 2020*
Accepted: *19 February 2021*
Published: *17 March 2021*

Citation:
Tully L, Case L, Arthurs N, Sorensen J, Marcin JP and O'Malley G (2021) Barriers and Facilitators for Implementing Paediatric Telemedicine: Rapid Review of User Perspectives. Front. Pediatr. 9:630365. doi: 10.3389/fped.2021.630365

Background: COVID-19 has brought to the fore an urgent need for secure information and communication technology (ICT) supported healthcare delivery, as the pertinence of infection control and social distancing continues. Telemedicine for paediatric care warrants special consideration around logistics, consent and assent, child welfare and communication that may differ to adult services. There is no systematic evidence synthesis available that outlines the implementation issues for incorporating telemedicine to paediatric services generally, or how users perceive these issues.

Methods: We conducted a rapid mixed-methods evidence synthesis to identify barriers, facilitators, and documented stakeholder experiences of implementing paediatric telemedicine, to inform the pandemic response. A systematic search was undertaken by a research librarian in MEDLINE for relevant studies. All identified records were blind double-screened by two reviewers. Implementation-related data were extracted, and studies quality appraised using the Mixed-Methods Appraisal Tool. Qualitative findings were analysed thematically and then mapped to the Consolidated Framework for Implementation Research. Quantitative findings about barriers and facilitators for implementation were narratively synthesised.

Results: We identified 27 eligible studies (19 quantitative; 5 mixed-methods, 3 qualitative). Important challenges highlighted from the perspective of the healthcare providers included issues with ICT proficiency, lack of confidence in the quality/reliability of the technology, connectivity issues, concerns around legal issues, increased administrative burden and/or fear of inability to conduct thorough examinations with reliance on subjective descriptions. Facilitators included clear dissemination of the aims of ICT services, involvement of staff throughout planning and implementation, sufficient training, and cultivation of telemedicine champions. Families often expressed preference for in-person visits but those who had tried tele-consultations, lived far from clinics, or perceived increased convenience with technology considered telemedicine more favourably. Concerns from parents included the responsibility of describing their child's condition in the absence of an in-person examination.

Discussion: Healthcare providers and families who have experienced tele-consultations generally report high satisfaction and usability for such services. The use of ICT to facilitate paediatric healthcare consultations is feasible for certain clinical encounters and can work well with appropriate planning and quality facilities in place.

Keywords: telemedicine, telehealth, e-health, digital health, paediatrics, implementation

INTRODUCTION

Telemedicine is an umbrella term for the use of information and communication technologies (ICTs) to facilitate remote consultations and deliver healthcare using computers and smart devices such as smart phones and tablet computers. Whilst the potential applications of telemedicine are all-encompassing, particularly in remote and underserved regions or for populations living with medical conditions for whom travel to healthcare appointments may be particularly burdensome, the emergence of the COVID-19 pandemic has significantly emphasised the need for secure ICT-supported healthcare. For healthcare delivery in particular, a need for safe alternatives to in-person care has rapidly come to the fore. During periods of rapid transmission of the virus, emergency department visits have sharply declined (1, 2) and routine screening and consultations have been virtually non-existent in many regions for long periods since the COVID-19 pandemic (3–5). This has resulted in a rapid and widespread increase in use of telemedicine and expansion of electronic healthcare to meet demand (6). It is likely that the need for infection control and social distancing measures will continue and may increase throughout the influenza and respiratory syncytial virus seasons. Reliable, secure, high-quality telemedicine will be vital for the continuation of healthcare services, particularly for those most vulnerable.

Telemedicine for paediatric care warrants special consideration around logistics, consent and assent, child welfare and communication issues that may differ to adult services (**Figure 1**) (7). There is no systematic evidence synthesis available that outlines the implementation issues for incorporating telemedicine to paediatric services generally, or how users perceive these issues. We sought to identify factors that affect the establishment of virtual paediatric care in order to inform and equip those that need to urgently implement telemedicine (8), and assist paediatric service delivery in the longer term. Indeed, as noted by Ross et al. implementation does not stop with "go live" and therefore this review also informs those that have already implemented telemedicine (9). We aimed to achieve this by synthesising scientific studies that have documented barriers, facilitators, user attitudes and experiences of implementing paediatric telemedicine.

Abbreviations: HCP, Healthcare Professional; ICT, Information and Communication Technology; MMAT, Mixed-Methods Appraisal Tool; CFIR, Consolidated Framework for Implementation Research.

METHODS

We conducted a rapid systematic review (10, 11), using a concurrent mixed-methods evidence synthesis methodology (12). This review was registered on PROSPERO (registration number CRD42020184115).

A search strategy was developed and run in the MEDLINE database by a research librarian (**Supplementary Image 1**). We included any study examining aspects of implementing telemedicine for paediatric care, published in English between 2005 and 2020. This included studies whereby the technology facilitated paediatric consultations for patients and their caring adults. Studies were included if they assessed telemedicine undertaken in a clinical setting by healthcare professionals (HCPs) including physicians, surgeons, allied health professionals and nurses. References of relevant articles were also reviewed for eligibility. Full inclusion and exclusion criteria are available in the **Supplementary Table 1**.

All titles/abstracts and all potentially eligible full texts were screened by two of the three reviewers (LT and LC/NA). The reviewers discussed all conflicts and a consensus decision was made regarding inclusion. Data (study and participant characteristics, methods, findings consistent with the aims of this review) were extracted to Microsoft Excel and the Mixed-Methods Appraisal Tool (MMAT) (13) was used to assess the quality of included studies and risk of bias at outcome level. A randomly selected 20% portion of the extraction and assessment were independently verified (by LC/NA) to ensure quality.

Qualitative findings were coded (by LT) and analysed by the analytical themes identified from the developed code structure. We used thematic analysis, with guidance from Thomas and Harden (14). This process involves adding descriptive codes to the data and combining these to categorise the findings into themes using an iterative process. The identified barriers and facilitators were mapped to the constructs within the Consolidated Framework for Implementation Research (CFIR) (15), which involved categorising findings according to whether they are intervention-, individual-, setting- or process-specific (**Table 1**). Quantitative findings were summarised narratively.

RESULTS

Eligible Studies

We identified 207 records in total from database searching and one additional title while scanning the references of the articles (**Figure 2**). Title and abstract screening

Communication and consent

Paediatrics

- Ensuring child is comfortable,
- can hear and understand developmentally appropriate information,
- has a chance to articulate opinions, wants/needs, verbal and non-verbal cues for pain or discomfort.
- Ensuring adequate parental consent and child assent process,
- standard procedures are in place to account for parent as voice of the child where appropriate or if an inability of child to articulate symptoms.

Telemedicine in paediatrics

- Challenge of conveying and assessing non-verbal cues,
- potential for child/parent to move away from technology,
- lack of control over the setting or level of privacy for clinical appointment,
- In adequate connectivity may hinder important indications of discomfort or concern,
- Need for a second pair of hands if assessing infants and young children (one to hold/position technology, another to hold/interact with child.
- Inability to complete objective physical examination.
- facilitates interacting with the family without having to wear PPE or face masks which can limit communication and relationship building.

Logistics

Paediatrics

- School/childcare plus workday interruptions,
- planning and preparation for parent and child for appointment (need for interpreter, special needs assistant etc.),
- need for paediatric-specific equipment & standardised outcome measures,
- appropriate space to conduct clinical assessment,
- appropriate clinic check in and direction from staff with suitable family facilities.

Telemedicine in paediatrics

- Appropriate devices, connection and technical expertise by all parties,
- ensuring appointment time is long enough to facilitate technical setup, providing directions for families to log on and planning if system fails.
- Lack of remote monitoring tools validated with paediatric cohorts.
- Space at home may not be suitable for certain assessments (e.g. gait observation).
- Ensuring home life for other family members is not interrupted excessively by appointment.

Privacy

Paediatrics

- Right and ability of young person to speak to HCP alone,
- **protection of child's dignity,**
- protocols in place for data protection legislation compliance.

Telemedicine in paediatrics

- Inability to assess who can hear the conversation at either end,
- software security concerns,
- challenge of physical examination by phone or with camera,
- ensuring compliance with data protection legislation as with in-person care.

Child welfare

Paediatrics

- HCP role in flagging evidence of harm,
- assessing response to inappropriate parent/carer behaviour,
- recording appointment attendance or failure to attend.

Telemedicine in paediatrics

- Inability to conduct physical exam in person may result in missed evidence of harm,
- inability to fully assess concerning behaviour by family member, concerning issue in the home or abuse by adult.
- Importance of standard protocols for cancelled or missed appointments to alert digital literacy barriers or to trigger child welfare concern.

Quality

Paediatrics

- Adherence to international best practice and local protocols and clinical guidelines for paediatric care,
- Clinical skills competency and completion of appropriate training

Telemedicine in paediatrics

- Audio/visual issues and connectivity issues have potential to interrupt/disturb process of clinical assessment.
- Lack of clinical guidelines/competency assessments for telemedical paediatric care.
- Potential waste of resources and time.

Adverse event risk

Paediatrics

- Use of child appropriate equipment and tools,
- diagnostic criteria intended for in-person paediatric care,
- communication with other staff on site to ensure HCP is informed and local processes followed,
- availability of adequate documentation and guidelines around insurance and regulation.

Telemedicine in paediatrics

- Ability to see, examine and listen may be hindered increasing risk of adverse events,
- may result in excess use of caution and increase emergency visits,
- clear protocol lacking around accountability or reporting of accidents during a clinical session (e.g. fall during tele-rehabilitation session).

FIGURE 1 | Special considerations for extending telemedicine to paediatric care.

TABLE 1 | Summary of barriers and facilitators for implementation of telemedicine assessed qualitatively.

CFIR construct	Barriers/challenges	Facilitators
Intervention characteristics: Source Evidence strength and quality Relative advantage Adaptability Trialability Complexity Design quality and packaging Cost	• Lack of buy-in for need • Perception of additional work, complex, onerous • Uncertainty legality/credentialing • Fear of litigation • Lack of insurance coverage • Lack of confidence in the technology to be reliable • Fear of embarrassment (unreliable technology) • Outsider implementing programmes out-with perceived needs	• Perceived convenience, time & money savings for families • Perceived opportunity for learning • Straight-forward technology • "Plan B" protocols e.g., photos to complement poor video image
Outer setting: Patient needs and resources Cosmopolitanism Peer pressure External policies and incentives	• Misaligned incentives: loss of patients = loss of earnings • Perception that management get to "fly the flag" at any cost to staff	• Trust in providers ensures privacy
Inner setting: Structural characteristics Networks and communication Culture Implementation climate Readiness for implementation	• Implementation climate: perception of being tested or monitored • Fear of being replaced • Insufficient time/staff • Inadequate/no compensation • Paternalistic tone of remote colleagues	• Clear dissemination of telemedicine aims to all users • Reallocating administrative tasks away from those expected to use technology • Ability to offer wider services and thus better care • Calm and supportive tone among remote specialists • Equipment that fit into the environment • Strengthened relationships with outside teams
Individual characteristics: Knowledge and beliefs about the intervention Self-efficacy Individual stage of change Individual identification with the organisation Other personal attributes	• Lack of familiarity between clinician and family • Lack of proficiency with technology • Working alone at home preventing interaction with colleagues • Reliance on subjective descriptions by parents & non-medical factors	• Having the option (for families) • Values: valuing effective care over reimbursement • Acknowledgement of cognitive bias which may influence decision-making
Process: Planning Engaging Executing Reflecting and evaluating	• Unclear aims goals of telemedicine service-inappropriate use	• Early comprehensive training, including communication training • Communication of the value of telemedicine—"selling it" • Allocated team time for debrief/reflecting with colleagues • Clarity on when to use telemedicine • Champions for telemedicine (for each discipline) • Accessible technical support • Appropriate triaging and referrals • Designating a suitable area for tele-consultations • Thorough planning and involvement of end users at all stages of planning and implementation

excluded 110 records, while full text screening excluded 71. We identified 27 eligible studies; 19 quantitative studies (16 quantitative descriptive, two RCTs and one non-randomised trial); five mixed-methods studies, and three qualitative studies. All studies and their characteristics are listed in **Supplementary Table 2**. There was initially 86.4% agreement on screening decisions between reviewers (179/207 decisions), which increased to 100% agreement after discussion.

Quality Appraisal

The full quality appraisal results, as presented according to the MMAT items, can be seen in **Supplementary Table 3**. To briefly summarise the quality of included studies, most quantitative descriptive studies (which represented 16/27, 59% of the included studies) were generally moderate to low quality. The primary reason for low scores was ambiguity or low quality relating to the instrument used for assessing attitudes/experiences among participants (i.e., the tool used, its development, validity

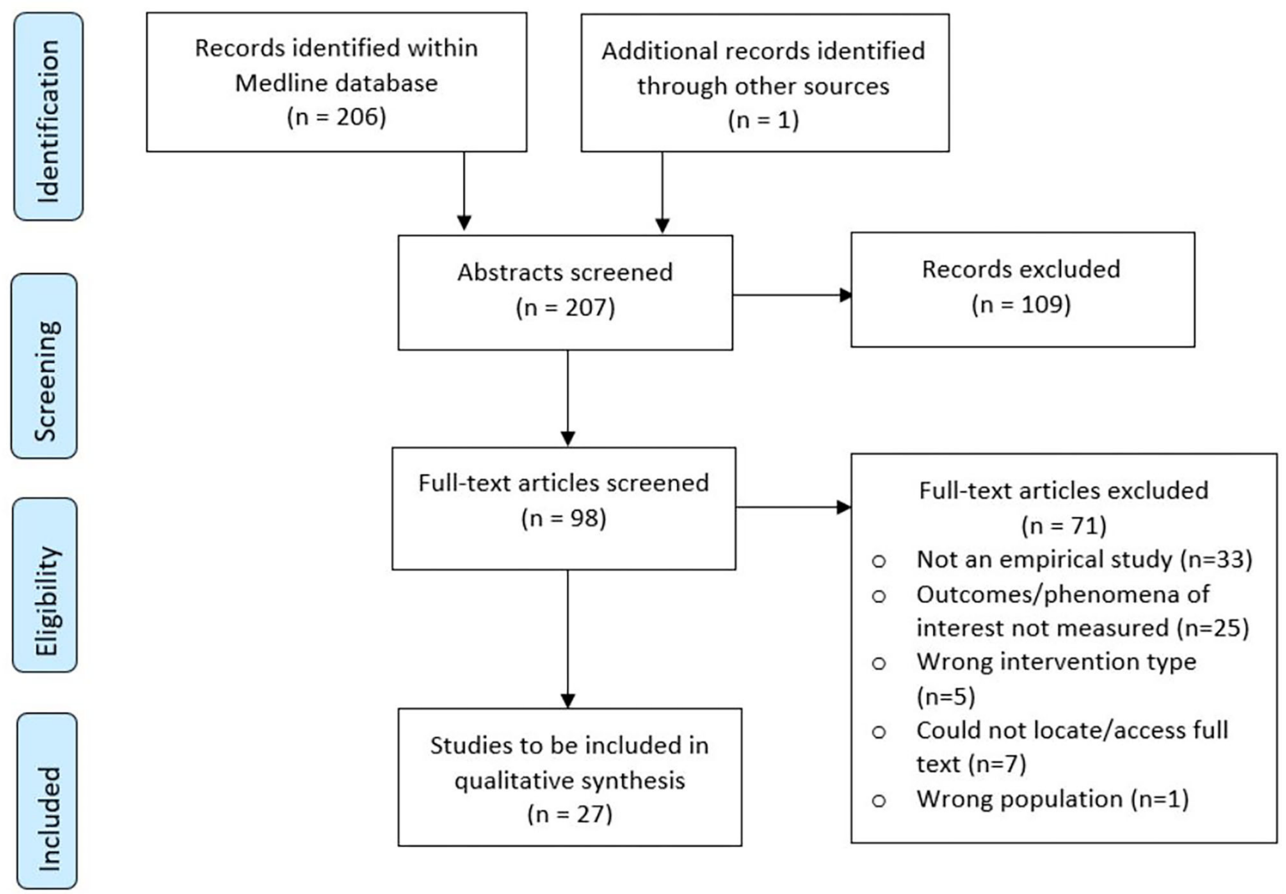

FIGURE 2 | PRISMA flow diagram.

or reliability, appropriateness within the specific setting), in addition to unclear reporting of response rates or whether the samples surveyed were representative. Three trials (16–18) were of high quality. However, the study by Cady et al. (16) only assessed the outcomes of interest for this review as open-ended feedback post-intervention. The mixed-methods studies consisted of two high quality papers and three lower quality. One study scored low based on an unclear research question and thus inability to assess whether the design was best placed to answer it, while two scored low due to insufficient detail presented for assessment of the qualitative components. The three qualitative studies were generally of high quality.

Qualitative Synthesis

The themes identified from the qualitative and mixed-methods data are described below. **Table 1** summarises the barriers and facilitators for implementation of telemedicine as presented within these themes, according to the domains of the CFIR framework.

Buy-In

Several issues were described relating to participant buy-in for the use of telemedicine as an alternative for in-person paediatric care, or as a tool for accessing specialist care remotely. Among HCPs, buy-in to the benefits of and need for telemedicine was an important facilitator for its uptake and use (19), and there was apprehension expressed by some providers about its introduction to paediatric services (20). Uscher-Pines et al. reported that HCPs believed that video conferencing was being proposed for cases whereby a "phone call would suffice," adding additional work and unnecessary complexity (19). Other barriers were related to the perception that they were being tested or monitored, or that it would increase the potential for having their decisions questioned (19, 20), specifically whereby the telemedicine service was between a remote site and a specialist hub. Participants in one study (20) proposed increased reassurance to staff that these were not the aims of the telemedicine service, in order to increase uptake and buy-in (21).

If providers suspected that the use of telemedicine would be onerous, complex or that the technology would be unreliable, they were less likely to use it according to one study (21). Initiating care through telemedicine without previous familiarity of a family/case was also cited as a concern among providers (22). Participants suggested various strategies for facilitating buy-in including early comprehensive training in the technology to increase comfort with its use, accommodating time for implementation by redirecting other time-consuming tasks away from busy providers (19), and communicating the value and potential benefits widely to potential users in advance (19, 23). Some patients and families had reservations about teleconsultations with unfamiliar clinicians, or those with whom they did not have a relationship. Choice between telemedicine and face-to-face care was a suggested facilitator for buy-in among families (24).

> *"I would like to think that this is something that is going to be a part of the care, not is going to become the norm. So that would bother me, because I think it's still important to be able to have that option to come in and have your child seen, vs. 'Oh, I think if we just do a conference call we're fine.' I don't…I'd like to see, you know—I don't know. That would just be a concern of mine"* (24).

Financial, Regulatory, and Legal Considerations

Concerns were raised by HCPs across multiple studies around the legality of care using telemedicine. One study reported that providers had serious reservations about telemedicine due to their inability to assess risk in paediatric patients the same way they could during an in-person visit, in addition to the risk of a misdiagnosis, resulting in a fear of litigation arising from its use (22). This fear influenced HCPs' decisions made via telemedicine.

> *"Everything was documented since I had more concern in this work about lawsuits. The documentation was very detailed and meticulous. There were those I would return to after a few hours... the inability to examine closely certainly influenced, and it is difficult to make decisions in this consultation. I did not feel confident enough to make decisions…"* (22).

The issue of credentialing, the process of ensuring legitimacy of care through the medium of telemedicine, was discussed in detail and described as onerous and time-consuming (19). A variety of interpretations of the need for specific credentialing for telemedicine was reported across different sites, which varied from this being a barrier for uptake due to local laws, to some sites concluding that no additional credentialing was necessary (19).

Karlsudd et al. reported that, where families waived their right to confidentiality, it facilitated a more open exchange of information and allowed for efficiency in terms of multi-disciplinary care (25). From the perspective of the patient/family, parents had little concern related to privacy, though did report hoping it was well-managed by the healthcare organisation (24).

Uptake of telemedicine among families was found to depend heavily on whether insurance companies were willing to reimburse care by this means (24). One study found that the administrative time spent organising billing for telemedicine was reported to be too time consuming, and that lack of insurance coverage in addition to inadequate reimbursement for teleconsultations were perceived to be major barriers for the long-term sustainability of telemedicine (19).

Relative Advantages vs. Opportunity Costs

The advantages of telemedicine for patients and families were widely recognised to include time saved by avoiding travelling to appointments (25), with the consequential effect of reduced absenteeism from school for patients and work for parents/carers (24, 26), reducing stress and burden for families (19, 24). This was reported to result in financial savings for families also, related to travel and associated expenses (26). Some observed benefits went much further than convenience however, with the implementation of telemedicine allowing for access to appropriate and timely specialist care for children far beyond what had previously been available, particularly in remote areas (19, 20, 24, 26). HCPs who participated in one study expressed relief at the enhanced capacity that telemedicine allowed for (26).

The same study found that rural families saw the ability to connect with tele-psychiatry and its benefits as an opportunity to become active members of their community again. Families expressed a sense of hope as a direct result of the implementation of this service, with a suggestion that this could even contribute to the stability of rural communities. For children with chronic illnesses, it was reported that telemedicine was viewed by families as offering the potential to streamline access to multi-disciplinary care and also reduce the risk of cancellation of appointments due to illness.

> *"There are times when she's too weak to get up, and I've had to cancel appointments. Instead of cancelling, I would have loved to have had the ability to say, 'Hey, she can't get up today. I don't want to cancel. Here you know, let's video-conference and discuss what's going on'…"* (24).

Ray et al. also reported that families expressed feeling that telemedicine would allow for reassurance and reduced anxiety about a child's condition between in-person hospital visits, and could also allow for more logical/efficient scheduling for healthcare, one example given being a screening/triage system to assess need for an in-person visit, and therefore increase the value of in-person care (24).

Change Management

In contrast, however, telemedicine was widely reported to be additional work on a practical level from the perspective of HCPs, and in particular its implementation tended to involve what staff perceived as excess paperwork/administrative tasks (19, 20, 27). This was compounded in cases by ICT illiteracy resulting in tasks being completed manually by those not proficient with the software (27). Some HCPs added that using telemedicine, which often meant working out of their own homes, was sometimes isolating and that the inability to run cases, issues and ideas past colleagues in the clinical environment was a drawback (22). In some cases, these issues were expressed with frustration that this work came without additional compensation, although other providers acknowledged feeling that the ability to provide effective care was more valuable than reimbursement (19).

On a more profound level, providers also expressed concerns around the broader pathways associated with implementation of telemedicine, whereby offering a one-time consultation would not be a solution to patients for whom there was a dearth of access options (26). Participants in another study expressed apprehension around misaligned incentives also, within a jurisdiction whereby healthcare provision is often for-profit, and therefore losing patients equated to loss of earnings/income and so, introducing telemedicine for remote care was not always in the interests of everyone involved (19). Haimi et al. on the other hand found that in some cases providers did not view saving money for the healthcare service/system to be a priority when considering the use of telemedicine (22).

Impact on Quality of Care

The use of telemedicine was reported to both positively influence, and at times hinder clinical decision-making among providers. The support of specialist input to satellite healthcare providers for instance, was found to instil confidence and reassurance in the ability of local providers to give appropriate care (20, 26). In some cases however, the fear of having their clinical judgement questioned or having a decision overturned as a result of using the telemedicine service was a barrier to uptake of the service (19).

Some clinicians discussed how telemedicine could not replace in-person consultations with families, and this was a source of apprehension about its use. Others were reassured that video allowed for an opportunity to provide care rather than nothing/only a phone call, despite being seen as inferior to in-person care (22). Among those who were less confident in their ability to make judgements via telemedicine, the worry of children's inability to express symptoms, in addition to frustration at being unable to gather sufficient information whilst under time pressure given the acute nature of paediatrics, was described as being a primary source of worry. Many participants discussed their need to rely on subjective descriptions provided by parents (22). This was echoed by parents in another study who felt under pressure to provide accurate descriptions of their child's condition and feared they would not convey all the necessary information, which increased their anxiety about the process (24).

> *"I suppose the fact that they can't really see him, I guess, and if I can't really say for sure what's wrong with him... if I couldn't explain what's going on with him, I might make it sound not as bad as it actually is or I might make it sound worse"* (24).

In contrast, other parents saw telemedicine as an opportunity for better access to care and timely diagnoses (24), though from a provider perspective, some talked about the conflict of "good service vs. proper medicine," whereby they felt the need to oblige parents who misused the telemedicine service for convenience (22).

Healthcare providers interviewed by Haimi et al. discussed the non-medical factors they relied on to help guide decisions where needed, and these included parents' tone of voice, perceived health literacy of the parent and their perceived ability to make shared decisions with the family. Some participants acknowledged the need for awareness of their own cognitive biases that may affect judgement in such circumstances, an example of this being the perception of a family's socioeconomic status, which participants cited as one factor considered when making decisions using telemedicine (22). The same study found that younger physicians, and those who had studied medicine in less "conservative or patriarchal" cultures tended to be better able and more open to shared decision-making with families.

Reliability and Usability of Technology

Issues with the usability and complexity of the technical platforms for facilitating telemedicine were widespread across studies. Their quality, reliability and the proficiency of clinical users were major factors in determining its acceptance and uptake among staff (19, 22, 27, 28), and some families (24). Participants discussed connectivity issues reducing their utilisation of telemedicine (27), with long setup times, audio-visual issues (21, 22), and "background fears" of something going wrong constantly affecting the quality of a consultation (20). Some clinicians described feeling embarrassed by these issues, which were often beyond their control. This issue was not unique to older studies, with the issue observed in those published up to 2018.

> *"Equipment can be hard to use and it looks like you don't know what you are doing to the person on the other end. It is an ongoing challenge to keep people competent when volume is low"* (19).

Insufficient training on the telemedicine equipment/technology was a reported source of technical problems in the same studies where ICT illiteracy was a cited major barrier to uptake of telemedicine (19, 27). Other interviewees however noted that confidence with the technology grew with increased use and experience of tele-consultations (22). Some clinical staff made suggestions for potential facilitators for smooth implementation, including having the facility for families to send photos when video quality was insufficient (22) and ensuring access to all necessary medical records via the telemedicine software (28). Participants also suggested investment in user-friendly equipment that fit well with the existing clinic, in addition to continued staff training (19, 20), availability of technical support (28), and frequent testing of the equipment by staff outside of scheduled consultations (19). It should be noted that among participants who found their telemedicine platform to work well, improved communication between families and clinical staff was reported, in addition to allowance for "genuine further education" (25).

Integration to the Organisation

Healthcare providers described the implementation of telemedicine as having allowed for streamlining of care processes, which had a positive impact on care (20). Appropriate triaging, appropriate referrals for telemedicine consultations and practicalities such as having a suitable area for staff to carry out tele-consultations comfortably were all cited as facilitators for its use (28).

Where clinical staff reported feeling less satisfied with the integration of telemedicine to the local workflow, these issues tended to be around how expectations and logistics had been managed (19). Participants conveyed dissonance between management and staff, describing the impression that telemedicine was implemented as a tick-box activity for the organisation, without careful planning.

"The [hub] hospital gets to wave the flag that they offer this service, but the [hub] doc just has to work harder for no additional compensation" (19).

Insufficient staff numbers with capacity to engage with patients via telemedicine was a problem encountered by others (20, 22), which prevented use of the service.

Beyond individual settings, the implementation of telemedicine was also described by some to facilitate strengthening of relationships between clinical sites (19) and disciplines (25), and where calm and supporting communication was used for tele-support between sites, this facilitated acceptance of this service (20). In contrast however, the use of overly paternalistic tone of communication by remote specialists was a barrier to engagement cited by satellite staff (20).

Suggestions for facilitating integration of telemedicine services to existing organisations arising from these discussions were common. Thorough planning with consideration for each aspect of implementation, logistics and administration as well as cultivation of clinical champions across the relevant disciplines within the healthcare setting were suggested (19). Additional suggestions included allocation of staff to coordinate and support telemedicine and its various tasks (20, 28), involvement of frontline staff within the organisation throughout the implementation process (20), a designated clinician to accompany patients at remote facilities (28), and additional support for ensuring follow-up and adherence to patient recommendations arising from the tele-consultation (26). Finally, need for clear dissemination of the purpose of telemedicine to ensure appropriate use, and allocated time online with peers for those working in isolation to reflect, debrief and discuss their experiences were described (22).

Quantitative Synthesis

Attitudes to Telemedicine vs. Usual Care

Four studies assessed attitudes to telemedicine as an alternative to in-person visits, among families who had not yet experienced telemedicine and found high (95%, 151/159) (29) to moderately high (58% 148/256; 57%, 588/1032) (30, 31) preference for in-person visits, despite openness to trying telemedicine (30, 32). For studies whereby telemedicine had been tested (18, 33–37), acceptability of tele-consultations ranged from 79 to 100%. Qubty et al. also reported feedback that telemedicine is useful if the child is doing well, otherwise face-to-face is preferable (34). Marconi et al. examined physician tele-presence during an emergency triage and found that 59% of parents and 83% of children would prefer this type of visit (18).

Time/distance spent travelling to appointments (29–31), perceived cost of in-person appointments (31), familiarity with telemedicine (31), and number of missed work hours (38) were all significantly correlated with positive attitudes to telemedicine.

Usability

Of the five studies that reported usability from the perspective of HCPs, the majority found the technology easy to use (90%; 95%) (20, 39) or rated it highly (9.3/10.0; 4.2/5.0) (25, 40). Zachariah et al. reported all clinicians to be competent with independent use of telemedicine following training on use of the equipment (35).

Among patients and families ($n = 1{,}032$), one study found participants to be comfortable communicating about medical issues through email (69.9%, $n = 721$), telephone (82.9%, $n = 856$), and video conferencing (52.9%, $n = 546$) (31). Others reported unanimous satisfaction and comfort with the experience of using telemedicine (98%; 100%) (33, 34), and high ratings for user-friendliness of the telemedicine platform (4.8/5.0) (25).

Challenges Encountered

Table 2 presents the main barriers to initiating use of telemedicine that were reported across six quantitative studies. The challenges encountered with the use of telemedicine that were reported quantitatively by seven studies are shown in **Table 3**.

Participants within some studies offered suggestions for improvements of telemedicine services. These included the need for training and education (17%, 7/41; 100%, 7/7), and suggested investment in higher quality equipment with higher resolution imaging (7%, 3/41; 100%, 7/7) (35, 41). Fefferman (40) reported no negative feedback, while Brova et al. reported 39% (42/107) to have experienced no significant implementation challenges. No studies reported whether any adverse events related to the use of telemedicine occurred and no detail was provided within the included trials about whether this was monitored (16–18).

Perceived Benefits of Telemedicine

Table 4 outlines the perceived benefits of telemedicine. Time-savings were cited across more studies than any other beneficial factor, with eight papers reporting that it was mentioned. One additional study (32) found that most respondents thought that time-saving was moderately/very important (88%), followed by cost-saving (85%) among those who had not yet tested telemedicine.

Satisfaction With the Telemedicine Service

Overall satisfaction with telemedicine was reported among six studies that assessed the patient/family perspective (16, 17, 25, 33, 34, 36), with two of these as part of randomised controlled trials (16, 17). Coker et al. (17) found that parents reported significantly higher satisfaction with a tele-referral system and with care overall compared with usual care. Cady et al. (16) reported significantly higher "adequacy of coordination of care" among participants within the intervention group of a three armed trial testing phone, video and usual care, compared to baseline. No significant differences were observed between groups. Four studies reported high satisfaction with telemedicine care received (25, 33, 34, 36).

HCPs' satisfaction with telemedicine was reported quantitatively by eight studies (20, 25, 35, 36, 39, 40, 42, 43), with generally high satisfaction ranging from 91-100% among those whereby the telemedicine was used for communication with patients/families (20, 35, 36, 39). McConnochie (42) found that 46% were at least as confident of diagnoses made via telemedicine as face-to-face. This increased to 83% among providers who had carried out over 50 tele-consultations. High satisfaction with

TABLE 2 | Reported barriers to initiating the use of telemedicine.

Author	Perspective	Barrier	Frequency reported
Fieleke	Healthcare provider	Lack of need Billing/reimbursement issues Concerns about medico-legal ramifications Lack of trust in telemedicine accuracy Lack of direct patient contact Cost Time constraints	Twice or more
Fang	Healthcare provider	Lack of clinical need	65·5% (36/55)
McCrossan	Healthcare provider	Insufficient training in relevant specialty	87% (13/15) of those using telemedicine infrequently (37% in total, 13/35)
		Inexperience with the equipment	31% (11/35), (73% in total, 11/15)
Seckeler	Healthcare provider	Patient privacy concerns	60% (27/46)
		Cost of implementation	10% (4/46)
		Ease of access in the catheterization laboratory	10% (4/46)
		Image quality	10% (4/46)
		Time constraints	10% (4/46)
		Trust of advisor (technology for communication with mentors)	10% (4/46)
Russo	Patient/family	Lack of trust toward telemedicine tools	30%
		Fear of excessive responsibilities for the family	28% (of those who expressed non-interest in telemedicine; n = unclear)
Marconi	Patient/family	Child too sick to take part	Most common reason for declining to participate; % not reported

technology for communication between professionals was also reported (40, 43). Karlsudd et al. reported greater satisfaction among parents (4.8/5.0) than HCPs (3.9/5.0) (25).

DISCUSSION

Summary of Findings

We aimed to identify and describe the scientific literature related to implementing telemedicine in paediatrics. This study is essential as it informs and supports the response of paediatric health services to the COVID-19 pandemic and the efforts needed to maintain clinical services while adhering to pandemic-response guidelines. We present a synthesis of evidence for factors affecting implementation of paediatric telemedicine from the perspectives of end-users, including HCPs and patients/families. In addition, we map the findings to the CFIR (**Table 1**) to facilitate systematic identification of multi-level factors reported to influence implementation of telemedicine in paediatrics. The use of CFIR provides readers with a practical guide allowing stakeholders to apply relevant findings to their own paediatric setting. Our review provides an outline of the broad issues that have been identified within a set of studies of variable quality, settings and clinic types, informing actionable considerations for current implementation plans whilst also providing evidence to inform further primary research and focused evidence syntheses. This review also collates evidence for both paediatric patient/family and HCP acceptance of telemedicine for the first time.

The quantitative studies assessed demonstrate that among those who have not yet tried telemedicine, there was a tendency to favour in-person care, however among those who had tested tele-consultations, acceptance and satisfaction was high, increasing also with experience. Families who lived further away from healthcare facilities, and who therefore had greater costs (both monetary and opportunity costs) for attending in-person appointments, were more open to tele-consultations. This is of particular importance in paediatrics whereby both school and workdays are potentially missed due to healthcare appointments.

Several barriers to uptake and challenges were identified within the quantitative literature specific to paediatric care and telemedicine generally, and scepticism about the reliability of the technology was a key barrier expressed by both providers and families. Telemedicine was perceived as inappropriate for various types of examinations logistically, and often could not replace in-person visits, while other common challenges included connectivity and quality issues, specifically inadequate audio/visual quality. Many of these issues were echoed by the qualitative studies, where it was also clear that HCPs experienced a great deal more practical issues and concerns around the use of telemedicine than patients and their families, who valued the convenience it allowed. Thorough planning before implementation commencement and involving frontline staff in order to identify practical concerns within a specific setting and to increase buy-in, is a key finding. Investment in quality, reliable technology that staff can trust to overcome the communication considerations for working with families,

TABLE 3 | Reported challenges encountered during use of telemedicine.

Author	Perspective	Issues reported	Frequency reported
Brova	Healthcare provider	Process concerns	39% (42/107)
		Technology concerns	14% (15/107)
Fieleke	Healthcare provider	Poor image quality Patient movement leading to blurred images Inability to perform necessary examination/treatment Billing/reimbursement issues	Twice or more
Hopper	Patient/family	Perception that telemedicine examination was insufficient	10% (1/10)
		Child distracted/bothered by screen	10% (1/10)
McConnochie	Healthcare provider	(Reasons for incomplete visits)	
		Inability to perform necessary examination/ treatment remotely	64% (51/79)
		Further test or imaging needed	14% (11/79)
		Child site or parent decision prevented clinician from seeing child	4% (3/79)
		Technical failure/inadequacy	17% (14/79)
		(Reasons for cancelled/refused visits)	
		Designated clinicians for tele-consultations out of office without cover	40% (96/243)
		Practise indicated being too busy to accommodate tele-visit	19% (47/243)
		Insurance did not cover telemedicine/no insurance	18% (43/243)
		Visit requested too late	11% (27/243)
		Administrative error/issue unrelated to the technology	3% (7/243)
		Practise unable to complete visit within available time	2% (4/243)
		Practise refused visit due to unpaid bill	<1% (1/243)
		(Reasons for abandoned visits)	
		Parent picked up child before information capture was complete	25% (23/90)
		Unable to acquire necessary information (e.g., child uncooperative)	15% (14/90)
		Administrative problem (e.g., unable to contact parent for consent)	20% (18/90)
		Technical problem	12% (11/90)
		Problem was beyond capacity of model	10% (9/90)
		Other (not specified)	18% (15/90)
Qubty	Patient/family	(from open feedback) Sub-optimal audio/video Connectivity issues due to capacity of home internet service Not optimised for tablet PC Insufficient troubleshooting resources for families Telemedicine calendar not open early enough to find available slots Administrative burden No sign interpreter	26% (13/51) 8% (4/51) 2% (1/51) 4% (2/51) 2% (1/51) 4% (2/51) 2% (1/51)
Seckeler	Healthcare provider	Encountered inadequate imaging to provide advice	42% (8/19)
Zachariah	Healthcare provider	Temporary disruptions in audio (sound distortion) and video (image streaking) quality requiring widening bandwidth of the internet provider.	86% (6/7)

in addition to appropriate reallocation of resources to allow the service to run and comprehensive training are also necessary. For paediatric care specifically, a key consideration is the importance of triaging patients for the suitability of telemedicine (e.g., whether a tele-medical consult might expedite access to specialist care, whether a physical assessment can feasibly be undertaken without physical examination or whether physical rehabilitation can occur without therapeutic handling). Secondly, the inability of children to describe and express symptoms depending on age/development should be considered and is of particular importance *in situ*ations where child welfare may be at risk. Thirdly, with young children, there can be difficulty in capturing images electronically, which in addition to general anxiety among staff using

TABLE 4 | Benefits of telemedicine as perceived by participants.

Benefit cited	Study	% (*n*)
Time savings	Fefferman[a]	-
	Fieleke[a]	-
	Lai[b]	24% (5/21)
	Qubty[b]	85% (4/51)
	Seckeler	82% mentors (16/19); 65% (30/46) mentees
	McConnochie	91% (207/227) (mean saving 4·5 h; SD 2·2)
	Cady[b]	1% (2/139)
	Karlsudd[c]	-
Increased efficiency	Fefferman[a]	-
	Fieleke[a]	-
	Cady[b]	4% (5/139)
Convenience	Fefferman[a]	-
	Lai[b]	10% (2/21)
	Qubty	100% (51/51)
	Cady[b]	2% (3/139)
Lower cost	Lai	10% (2/21)
	Qubty	100% (51/51)
Increased communication/ familiarity/ solidarity between staff/services	Fefferman[a]	–
	Seckeler	82% (16/19) mentors
	Zachariah	71% (5/7)
	Fang	90% (84/93)
	Karlsudd[c]	–
Improved workflow/patient management/protocols	Fefferman	100% (16/16)
	Fieleke[a]	–
	Zachariah	86% (6/7)
	Fang	85% (79/93)
	Karlsudd[c]	–
Increased learning opportunities	Fefferman[a]	–
	Fieleke[a]	–
	Zachariah	100% (7/7)
Improved enjoyment of visits for paediatric patients	Fieleke[a]	–
Reassurance (for professional or parent)	Lai	14% (3/21)
	Cady[b]	1% (1/139)
Reduced stress	Qubty[b]	2% (1/51)
	Cady[b]	1% (1/139)
Reduced risk of infection	Cady[b]	1% (1/139)

[a]*Open-ended feedback, frequency not reported.*
[b]*Open-ended feedback.*
[c]*Presented as average scores out of 5.0 (parents/staff): time savings (4.6/3.5); synergy effects (4.6/3.4); increased quality of contact and information (4.5/3.5).*

telemedicine, impacts decision making and can result in additional caution.

Previous Literature

Many of our findings are consistent with those outlined by reviews of telemedicine in broader populations, for many of the aspects of implementing telemedicine generally (9, 44). Concerns about liability and reimbursement were also raised in a review of statutes and regulations for telemedicine for stroke care in the U.S. (45) and this was prominent with our review, particularly among clinicians in the U.S.. Costs and reimbursement issues were further highlighted by Helleman et al. in a review of tele-care for amyotrophic lateral sclerosis (46), who also reported evidence of perceived benefits that were closely aligned with the findings of this review; continuity of care, convenience, time-savings and reduced travel burden. Concerns among clinicians about lack of opportunity to conduct a physical examination and the resulting limitations on care were also emphasised (46). Our review, however, is the first to synthesise the evidence for barriers and facilitators for implementing telemedicine in paediatric settings and highlights additional considerations pertinent to paediatric care. For example, the inability of younger children or those with communication difficulties to describe their symptoms requires interpretation by carers and HCPs. Such assessment and interpretation may not be as easily conducted through tele-consultations. Secondly, taking informed parental consent and child assent using tele-consultations may be challenging. This adds additional pressure to both parents/carers and clinicians to accurately assess the level of risk associated with the child's condition and act accordingly, and may result in decreased confidence in the use of the telemedicine medium for paediatric care compared with adult care.

Considerations and Future Research

In addition to the findings of this review, further considerations for the context of urgent implementation of telemedicine as a response to a global pandemic are needed. The absence of in-person care may greatly infringe upon the ability of HCPs to identify issues relating to child protection such as compliance with immunisation schedules or evidence of potential harm, particularly in regions whereby schools may close during the COVID-19 pandemic and the opportunities to flag such issues are greatly reduced. Concerns about assessment of risk were highlighted within this review (22). However, the broader assessment of risk within the context of child welfare in the home is another role of the healthcare provider (47, 48) and emphasises the balance needed between maintaining care via telemedicine while no alternative is available, while monitoring and evaluating its feasibility as a long-term replacement for in-person care. Our review also highlights the dearth of data related to the reporting of adverse events in tele-medical interventions and future studies should ensure such data is collected and reported.

In many cases the planning, staff consultations, time, and funding necessary for gold standard implementation will simply not be available, while additional necessities such as staff working from their own homes and related privacy issues must also be considered. From the perspective of families, the need for quality technology and connectivity may contribute to issues of inequity and could increase socioeconomic disparities. Recently documented issues have emphasised security concerns however (49) and particularly in Europe, compliance with General Data Protection Regulations (GDPR) is the primary criterion for selecting appropriate platforms. Monitoring and evaluation of implementation that occurs, over the course of the pandemic and beyond, will offer insight into barriers and facilitators of rapid implementation in the context of a pandemic. It is important that well-designed process evaluations and assessments of user-experiences are undertaken, with meaningful data captured in order to inform future service design and optimise the capacity for using telemedicine safely and effectively.

Strengths and Limitations

This study had several strengths and limitations due to its nature as a rapid evidence synthesis. We searched one database due to time constraints, in the interest of producing a review of the key issues in a timely manner to be of maximum use. As a result, we have not assessed the breadth of the available literature on this topic for this review. Additionally, this review covers a variety of studies, which are heterogeneous in terms of the technology used, the clinical setting observed, a mix of high, low and middle income countries, and having been undertaken over a period of 15 years. Technological issues described by older studies may no longer have relevance in countries where IT infrastructure has rapidly evolved. However, many of the articles identified for inclusion still produced insightful comparable data on implementation. This article provides an overview of aspects of implementation of paediatric telemedicine that future research can build upon through carefully planned, robust and exhaustive reviews with more tightly focussed inclusion criteria.

Our inclusion of multiple research methods however, allowed for a comprehensive and rich overview of the factors involved in paediatric telemedicine. We undertook steps to minimise risks of bias, including double screening of records and verification of quality appraisal and data extraction by additional members of the review team. While the quality of the included quantitative literature was not consistently high, this highlighted a need for comprehensive feasibility studies that incorporate implementation fully into their design.

Conclusion

To conclude, the use of telemedicine to facilitate and augment paediatric healthcare consultations is feasible and, in many cases, can work well with appropriate planning and quality facilities in place. HCPs and families who have experienced tele-consultations generally report high satisfaction and usability for such services. However, telemedicine is not practical for every clinical situation (such as cases where complex physical examinations or specific physical therapies are needed or a parent cannot articulate a child's condition), and its implementation can create an array of obstacles for healthcare workers in providing care to their full potential. Well-designed studies, undertaken throughout the implementation process are needed, in addition to a comprehensive systematic review of academic databases and grey literature, to establish the evidence base for user experiences of implementing paediatric telemedicine. Notwithstanding, our review will assist HCPs with the knowledge and information necessary to optimise clinical care safely through telemedicine *in situ*ations where normal clinical services are interrupted or reduced. Further reviews with more refined and focused research settings and exhaustive literature searches are warranted. A visual summary of our findings and conclusions is available in **Supplementary Image 2**.

DATA AVAILABILITY STATEMENT

The original contributions generated in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

GO'M, LT, and JS designed the study. LC, NA, and LT screened abstracts, titles, and full texts. LT extracted data and completed critical appraisal/risk of bias. LC and NA verified 20% of extracted data and completed critical appraisal for 20% of studies to ensure consistency. LT, GO'M, and JPM drafted and finalised the manuscript with critical feedback from JS, NA, and LC. All authors contributed to the article and approved the submitted version.

FUNDING

This study was funded by the Royal College of Surgeons in Ireland StAR programme (Grant No. 2151), and undertaken as part of the Health Research Board (HRB) Structured Population and Health Services Research Education (SPHeRE) training programme (Grant No. SPHeRE/2013/1). The HRB supports excellent research that improves people's health, patient care, and health service delivery.

ACKNOWLEDGMENTS

Special thanks to Andrew Simpson (Research Librarian, RCSI University of Medicine and Health Sciences) for support with database searching for this review.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fped.2021.630365/full#supplementary-material

REFERENCES

1. Boeken T, Le Berre A, Mebazaa A, Boulay-Coletta I, Hodel J, Zins M. Non-COVID-19 emergencies: where have all the patients gone? *J Eur Radiol*. (2020) 30:5220–1. doi: 10.1007/s00330-020-06961-z
2. Hartnett KP, Kite-Powell A, DeVies J, Coletta MA, Boehmer TK, Adjemian J, et al. *Impact of the COVID-19 Pandemic on Emergency Department Visits-United States, January 1, 2019-May 30, 2020*. Washington, DC: Centers for Disease Control and Prevention (2020).
3. Willan J, King AJ, Jeffery K, Bienz N. Challenges for NHS hospitals during covid-19 epidemic. *BMJ*. (2020) 368:m1117. doi: 10.1136/bmj.m1117

4. Eccleston C, Blyth FM, Dear BF, Fisher EA, Keefe FJ, Lynch ME, et al. Managing patients with chronic pain during the COVID-19 outbreak: considerations for the rapid introduction of remotely supported (eHealth) pain management services. *Pain*. (2020) 161:889–93. doi: 10.1097/j.pain.0000000000001885
5. Center for Disease Control and Prevention. *Healthcare Facilities: Managing Operations During the COVID-19 Pandemic 2020*. Available online at: https://www.cdc.gov/coronavirus/2019-ncov/hcp/guidance-hcf.html (accessed June 28, 2020).
6. Schulz T, Long K, Kanhutu K, Bayrak I, Johnson D, Fazio T. Telehealth during the coronavirus disease 2019 pandemic: Rapid expansion of telehealth outpatient use during a pandemic is possible if the programme is previously established. *J Telemed Telecare*. (2020) 1357633X20942045. doi: 10.1177/1357633X20942045. [Epub ahead of print].
7. Utidjian L, Abramson E. Pediatric telehealth: opportunities and challenges. *Pediatr Clin N Am*. (2016) 63:367–78. doi: 10.1016/j.pcl.2015.11.006
8. World Health Organization. *Maintaining Essential Health Services: Operational Guidance for the COVID-19 Context: Interim Guidance, 1 June 2020*. Geneva: World Health Organization (2020).
9. Ross J, Stevenson F, Lau R, Murray EJIs. Factors that influence the implementation of e-health: a systematic review of systematic reviews (an update). *Implement Sci*. (2016) 11:146. doi: 10.1186/s13012-016-0510-7
10. Harker J, Kleijnen J. What is a rapid review? A methodological exploration of rapid reviews in health technology assessments. *Int J Evid Based Healthc*. (2012) 10:397–410. doi: 10.1111/j.1744-1609.2012.00290.x
11. Stevens A, Garritty C, Hersi M, Moher D. *Developing PRISMA-RR, a Reporting Guideline for Rapid Reviews of Primary Studies (Protocol)*. Oxford: Centre for Statistics in Medicine, NDORMS, University of Oxford (2018).
12. Heyvaert M, Maes B, Onghena P, Quantity. Mixed methods research synthesis: definition, framework, and potential. *J Quality*. (2013) 47:659–76. doi: 10.1007/s11135-011-9538-6
13. Hong QN, Fàbregues S, Bartlett G, Boardman F, Cargo M, Dagenais P, et al. The mixed methods appraisal tool (MMAT) version 2018 for information professionals and researchers. *Educ Inform*. (2018) 34:285–91. doi: 10.3233/EFI-180221
14. Thomas J, Harden A. Methods for the thematic synthesis of qualitative research in systematic reviews. *BMC Med Res Methodol*. (2008) 8:45. doi: 10.1186/1471-2288-8-45
15. Damschroder LJ, Aron DC, Keith RE, Kirsh SR, Alexander JA, Lowery JC. Fostering implementation of health services research findings into practice: a consolidated framework for advancing implementation science. *Implement Sci*. (2009) 4:50. doi: 10.1186/1748-5908-4-50
16. Cady RG, Erickson M, Lunos S, Finkelstein SM, Looman W, Celebreeze M, et al. Meeting the needs of children with medical complexity using a telehealth advanced practice registered nurse care coordination model. *Matern Child Health J*. (2015) 19:1497–506. doi: 10.1007/s10995-014-1654-1
17. Coker TR, Porras-Javier L, Zhang L, Soares N, Park C, Patel A, et al. A telehealth-enhanced referral process in pediatric primary care: a cluster randomized trial. *Pediatrics*. (2019) 143:e20182738. doi: 10.1542/peds.2018-2738
18. Marconi GP, Chang T, Pham PK, Grajower DN, Nager AL. Traditional nurse triage vs. physician telepresence in a pediatric ED. *Am J Emerg Med*. (2014) 32:325–9. doi: 10.1016/j.ajem.2013.12.032
19. Uscher-Pines L, Kahn JM. Barriers and facilitators to pediatric emergency telemedicine in the United States. *Telemed J E-health*. (2014) 20:990–6. doi: 10.1089/tmj.2014.0015
20. Fang JL, Asiedu GB, Harris AM, Carroll K, Colby CE. A mixed-methods study on the barriers and facilitators of telemedicine for newborn resuscitation. *Telemed J E-health*. (2018) 24:811–7. doi: 10.1089/tmj.2017.0182
21. Abaza H, Marschollek M. mHealth application areas and technology combinations: a comparison of literature from high and low/middle income countries. *Methods Inform Med*. (2017) 56:e105–22. doi: 10.3414/ME17-05-0003
22. Haimi M, Brammli-Greenberg S, Waisman Y, Baron-Epel O. Physicians' experiences, attitudes and challenges in a pediatric telemedicine service. *Pediatr Res*. (2018) 84:650–6. doi: 10.1038/s41390-018-0117-6
23. Fang JL, Campbell MS, Weaver AL, Mara KC, Schuning VS, Carey WA, et al. The impact of telemedicine on the quality of newborn resuscitation: a retrospective study. *Resuscitation*. (2018) 125:48–55. doi: 10.1016/j.resuscitation.2018.01.045
24. Ray KN, Ashcraft LE, Mehrotra A, Miller E, Kahn JM. Family perspectives on telemedicine for pediatric subspecialty care. *Telemed J E-health*. (2017) 23:852–62. doi: 10.1089/tmj.2016.0236
25. Karlsudd P. E-collaboration for children with functional disabilities. *Telemed J E-health*. (2008) 14:687–94. doi: 10.1089/tmj.2007.0112
26. Greenberg N, Boydell KM, Volpe T. Pediatric telepsychiatry in ontario: caregiver and service provider perspectives. *J Behav Health Serv Res*. (2006) 33:105–11. doi: 10.1007/s11414-005-9001-3
27. Krüger C, Niemi M. A telemedicine network to support paediatric care in small hospitals in rural Tanzania. *J Telemed Telecare*. (2012) 18:59–62. doi: 10.1258/jtt.2011.110312
28. Smith AC, Garner L, Caffery LJ, McBride CA. A review of paediatric telehealth for pre- and post-operative surgical patients. *J Telemed Telecare*. (2014) 20:400–4. doi: 10.1177/1357633X14552373
29. Bullock DR, Vehe RK, Zhang L, Correll CK. Telemedicine and other care models in pediatric rheumatology: an exploratory study of parents' perceptions of barriers to care and care preferences. *Pediatr Rheumatol Online J*. (2017) 15:55. doi: 10.1186/s12969-017-0184-y
30. Kessler EA, Sherman AK, Becker ML. Decreasing patient cost and travel time through pediatric rheumatology telemedicine visits. *Pediatr Rheumatol Online J*. (2016) 14:54. doi: 10.1186/s12969-016-0116-2
31. Bator EX, Gleason JM, Lorenzo AJ, Kanaroglou N, Farhat WA, Bägli DJ, et al. The burden of attending a pediatric surgical clinic and family preferences toward telemedicine. *J Pediatr Surg*. (2015) 50:1776–82. doi: 10.1016/j.jpedsurg.2015.06.005
32. Russo L, Campagna I, Ferretti B, Agricola E, Pandolfi E, Carloni E, et al. What drives attitude towards telemedicine among families of pediatric patients? A survey. *BMC Pediatr*. (2017) 17:21. doi: 10.1186/s12887-016-0756-x
33. Hopper B, Buckman M, Edwards M. Evaluation of satisfaction of parents with the use of videoconferencing for a pediatric genetic consultation. *Twin Res Hum Genet*. (2011) 14:343–6. doi: 10.1375/twin.14.4.343
34. Qubty W, Patniyot I, Gelfand A. Telemedicine in a pediatric headache clinic: a prospective survey. *Neurology*. (2018) 90:e1702–5. doi: 10.1212/WNL.0000000000005482
35. Zachariah R, Bienvenue B, Ayada L, Manzi M, Maalim A, Engy E, et al. Practicing medicine without borders: tele-consultations and tele-mentoring for improving paediatric care in a conflict setting in Somalia? *Trop Med Int Health*. (2012) 17:1156–62. doi: 10.1111/j.1365-3156.2012.03047.x
36. DeAntonio JH, Kang HS, Cockrell HC, Rothstein W, Oiticica C, Lanning DA. Utilization of a handheld telemedicine device in postoperative pediatric surgical care. *J Pediatr Surg*. (2019) 54:1005–8. doi: 10.1016/j.jpedsurg.2019.01.032
37. McConnochie KM, Wood NE, Kitzman HJ, Herendeen NE, Roy J, Roghmann KJ. Telemedicine reduces absence resulting from illness in urban child care: evaluation of an innovation. *Pediatrics*. (2005) 115:1273–82. doi: 10.1542/peds.2004-0335
38. Chapal M, Le Borgne F, Legendre C, Kreis H, Mourad G, Garrigue V, et al. A useful scoring system for the prediction and management of delayed graft function following kidney transplantation from cadaveric donors. *Kidney Int*. (2014) 86:1130–9. doi: 10.1038/ki.2014.188
39. Lai L, Liddy C, Keely E, Afkham A, Kurzawa J, Abdeen N, et al. The impact of electronic consultation on a Canadian tertiary care pediatric specialty referral system: a prospective single-center observational study. *PLoS ONE*. (2018) 13:e0190247. doi: 10.1371/journal.pone.0190247
40. Fefferman NR, Strubel NA, Prithiani C, Chakravarti S, Caprio M, Recht MP. Virtual radiology rounds: adding value in the digital era. *Pediatr Radiol*. (2016) 46:1645–50. doi: 10.1007/s00247-016-3675-y
41. Fieleke DR, Edison K, Dyer JA. Pediatric teledermatology–a survey of current use. *Pediatr Dermatol*. (2008) 25:158–62. doi: 10.1111/j.1525-1470.2008.00624.x
42. McConnochie K, Wood N, Herendeen N, Ten Hoopen C, Denk L, Neuderfer J. Integrating telemedicine in urban pediatric primary care: provider perspectives and performance. *Telemed J E-health*. (2010) 16:280–8. doi: 10.1089/tmj.2009.0112

43. Seckeler MD, Gordon BM, Williams DA, Goldstein BH. Use of smart technology for remote consultation in the pediatric cardiac catheterization laboratory. *Congenit Heart Dis*. (2015) 10:E288–94. doi: 10.1111/chd.12308
44. Brewster L, Mountain G, Wessels B, Kelly C, Hawley M. Factors affecting front line staff acceptance of telehealth technologies: a mixed-method systematic review. *J Adv Nurs*. (2014) 70:21–33. doi: 10.1111/jan.12196
45. Kulcsar M, Gilchrist S, George MG. Improving stroke outcomes in rural areas through telestroke programs: an examination of barriers, facilitators, and state policies. *J Telemed E-Health*. (2014) 20:3–10. doi: 10.1089/tmj.2013.0048
46. Helleman J, Kruitwagen ET, van den Berg LH, Visser-Meily JM, Beelen A. The current use of telehealth in ALS care and the barriers to and facilitators of implementation: a systematic review. *J Amyotroph Lateral Sclerosis*. (2020) 21:167–82. doi: 10.1080/21678421.2019.1706581
47. Pietrantonio AM, Wright E, Gibson KN, Alldred T, Jacobson D, Niec A. Mandatory reporting of child abuse and neglect: crafting a positive process for health professionals and caregivers. *Child Abuse Neglect*. (2013) 37:102–9. doi: 10.1016/j.chiabu.2012.12.007
48. Fraser JA, Mathews B, Walsh K, Chen L, Dunne M. Factors influencing child abuse and neglect recognition and reporting by nurses: a multivariate analysis. *Int J Nurs Stud*. (2010) 47:146–53. doi: 10.1016/j.ijnurstu.2009.05.015
49. Kaplan B. Revisting health information technology ethical, legal, and social issues and evaluation: telehealth/telemedicine and COVID-19. *J Med Inform*. (2020) 143:104239. doi: 10.1016/j.ijmedinf.2020.104239

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Pediatrics

BRIEF RESEARCH REPORT
published: 19 March 2021
doi: 10.3389/fped.2021.642279

Check for updates

The Impact of Telehealth on Clinical Education in Adolescent Medicine During the COVID-19 Pandemic: Positive Preliminary Findings

Do-Quyen Pham [1,2†], Sarah A. Golub [1,2†], Cora Collette Breuner [1,2] and Yolanda N. Evans [1,2]*

[1] *Division of Adolescent Medicine, Seattle Children's Hospital, Seattle, WA, United States,* [2] *Department of Pediatrics, University of Washington School of Medicine, Seattle, WA, United States*

OPEN ACCESS

Edited by:
Tzielan Lee,
Stanford University, United States

Reviewed by:
Mariane De Montalembert,
Assistance Publique 96 Hôpitaux de Paris, France
Ryan Pasternak,
Louisiana State University, United States

****Correspondence:***
Do-Quyen Pham
do-quyen.pham@seattlechildrens.org

†These authors have contributed equally to this work and share first authorship

Specialty section:
This article was submitted to General Pediatrics and Pediatric Emergency Care, a section of the journal Frontiers in Pediatrics

Received: *15 December 2020*
Accepted: *01 March 2021*
Published: *19 March 2021*

Citation:
Pham D-Q, Golub SA, Breuner CC and Evans YN (2021) The Impact of Telehealth on Clinical Education in Adolescent Medicine During the COVID-19 Pandemic: Positive Preliminary Findings. Front. Pediatr. 9:642279. doi: 10.3389/fped.2021.642279

Purpose: Following the start of the COVID-19 pandemic, much of clinical care rapidly transitioned to telehealth, shifting the clinical training milieu for most trainees. In the wake of this shift, educators have attempted to keep learners engaged in patient care and optimize medical education as much as possible. There is, however, limited understanding of the effect of telehealth on clinical education. The aim of our study was to better understand the educational experience of pediatric and Adolescent Medicine trainees participating in clinical encounters via telehealth in a specialty consultation Adolescent Medicine Clinic at a quaternary pediatric care hospital.

Methods: Using a web-based anonymous questionnaire, we surveyed trainees rotating through the Adolescent Medicine Clinic between March and June 2020. We used descriptive statistics to evaluate their experiences with telehealth and identify techniques that were effective to facilitate learning during a telehealth visit.

Results: Surveys from 12 pediatric and Adolescent Medicine trainees were received, a 75% response rate. Most trainees (83.3%) reported no prior experience with telehealth before the onset of the pandemic. By the end of their rotation, trainees identified techniques that helped facilitate learning during a telehealth visit. The majority of trainees (83.3%) rated their experience as effective or very effective, and all reported interest in incorporating telehealth into their future practice.

Conclusions: Pediatric and Adolescent Medicine trainees reported overall positive experiences with telehealth in clinical education and an interest in incorporating this tool into future practice. Additional research is needed to refine techniques in engaging learners through telehealth.

Keywords: telehealth, COVID-19, pandemic, adolescent medicine, clinical education, medical education

INTRODUCTION

The onset of the COVID-19 pandemic propelled into motion a rapid transition of many aspects of society across the globe, as life as we once knew it transformed over a period of weeks. While telehealth has been a well-established means of providing clinical services for over a decade, the global pandemic has brought it to the forefront as a crucial means of providing continued access to care while minimizing disease transmission (1, 2).

Existing literature has shown that many components of adolescent health care can be provided effectively through telehealth (3–5). In the past year, several academic institutions in the United States have also published on the challenges, opportunities, and impact of a rapid scale-up of telehealth use in Adolescent Medicine in the setting of the pandemic (6–9). However, with academic medical centers worldwide converting much of their clinical care to telehealth, the educational opportunities and roles of medical trainees have shifted as well. Given the extraordinary nature of the pandemic, there have been varied approaches to managing trainees, ranging from complete discouragement of participation in clinical care to throwing trainees into action or fast-tracking students to graduate early to enable their participation in clinical care (10).

Keeping trainees engaged and on the frontline is viewed by some as a great teaching opportunity despite the fact that their participation potentially increases their exposure to disease. Many would argue that it promotes critical thinking skills essential for growth. On the other hand, trainees left at home on the sideline may feel excluded, wondering how they could meaningfully contribute to clinical care and further their education (11). Telehealth, however, has thus far proven to be a solution in bridging this gap, enabling medical trainees to safely observe and participate in patient care remotely during the COVID-19 pandemic (12). In some cases, medical trainees have also served as "digital natives" and helped play a role in the expansion and delivery of healthcare in the setting of COVID-19 (10). Through various frameworks, medical educators have proposed methods to ensure inclusion of learners; however, balancing safety for patients and staff, while keeping trainees engaged, has proven to be a difficult task (13).

Despite the growing body of relevant literature describing the importance of including learners in the virtual setting, there is a dearth of evidence regarding the efficacy of the telehealth platform in how it specifically affects clinical education. In addition, many of these publications have focused on medical student education and not on residents or clinical fellows, and none have explored Adolescent Medicine trainees' perspectives (1, 14–16). The aim of our study was to assess the educational experience of pediatric and Adolescent Medicine trainees participating in clinical encounters via telehealth in a specialty Adolescent Medicine Clinic.

METHODS

We developed a brief, web-based survey to gather responses from residents and fellows rotating through the Adolescent Medicine Clinic at Seattle Children's Hospital (SCH). Participants included pediatric residents in their 3rd year of training during a required 4-week rotation concentrated on adolescent health. In addition, Adolescent Medicine fellows who had previously completed residency training prior to pursuing subspecialty training in Adolescent Medicine were also included. We have 3–4 Adolescent Medicine fellows and 2–4 pediatric residents working in our clinic each month. This clinic provides multiple consultative services including gender-affirming care, eating disorders, reproductive healthcare, behavioral health services, and biofeedback therapy. Each clinic half-day session is 4 h. The setting includes unique educational opportunities to participate in multidisciplinary care while navigating adolescent confidentiality.

This anonymous questionnaire consisted of 11 discrete items which elicited learners' feedback regarding their experiences using telemedicine. Items included multiple choice, Likert-scale, and free-text responses. The survey was administered between March and June 2020. Initial request to complete the survey was sent out by email, followed by a reminder email 1 week later. We used simple descriptive statistics to analyze quantitative survey results. The current paper presents the quantitative component of a mixed-methods study; free-text responses were analyzed qualitatively and were described in our previous work. We received approval from the SCH Institutional Review Board (IRB) to conduct this study.

RESULTS

We received completed surveys from 12 trainees (a 75% response rate) that consisted of 9 third-year pediatric residents and 3 Adolescent Medicine fellows. At the time of survey administration, our Division supported 4 clinical fellows, and up to 4 pediatric residents per 4-week block. **Table 1** summarizes participants' level of training, post-graduate career plans, and experience with telehealth prior to and after the onset of the pandemic. Prior to the rotation, <20% of trainees had previous experience with telehealth. By the end of the study, the majority of trainees (66.7%) had attended more than 10 telehealth clinic sessions.

Participants identified several techniques, some of which were unique to the telehealth setting, that facilitated their clinical education during the rotation (**Figure 1**). Secure texting or private chat function during the appointment, where a trainee and attending physician sent direct messages to one another through the telehealth platform, was identified by 50% of trainees to be effective. Moving a patient to a virtual waiting room in the telehealth platform to facilitate direct discussion between the preceptor and trainee was reported by 58.3% of trainees to be effective. Many attendings also sent an electronic huddle (hereafter referred to as an e-huddle) to trainees and clinical staff prior to clinic. E-huddles allow attendings to provide a brief summary of patients scheduled for the purpose of designating clinical tasks to medical assistants, nurses and social workers, and to outline a presumptive plan for each patient. Attendings email these huddles to appropriate members of the clinic team and their assigned trainee prior to their scheduled clinics in order

TABLE 1 | Characteristics of trainees and experience with telehealth.

	***N* (%)**
Level of training	
Pediatric resident	9 (75)
Fellow	3 (25)
Post-graduate career plans*	
Primary care	5 (41.7)
Subspecialty care	6 (50)
Hospital medicine	2 (16.7)
Career in research	1 (8.3)
Previous experience with telehealth	
Yes	2 (16.7)
No	10 (83.3)
Number of telehealth clinic sessions attended**	
1–5	3 (25)
6–10	1 (8.3)
11–15	5 (41.7)
>15	3 (25)

Categories are not mutually exclusive.

***Refers to the total number of sessions attended in the Adolescent Medicine clinic. One clinic session refers to a half-day of clinic (4 h).*

to facilitate patient care. Fellows were responsible for preparing and sending their own e-huddles, as patients are scheduled on their own clinic templates (while residents see patients on the attending physician's template). Although not unique to the telehealth platform, e-huddles sent out by the preceptor and pre-visit case discussions with preceptor were additional ways to facilitate clinical education through telehealth. E-huddles and pre-visit case discussions were reported as effective by 41.7% and 83.3% of trainees, respectively. Pre-visit case discussions were opportunities where the attending and trainee could discuss a clinical case prior to the medical visit and facilitated direct conversations between the attending and trainee. When reviewing perceived efficacy of e-huddles reported by residents and fellows separately, a greater proportion of residents (66.7%) reported this tool as effective compared to fellows (0%).

The majority of trainees (83.3%) rated their experience with telehealth as either effective or very effective. Among those who had more than 5 telehealth sessions, all reported that telehealth was effective or very effective in clinical education. All 12 trainees, regardless of frequency of telehealth clinics, reported interest in incorporating telehealth into their future practice.

DISCUSSION

Despite the abrupt changes brought on by the pandemic and the swift transition to telehealth, our study suggests that trainees have found telehealth to be an effective and positive aspect of their clinical education and training in the Adolescent Medicine Clinic. This study expands on our previous work, which included a qualitative analysis exploring Adolescent Medicine trainees' perspectives on the educational impact of telehealth (work in submission). The current manuscript adds by identifying and evaluating the utility of specific educational techniques that have been employed to enhance the clinical experience for trainees.

In the months since the onset of the pandemic, literature on the myriad challenges of medical education during COVID-19 has increased, though few prior studies have explored or targeted specific strategies used for clinical teaching in the virtual space. Of these studies, the vast majority have focused on education not involving direct patient care. Theoret et al. mentions the concept of a virtual anatomy dissection for medical students, by means of utilizing the screen-sharing function (17). In addition, Dedeilia et al. reviews various innovations for surgical and medical trainees including flipped online learning classrooms, simulation models and even oral examinations performed via teleconferences (18). Chick et al. outlines in detail the precepting model used in telehealth clinics for surgical residents, with trainees initially gathering history, formulating a plan, and then reviewing the case with the attending surgeon by phone before a final wrap-up via video conference, followed by a post-visit discussion of the case after the patient has signed off (19). Pourmand et al. also suggests that in considering future curricula involving telemedicine for medical trainees, it may be important to develop a consensus of which skills or milestones should be required at each stage of training (20). None of these studies, however, provide recommendations or feedback regarding mechanisms to support trainee education through telehealth encounters. In addition, to our knowledge, at the time of this manuscript preparation, there were no studies focusing on the educational experience of telehealth from the perspective of trainees in a pediatric hospital, or trainees caring for adolescents.

Strengths of the study include a high response rate of 75%. Additionally, responses were gathered from trainees shortly after the completion of their rotation, limiting recall bias. Given the anonymous nature of the survey and the fact that responses were elicited after completion of the rotation, there was little concern for trainees feeling influenced by faculty when providing their feedback. Our study has several limitations, one of which is the small sample size of trainees. In addition, given that supervising providers were learning and adapting to a relatively new modality of healthcare delivery, the educational experiences of trainees may have varied over time; it is likely that trainees rotating in June may have had a different educational experience than those rotating in March, at the very start of the pandemic. As healthcare providers and institutions continue to refine delivery of healthcare in the virtual setting, we anticipate that these improvements will allow preceptors to continue to enhance their teaching skills and thus, further education of trainees in this setting as well.

This small study was carried out with the goal of hypothesis development for further larger-scale studies of similar nature in the future. In the months since initial survey administration, in efforts to limit disease transmission, our Division has begun to expand telehealth services in order to reach vulnerable youth. Examples of these settings include juvenile detention center, transitional housing centers, and

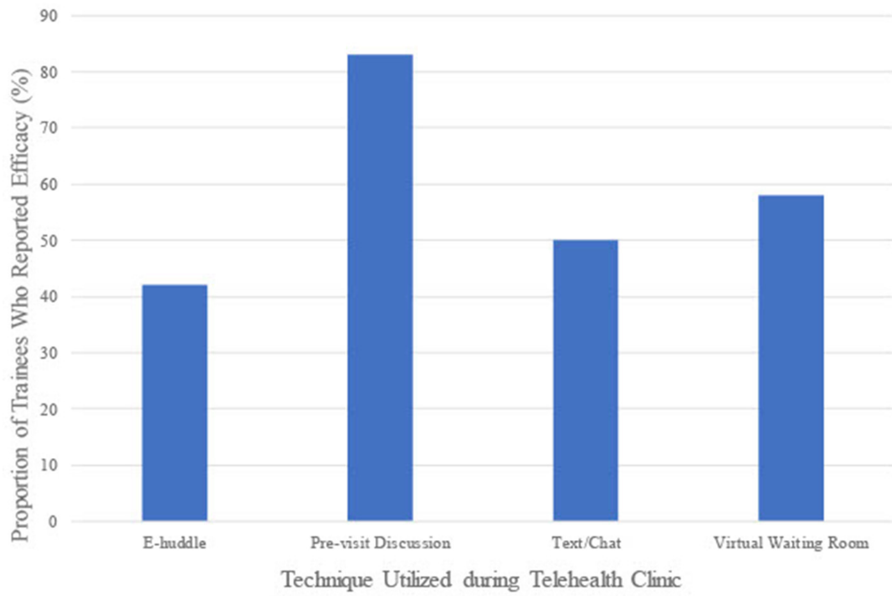

FIGURE 1 | Effective techniques to facilitate clinical education through telehealth.

emergency shelters for adolescents experiencing homelessness. We aim to consistently involve learners in these areas and subsequently hope to evaluate the quality of their educational experiences in these unique spaces. While this preliminary study has identified some tools and strategies to provide clinical education via telehealth, more research is needed to refine these techniques.

In summary, our study implies that with utilization of appropriate teaching strategies, telehealth can be a valuable tool in the clinical education of pediatric and Adolescent Medicine trainees. The abrupt transformation to widespread use of telehealth in clinical care has forced educators to reexamine their approaches to clinical teaching, while upholding their duty to support trainees during this unprecedented time in history. While disruptive, this forced overhaul of medical curricula may push us to explore novel approaches to education to benefit the next generation of medical providers.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Seattle Children's Hospital Institutional Review Board (IRB). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

D-QP and SG were responsible for study design, survey development, data analysis, and manuscript preparation. CB and YE were responsible for study design, survey development, and manuscript editing. All authors contributed to the article and approved the submitted version.

ACKNOWLEDGMENTS

The authors would like to thank the residents and fellows rotating through the Adolescent Medicine Clinic at Seattle Children's Hospital for taking the time to complete our questionnaire. We are grateful for their patience and continued engagement during the endless challenges and disruptions to their education that the COVID-19 pandemic has posed.

REFERENCES

1. North S. Telemedicine in the time of COVID and beyond. *J Adolesc Health*. (2020). 67:145–6. doi: 10.1016/j.jadohealth.2020.05.024
2. Olson CA, Thomas JF. Telehealth: no longer an idea for the future. *Adv Pediatr*. (2017) 64:347–70. doi: 10.1016/j.yapd.2017.03.009
3. Sequeira GM, Kidd KM, Coulter RWS, Miller E, Fortenberry D, Garofalo R, et al. Transgender youth perspectives on telehealth for delivery of gender affirming care. *J Adolesc Health*. (2020) 66(Suppl. 2): S31–2. doi: 10.1016/j.jadohealth.2019.11.062
4. Anderson KE, Byrne C, Goodyear A, Reichel R, Le Grange D. Telemedicine of family-based treatment for adolescent anorexia nervosa:

a protocol of a treatment development study. *J Eat Disord*. (2015) 3:25. doi: 10.1186/s40337-015-0063-1
5. Bashshur RL, Shannon GW, Bashshur N, Yellowlees PM. The empirical evidence for telemedicine interventions in mental disorders. *Telemed J E Health*. (2016) 22:87–113. doi: 10.1089/tmj.2015.0206
6. Emans SJ, Ford CA, Irwin CE, Richardson LP, Sherer S, Sieving RE, et al. Early COVID-19 impact on adolescent health and medicine programs in the United States: LEAH program leadership reflections. *J Adolesc Health*. (2020) 67:11–15. doi: 10.1016/j.jadohealth.2020.04.010
7. Barney A, Buckelew S, Mesheriakova V, Raymond-Flesch M. The COVID-19 pandemic and rapid implementation of adolescent and young adult telemedicine: challenges and opportunities for innovation. *J Adolesc Health.* (2020) 67:164–71. doi: 10.1016/j.jadohealth.2020.05.006
8. Wood SM, White K, Peebles R, Pickel J, Alausa M, Mehringer J, et al. Outcomes of a rapid adolescent telehealth scale-up during the COVID-19 pandemic. *J Adolesc Health*. (2020) 67:172–78. doi: 10.1016/j.jadohealth.2020.05.025
9. Carlson JL, Goldstein R. Using the electronic health record to conduct adolescent telehealth visits in the time of COVID-19. *J Adolesc Health*. (2020) 67:157–8. doi: 10.1016/j.jadohealth.2020.05.022
10. Klasen JM, Vithyapathy A, Zante B, Burm S. "The storm has arrived": the impact of SARS-CoV-2 on medical students. *Perspect Med Educ*. (2020) 9:181–5. doi: 10.1007/s40037-020-00592-2
11. Gallagher TH, Schleyer AM. "We signed up for this!" —student and trainee responses to the Covid-19 pandemic. *N Engl J Med.* (2020) 382:e96. doi: 10.1056/NEJMp2005234
12. Wijesooriya NR, Mishra V, Brand PLP, Rubin BK. COVID-19 and telehealth, education, and research adaptations. *Paediatr Respir Rev*. (2020) 35:38–42. doi: 10.1016/j.prrv.2020.06.009
13. Anderson ML, Turbow S, Willgerodt MA, Ruhnke GW. Education in a crisis: the opportunity of our lives. *J Hosp Med*. (2020) 15:287–9. doi: 10.12788/jhm.3431
14. Evans YN, Golub S, Sequeira GM, Eisenstein E, North S. Using telemedicine to reach adolescents during the COVID-19 pandemic. *J Adolesc Health*. (2020) 67:469–71. doi: 10.1016/j.jadohealth.2020.07.015
15. Iancu AM, Kemp MT, Alam HB. Unmuting medical students' education: utilizing telemedicine during the COVID-19 pandemic and beyond. *J Med Internet Res*. (2020) 22:e19667. doi: 10.2196/19667
16. Wayne DB, Green M, Neilson EG. Medical education in the time of COVID-19. *Sci Adv.* (2020) 6:1–2. doi: 10.1126/sciadv.abc7110
17. Theoret C, Ming X. Our education, our concerns: the impact on medical student education of COVID-19. *Med Educ.* (2020) 54:591–2. doi: 10.1111/medu.14181
18. Dedeilia A, Sotiropoulos MG, Hanrahan JG, Janga D, Dedeilias P, Sideris M. Medical and surgical education challenges and innovations in the COVID-19 era: a systematic review. *In Vivo*. (2020) 34(Suppl. 3):1603–11. doi: 10.21873/invivo.11950
19. Chick RC, Clifton GT, Peace KM, Propper BW, Hale DF, Alseidi AA, et al. Using technology to maintain the education of residents during the COVID-19 pandemic. *J Surg Educ.* (2020) 77:729–32. doi: 10.1016/j.jsurg.2020.03.018
20. Pourmand A, Ghassemi M, Sumon K, Amini SB, Hood C, Sikka N. Lack of telemedicine training in academic medicine: are we preparing the next generation? *Telemed J E Health*. (2020) 27:62–7. doi: 10.1089/tmj.2019.0287

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Pediatrics

ORIGINAL RESEARCH
published: 23 March 2021
doi: 10.3389/fped.2021.627337

Real-World Verification of Artificial Intelligence Algorithm-Assisted Auscultation of Breath Sounds in Children

Jing Zhang[1], Han-Song Wang[2,3], Hong-Yuan Zhou[4], Bin Dong[2], Lei Zhang[1], Fen Zhang[1], Shi-Jian Liu[2], Yu-Fen Wu[1], Shu-Hua Yuan[1], Ming-Yu Tang[1], Wen-Fang Dong[1], Jie Lin[1], Ming Chen[1], Xing Tong[1], Lie-Bin Zhao[2,3] and Yong Yin[1]**

[1] Department of Respiratory Medicine, Shanghai Children's Medical Center, Shanghai Jiao Tong University School of Medicine, Shanghai, China, [2] Paediatric AI Clinical Application and Research Center, Shanghai Children's Medical Center, Shanghai, China, [3] Child Health Advocacy Institute, China Hospital Development Institute of Shanghai Jiao Tong University, Shanghai, China, [4] Tuoxiao Intelligent Technology Company, Shanghai, China

OPEN ACCESS

Edited by:
*Mark Lo,
University of Washington,
United States*

Reviewed by:
*William Gower,
University of North Carolina at Chapel Hill, United States
Catherine Ann Byrnes,
The University of Auckland,
New Zealand*

***Correspondence:**
*Lie-Bin Zhao
zhaoliebin@scmc.com.cn
Yong Yin
yinyong9999@163.com*

Specialty section:
This article was submitted to Pediatric Pulmonology, a section of the journal Frontiers in Pediatrics

Received: 09 November 2020
Accepted: 12 February 2021
Published: 23 March 2021

Citation:
Zhang J, Wang H-S, Zhou H-Y, Dong B, Zhang L, Zhang F, Liu S-J, Wu Y-F, Yuan S-H, Tang M-Y, Dong W-F, Lin J, Chen M, Tong X, Zhao L-B and Yin Y (2021) Real-World Verification of Artificial Intelligence Algorithm-Assisted Auscultation of Breath Sounds in Children. Front. Pediatr. 9:627337. doi: 10.3389/fped.2021.627337

Objective: Lung auscultation plays an important role in the diagnosis of pulmonary diseases in children. The objective of this study was to evaluate the use of an artificial intelligence (AI) algorithm for the detection of breath sounds in a real clinical environment among children with pulmonary diseases.

Method: The auscultations of breath sounds were collected in the respiratory department of Shanghai Children's Medical Center (SCMC) by using an electronic stethoscope. The discrimination results for all chest locations with respect to a gold standard (GS) established by 2 experienced pediatric pulmonologists from SCMC and 6 general pediatricians were recorded. The accuracy, sensitivity, specificity, precision, and F1-score of the AI algorithm and general pediatricians with respect to the GS were evaluated. Meanwhile, the performance of the AI algorithm for different patient ages and recording locations was evaluated.

Result: A total of 112 hospitalized children with pulmonary diseases were recruited for the study from May to December 2019. A total of 672 breath sounds were collected, and 627 (93.3%) breath sounds, including 159 crackles (23.1%), 264 wheeze (38.4%), and 264 normal breath sounds (38.4%), were fully analyzed by the AI algorithm. The accuracy of the detection of adventitious breath sounds by the AI algorithm and general pediatricians with respect to the GS were 77.7% and 59.9% ($p < 0.001$), respectively. The sensitivity, specificity, and F1-score in the detection of crackles and wheeze from the AI algorithm were higher than those from the general pediatricians (crackles 81.1 vs. 47.8%, 94.1 vs. 77.1%, and 80.9 vs. 42.74%, respectively; wheeze 86.4 vs. 82.2%, 83.0 vs. 72.1%, and 80.9 vs. 72.5%, respectively; $p < 0.001$). Performance varied according to the age of the patient, with patients younger than 12 months yielding the highest accuracy (81.3%, $p < 0.001$) among the age groups.

Conclusion: In a real clinical environment, children's breath sounds were collected and transmitted remotely by an electronic stethoscope; these breath sounds could be recognized by both pediatricians and an AI algorithm. The ability of the AI algorithm to analyze adventitious breath sounds was better than that of the general pediatricians.

Keywords: auscultation, breath sound, electronic stethoscope, artificial intelligence, children

INTRODUCTION

Although non-invasive methods for the diagnosis and follow-up of lung diseases have undergone rapid development, the auscultation of breath sounds with a stethoscope remains a key part of the initial examination of lung diseases. The stethoscope has the advantages of being non-invasive, easy to use, affordable, and non-radioactive, and stethoscope-based examinations can be repeated quickly, making the device especially suitable for use for pediatric patients. It is well-known that the results of traditional auscultation are subjective and depend on the clinical experience and auditory perception ability of the physician; additional limitations of traditional auscultation include the inability to save or share the sound signal, its poor repeatability, and the inability to continuously monitor the breath sounds, among others.

To compensate for the above shortcomings of the traditional stethoscope, we used an electronic stethoscope to collect the breath sounds of children with pulmonary diseases in a real respiratory ward environment and used an AI algorithm to automatically identify the collected breath sounds. The breath sounds were distinguished into crackles, wheeze and normal sounds. Our study found that the results of the AI algorithm were substantially consistent with those of experienced pediatric pulmonologists.

China has a vast territory and a large population; however, the distribution of health resources throughout the country is not evenly distributed and differing pediatricians have variable clinical abilities. The combination of an electronic stethoscope and an AI algorithm may aid in conducting telemedicine sessions, improve the lung auscultation skills of general pediatricians, and become an important tool for child health management and chronic disease follow-up for families in the future.

Although non-invasive methods such as chest X-ray, chest computed tomography (CT) scan, and chest ultrasound have developed rapidly in the diagnosis and follow-up of pulmonary diseases, the auscultation of breath sounds with a stethoscope is still a key part of any initial examination. Following the invention of the stethoscope by Laennec in 1861, auscultation has become an important part of the diagnostic process, and the stethoscope has gradually evolved into the most commonly used instrument in the medical and healthcare industry.

The stethoscope has the advantages of being non-invasive, easy to use, affordable, and non-radioactive, and stethoscope examinations can be repeated quickly, making this tool especially suitable for children with respiratory symptoms. Among its benefits, lung auscultation can improve the sensitivity of the diagnosis of pneumonia in children (1), help in building a discrimination model of admission signs for drowning children (2), and be applied to recognizing wheezing and judging the presence of an asthma attack (3), and changes in breathing sound parameters can indirectly reflect the clinical scenario, such as limited airflow in the lung (4). However, traditional auscultation technology has obvious limitations in clinical application, including the dependence of the auscultation results on the clinical experience and auditory perception ability of physicians, which is strongly subjective; the inability to save and share the auscultated sound signal; poor repeatability; and the inability to continuously monitor breath sounds. Especially in terms of the subjective aspect of the auscultation results, a previous study confirmed that the accuracy of lung auscultation of physicians with different levels of experience or different specialties was significantly different; the accuracy of the respiratory specialists was the highest, while that of family doctors and medical students was generally lower (5), potentially reducing the value of auscultation in making clinical diagnoses.

Faced with the above situation, scientists invented the electronic stethoscope and have attempted to apply it to the real clinical environment. To some extent, the electronic stethoscope overcomes some of the shortcomings of the traditional stethoscope in sound data storage and sharing, but it does not improve the accuracy and efficiency of breath sound recognition (6). In recent years, artificial intelligence (AI) algorithms have been applied to the processing and recognition of breath sounds, among which the most commonly used algorithms include artificial neural networks, Gaussian mixture models and support vector machines, and some promising achievements have been reported (7).

The purpose of this study is to quantitatively evaluate the recognizability of adventitious breath sounds according to an AI algorithm in a real pediatric clinical environment.

MATERIALS AND METHODS

Study Population

The study was carried out from May to December 2019 at the pediatric respiratory department in Shanghai Children's Medical Center (SCMC). This study was based in a hospital environment, and the auscultation recordings were collected in a real inpatient department. The inclusion criteria were as follows: (1) pediatric inpatients of either sex who were between 28 days and 18 years of age; (2) patients whose auscultations were described as normal, crackles or wheeze by a pediatric pulmonologist with at least 10 years of work experience in SCMC; (3) patients whose parent or guardian provided consent; and (4) patients who could cooperate with the process and keep

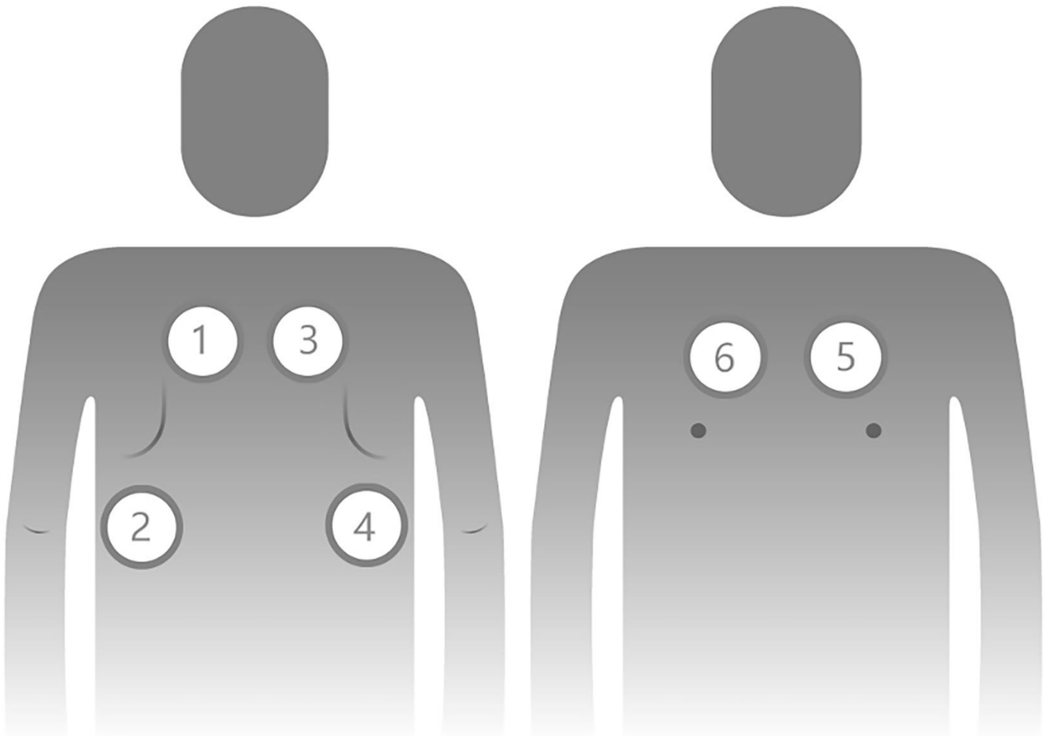

FIGURE 1 | Order and localization of lung auscultation points for pediatric patients. Points 1 to 4 are on the posterior side of the chest, and points 5 and 6 are on the anterior side of the chest.

quiet during the auscultation recording collection. Auscultation results described as both crackles and wheeze by the pediatric pulmonologist were excluded. For each patient, auscultation recordings were collected by an electronic stethoscope from different points on the chest. In addition to the breath sound recordings, we also recorded clinical data, including patient demographic characteristics and diagnosis.

Auscultation Recording Procedure

We trained three respiratory specialist nurses from SCMC to collect breath sounds with a Class II CE-marked electronic stethoscope (Yunting model II, Tuoxiao, Shanghai, China) prior to the study. The training included the recording and uploading processes and supervised practice. We collected a set of 6 recordings that included each child's chest (two) and back (four) and covered all parts of the lung (**Figure 1**). Auscultation was recorded for 9 s to obtain at least two breathing cycles per location (8). The electronic stethoscope and a smartphone were connected by a data wire, and the recordings were uploaded to the cloud through a smartphone app (**Figure 2**). Children's breath sounds were collected in a relatively quiet environment in the ward while the child was in either a sitting or supine/prone position. During the collection process, the children and their parents were asked to remain quiet; the children did not need to breathe deeply.

Description of the Auscultation Recordings and Gold Standard Establishment

We asked experienced pediatric pulmonologists from SCMC, general pediatricians from various communities and the AI algorithm to describe the recordings as crackles, wheeze or normal breath sounds. Before the study began, all the participants were trained and assessed according to the nomenclature advised by the Europe Respiratory Society (9). At the same time, we provided both the age and sex of the patients with every recording to the participants for analysis. We recruited six general pediatricians from various communities with more than 5 years of work experience to mark all of the auscultation recordings independently.

The classification of adventitious sounds is subjective, and the results depend on the clinical experience of the physician. Therefore, it was necessary to establish a gold standard (GS) of breath sounds for this study. We selected eight pediatric pulmonologists with at least 10 years of work experience at SCMC to take part in establishing the GS. Among them, two pulmonologists with more than 20 years of experience composed the expert group, and the other six pulmonologists constituted the specialist group. Meanwhile, we randomly separated the collected auscultation recordings into two parts, each of which was marked by any three pulmonologists in the specialist group; in other words, each breath sound was marked three times

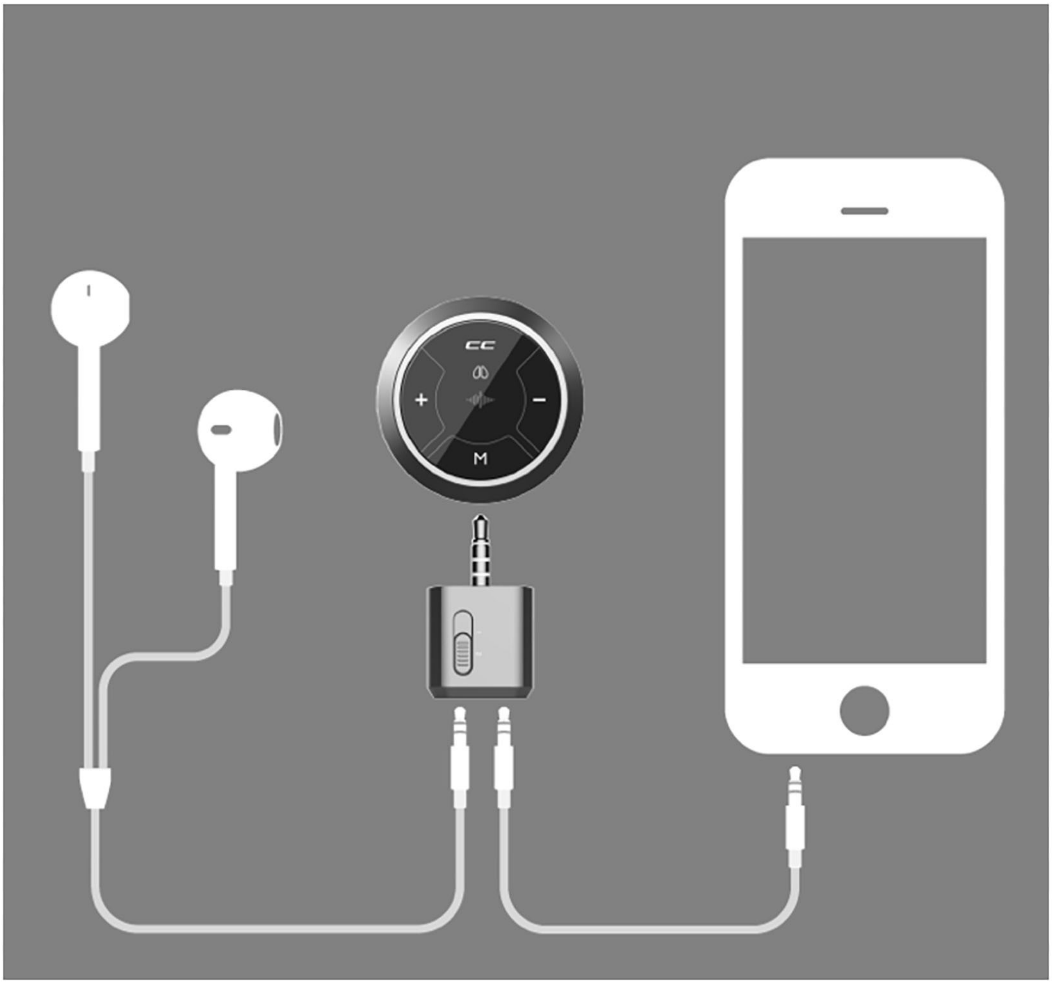

FIGURE 2 | The electronic stethoscope connects to the smartphone and uploads the lung auscultation recordings to the cloud.

independently by different pulmonologists. If the opinions of the three pulmonologists in the specialist group were consistent, the recordings were directly qualified as the GS. When two or more pulmonologists in the specialist group were unable to distinguish the recording or if the results of all three pulmonologists were inconsistent, the specialists directly rejected using the recordings as the GS. If two of the three pulmonologists' opinions in the specialist group were inconsistent, the expert group would discuss the findings for further verification and decide if the recording meets the requirement for the GS. The steps of the establishment process of the GS are shown in **Figure 3**. The study protocol was approved by the Institutional Review Board of SCMC (approval No. SCMCIRB-K2019056-1).

Artificial Intelligence Algorithm

The breath sound detection algorithm was developed by Tuoxiao Intelligent Technology Company, Shanghai, China, without the use of the recordings in the current study for training. It is designed with a record-upload-analyse mode and uses a cloud server. First, analysis of the characteristics of clinical crackle audio data revealed that the crackle was a pertinent discontinuous signal, with a duration of <20 ms and a peak magnitude more than two times the average magnitude. Analysis of the wheeze revealed that its average duration was usually more than 500 ms, and the peak portion of the ringing sound fragment over a 160 ms window was greater than the average of the filtered signal after performing low-pass filtering with a 200 ms Hamming window (10). The obtained clinical breath sound recordings were pre-processed according to the above features, and then the features were extracted using wavelet packet decomposition (11, 12). Finally, a support vector machine (SVM) was trained, and the parameters were obtained to establish an AI algorithm model. The algorithm comprises several major components in this study (**Figure 4**). The SVM had been trained and validated on a set of 6,234 and 6,423 real recordings, respectively. The performance of the AI algorithm showed an

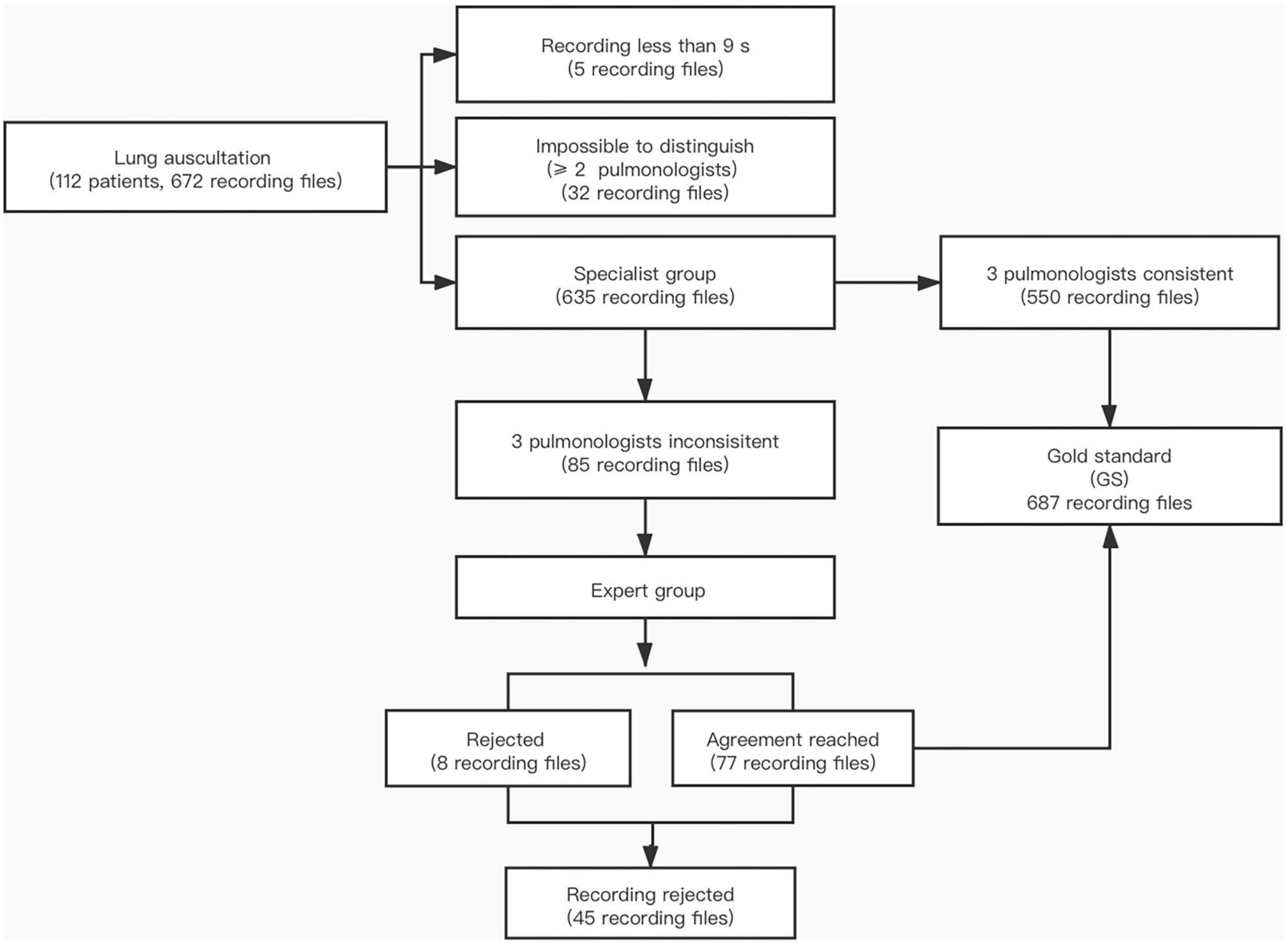

FIGURE 3 | Flow chart of the establishment of the gold standard. Expert group: 2 pediatric pulmonologists with more than 20 years of work experience. Specialist group: 6 pediatric pulmonologists with at least 10 years of work experience.

accuracy, sensitivity and specificity of 90.3, 88.3, and 92.3% in the detection of crackles and 87.1%, 86.7% and 87.5% in the detection of wheeze, respectively.

Statistical Analysis

A confusion matrix was used to measure the performance of the AI algorithm, in which the values of accuracy, recall, precision, specificity, and F1-score were included as important evaluation parameters. Accuracy is the ratio of the correct samples predicted to the total number of samples and was used to represent the predictive ability of all the classification models. Recall is the proportion of correctly recognized true positives, also known as sensitivity. Precision quantifies the proportion of true positive-class predictions made from all positive predicted samples in the database. Specificity is the proportion of correctly recognized true negatives. The F1-score is the harmonic mean of recall and precision.

One-way ANOVA (chi-square test) was used to calculate whether there was a significant difference between the AI algorithm and each general pediatrician. The agreement levels between the AI algorithm and GS and between the AI algorithm and the individual general pediatricians were compared by the weighted kappa (κ) test and the corresponding 95% confidence intervals (CIs). Agreement among the general pediatricians across all the breath sound recordings was evaluated using Kendall's coefficient of concordance (Kendall's W). The parameters including accuracy, recall, precision, specificity, and F1-score of the breath sound recordings discrimination were calculated for the AI algorithm and the general pediatricians for the different locations on the chest and for different age groups.

RESULTS

Demographics

A total of 112 patients were recruited for this study. The median age at the time of visit was 12.5 months (P_{25}-P_{75}, 5 to 41.8 months), and 82 patients were male (73.2%). The patients' ages were distributed as follows: $\leq$ 12 months, 56 (50%); between 13 and 60 months, 43 (38.4%) and $>$ 60 months, 13 (11.6%). The patients' recordings were classified into crackles (159, 25.4%),

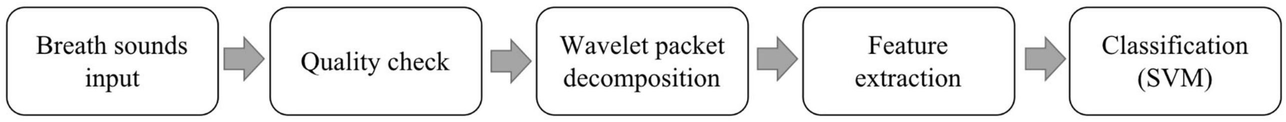

FIGURE 4 | Major components of the automated adventitious breath sound detection performed by the AI algorithm.

TABLE 1 | Participant demographics.

Characteristics	**Study group (*n* = 112)**
Sex, *n* (%)	
Male	82 (73.2)
Female	30 (26.8)
Age group, months*	12.5 (5, 41.8)
<12, *n* (%)	56 (50.0)
12–60, *n* (%)	43 (38.4)
> 60, *n* (%)	13 (11.6)
Weight, kg*	9.6 (7.0, 15.8)
Height, cm*	75.0 (63.3, 100.0)
Primary diagnosis, *n* (%)	
Pneumonia	75 (67.0)
Bronchitis	15 (13.4)
Bronchiolitis	15 (13.4)
Asthma attack	5 (4.5)
Foreign body aspiration	1 (0.9)
Bronchiolitis obliterans	1 (0.9)

**Median and quartiles [median (25%,75%)].*

wheeze (204, 32.5%) and normal breath sounds (264, 42.1%). The primary diagnoses were pneumonia (67%), bronchitis (13.4%), bronchiolitis (13.4%) and asthma attack (4.5%) (**Table 1**).

Agreement

A total of 672 auscultation recordings were collected, and 627 (93.3%) were analyzed by the AI algorithm. Recordings were rejected if the duration of the recording was <9 s, the signal was of low quality, or the recording did not meet the GS requirements. There was a significant difference between the GS and the AI algorithm results ($c^2 = 675.49$, $p < 0.001$) and between the results of the AI algorithm and of each general pediatrician ($p < 0.001$). The weighted κ was 0.687 between the GS established by the experienced pediatric pulmonologists and the AI algorithm, indicating substantial agreement. However, the values of the weighted κ between each of the general pediatricians and the GS were significantly different (general pediatricians 0.537–0.308), most of which indicated fair to moderate agreement (**Table 2**). Kendall's W for interrater agreement among the general pediatricians was 0.39 ($p < 0.001$).

Accuracy, Sensitivity, Precision, Specificity, and F1-Score

The accuracy of the detection of adventitious breath sounds by the AI algorithm and the general pediatricians with respect to the GS were 77.7% and 59.9% ($p < 0.001$), respectively. **Table 3** summarizes the performance of the AI algorithm and the general pediatricians in classifying the recordings. Analysis of the performance of the AI algorithm showed that the sensitivity and specificity in the detection of crackles were 81.3 and 94.1%, respectively, with an F1-score of 80.9%. However, when marked by the general pediatricians, the sensitivity and specificity decreased to 47.8 and 77.1%, respectively, while the F1-score was 42.7%. The sensitivity, specificity and F1-score of the AI algorithm in stratifying wheeze were, respectively, 86.4, 83.0, and 80.9%, which were higher than those of the general pediatricians (82.2, 72.1, and 72.5%).

When the collection points on the chest were compared, there was no significant difference in the accuracy of the AI algorithm in the recognition of breath sounds collected from different locations ($\chi^2 = 1.178$, $P = 0.947$), and the overall accuracy was approximately 75% (**Table 4**). The results of the AI algorithm analysis were compared for the different patient age groups. The accuracy of the AI algorithm was highest among children younger than 12 months; additionally, the F1-score was highest in the recognition of crackles and wheeze in this age group (**Table 5**).

DISCUSSION

In this study, breath sound recordings were collected in a real clinical environment, with the typical noises, crying, speaking voices and child movements inherent therein. The AI algorithm was able to fully analyze 93.3% of the recordings, with an accuracy mostly similar to that of the GS established by experienced pediatric pulmonologists. In another verified clinical study of 552 auscultatory sounds from 50 pediatric patients with an average age of 8 years old, the sensitivity, specificity and F1-score of the AI algorithm in distinguishing crackles and wheeze were 83.9 and 78.2%, 79.3 and 57.5%, and 64.6 and 66.4%, respectively. The sensitivity of the AI algorithm was similar to that of the present study, but both the specificity and F1-score were lower than our results. This may be associated with the different feature extraction methods and AI algorithms employed in the two studies (13). Furthermore, our research found that the F1-score decreased with increasing age, so the age differences in the studies may be related to the differences in the evaluation parameters of the models.

There is no doubt that the recognition of adventitious lung sounds is subjective, and the accuracy of the results is highly associated with the specialty and clinical experience of the physician. The lack of an objective standard for evaluating breath sounds restricts the development of relevant clinical research.

TABLE 2 | Cohen's kappa between GS and AI algorithm and general pediatricians.

	AI	General pediatricians					
		Listener 1 24 years*	Listener 2 19 years*	Listener 3 22 years*	Listener 4 7 years*	Listener 5 7 years*	Listener 6 6 years*
Cohen's kappa (95%CI)	0.687 (0.640–0.734)	0.537 (0.486–0.588)	0.429 (0.380–0.478)	0.308 (0.257–0.359)	0.670 (0.625–0.715)	0.439 (0.390–0.488)	0.306 (0.255–0.357)

**Years of work experience.*

TABLE 3 | Sensitivity, precision, specificity, and F1-score for the AI algorithm and the general pediatricians.

	Sensitivity %			Precision (%)			Specificity (%)			F1-score (%)		
	AI	General pediatricians	*P*	AI	General pediatricians	*P*	AI	General pediatricians	*P*	AI	General pediatricians	*P*
Crackles	81.1	47.8	<0.001	80.6	38.6	<0.001	94.1	77.1	<0.001	80.9	42.7	<0.001
Wheeze	86.4	82.2	>0.05	76.0	64.9	<0.001	83.0	72.1	<0.001	80.9	72.5	<0.001
Mean	83.8	65.0	<0.001	78.3	51.8	<0.001	88.6	74.6	<0.001	80.9	57.6	<0.001

In the field of heart auscultation, one study implemented the findings of three cardiologists as the GS to quantify the utility of electronic stethoscopes and hand-held echoes in the evaluation of heart murmurs (14). In a study that used breath sounds to validate the diagnostic accuracy of an AI algorithm for interstitial lung disease for rheumatoid arthritis patients, high-resolution CT was used as the gold standard (15). This would have been the best way to produce an objective indicator for use as the standard for the present research; the most closely related examination for lung auscultation is radiological examination, but it is inappropriate to use the results of radiology as the GS for children with common pulmonary disease. The ideal way to establish a gold standard is to have an experienced pediatric pulmonologist at the bedside to immediately analyze and judge the breath sounds collected by the electronic stethoscope. However, the number of experienced pediatric pulmonologists in our hospital is very limited and was unable to meet the needs of our study; therefore, we ultimately chose the current method. In this study, we recruited pediatric respiratory specialists with at least 10 years of work experience to form an expert group. The inclusion criterion for the recordings for entry into the GS database was a consistent evaluation of the result by at least 3 pulmonologists, which is more stringent than previous studies (13). Finally, the GS was used to test the ability of the AI algorithm and general pediatricians to detect adventitious breath sounds. Through the establishment of a GS, we have solved the difficulties in evaluating and comparing different methods or physicians in terms of breath sound detection.

It was found that the recognizability of children's adventitious breath sounds, including crackles and wheeze, of the AI algorithm was higher than that of the general pediatricians. The above results show that even after completing pediatric resident training and achieving more than 5 years of pediatric clinical experience, the pediatricians were unable to match the performance of the AI. Another study consistently found that pulmonologists performed better than other specializations, and interns and pediatricians performed second only to medical students and other specializations. In general, physicians, except for pulmonologists, were no better than medical students (5). A study evaluating the discrimination of breath sound recordings found that the ability to detect stridor was inversely related to work experience (16). Breath sounds, as one the most important physical signs, play an important role in identifying pulmonary disorders in children. It has been found that adventitious sounds, especially crackles and wheeze, have a suggestive effect for many diseases; for example, wheeze can indicate an asthma attack (17), crackles are related to the presence of pneumonia (1), and so on. Therefore, failure to recognize breath sounds correctly will have adverse effects on pediatric clinical work, which may lead to incorrect or delayed diagnosis and treatment of a disease and excessive dependence on radiological examination, including chest X-ray or CT, resulting in the waste of medical resources and other issues.

In terms of medical education and training, a study on training auscultation skills through the use of simulations found that short individual training sessions on a patient simulator significantly improved heart auscultation skills but not lung auscultation skills (18). It is unrealistic to expect that short-term training will improve pediatricians' auscultation skills, so we need to find other, faster, and more direct and convenient ways to help them. A digital stethoscope can collect breath sounds and convert the sound signals into digital signals for saving, sharing, or remote transmission (19). In China, given the very large number of patients, it is impossible to transmit data to specialized hospitals and then have a specialized physician manually discriminate the data one by one; consequently, the needs of community health institutions cannot be met. Therefore, in this study, we use an AI algorithm to train a

TABLE 4 | Analysis of the performance of the algorithm by chest location.

Chest location	Recordings (*n*)	Accuracy (%)	Crackles				Wheeze			
			Sensitivity (%)	Precision (%)	Specificity (%)	F1-score (%)	Sensitivity (%)	Precision (%)	Specificity (%)	F1-score (%)
Posterior										
Upper left	104	74.7	92.9	76.5	93.4	83.9	83.3	62.5	76.5	71.4
Upper right	110	77.8	77.3	81.0	93.2	79.1	85.7	72.7	83.0	78.7
Lower left	100	76.0	88.9	84.2	94.7	86.5	68.4	54.2	80.4	60.5
Lower right	101	80.0	68.8	78.6	94.4	73.3	93.1	75.0	78.0	83.1
Anterior										
Upper left	105	78.4	73.7	83.4	94.5	77.8	82.6	73.1	86.3	77.6
Upper right	107	79.8	77.3	85.0	94.7	81.0	85.7	77.4	86.3	81.4

TABLE 5 | Analysis of the performance of the algorithm by patient age group.

Patient age (months)	Recordings (*n*)	Accuracy (%)	Sensitivity (%)	Precision (%)	Specificity (%)	F1-score (%)
<12	321	81.3				
Crackles			86.5	85.7	93.1	86.1
Wheeze			84.1	84.7	86.5	84.4
12–60	234	74.4				
Crackles			78.0	45.3	93.3	74.4
Wheeze			70.7	45.3	81.9	55.2
>60	72	72.2				
Crackles			50.0	70.0	94.8	58.3
Wheeze			100.0	46.2	76.7	63.2

model to distinguish adventitious sounds and improve diagnostic efficiency. Although the AI algorithm we used is not perfect at present, its performance was at least superior to that of junior residents and general pediatricians with many years of work experience and is consistent with other studies (13). The AI algorithm, as an element of clinical intelligent assistance, can help general pediatricians improve their diagnostic ability and treatment decision making in the future.

The breath sounds were collected in a real clinical environment, and 88.4% of the patients were preschool children in this study. The prevalence of pulmonary diseases in preschool children is relatively high, so it was of great clinical value to verify the AI algorithm for identifying the adventitious breath sounds of children at this stage. Previous studies tended to be limited to school-age children, even adolescents (20), or used standard breath sounds downloaded from a website (21) to evaluate the AI algorithm, which can result in limited research conclusions that cannot be generalized to other pediatric clinics.

By comparing the performance of the AI algorithm at different points on the chest wall, we found no significant differences in the accuracy and F1-score. These results may be useful in developing an optimized clinical panel of breathing sound collection for children. The AI algorithm was designed to perform remote analysis; data were uploaded to the cloud server only by nurses who underwent brief training and took part in this programme. This suggests that the remote analysis can be realized in the clinical process in the future.

This study has some limitations. Among real pediatric respiratory inpatients, the percentage of children over 60 months of age tends to be the lowest; consequently, the fewest number of breath sounds was collected from that group in the study, which may have led to the low accuracy from the algorithm for this age group. The sample population could be expanded, especially to children who are older than 60 months. The pediatricians participating in the study were limited to those practicing in Shanghai and do not reflect the auscultation ability of pediatricians in other regions of China. Therefore, a multi-center study should be carried out in the future, and more experienced pediatric pulmonologists can become involved in the project, at which time the idealized gold standard may be feasibly established. Due to the limitations of our current AI algorithm, we were unable to recognize the crackles and wheezes in the breathing sounds simultaneously, which may have affected the judgment of certain pediatric lung diseases. In future research, we will further improve the AI algorithm to meet the clinical requirements. The study focuses on the accuracy of general breath sound detection; one of our future research directions will combine breath sound detection with a specific pediatric pulmonary disease to build a model for disease diagnosis or follow-up.

In conclusion, it is possible to use an electronic stethoscope to collect breath sounds from children with lung diseases in a real clinical environment and transmit them to specialists for further identification. The accuracy of the AI algorithm in discriminating breath sounds collected at different locations on the chest wall is approximately 75%, which can provide a basis for the design of breath sound acquisition panels for other studies. The ability of the AI algorithm to recognize breath sounds in children is similar to that of a group of experienced pediatric pulmonologists and better than that of general pediatricians from community health service centers, especially in infants younger than 12 months. We will further explore the AI algorithms to recognize crackles and wheezes that occur simultaneously, distinguish between monotonic and polyphonic wheezes, and locate the breathing sounds in the respiratory cycle to ensure that the algorithms are more suitable for real-world clinical application in the future. The combination of an electronic stethoscope with an AI algorithm can potentially be implemented in community health service centers and clinics in the future and may improve the lung auscultation ability of general pediatricians.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The study protocol was approved by the Institutional Review Board of SCMC (approval No. SCMCIRB-K2019056-1). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

L-BZ, YY, and JZ contributed to the conception, design of the study and revised the draft critically for important intellectual content. JZ and S-JL contributed to the data analysis. JZ and H-YZ contributed to drafting the submitted article. S-JL contributed to the statistical data analysis. H-SW, BD, LZ, FZ, Y-FW, S-HY, M-YT, W-FD, JL, MC, and XT contributed to the data acquisition and interpretation of the outcomes. L-BZ and YY contributed to crucial revisions of the draft for important intellectual content and providing final confirmation of the revised version to be published. All authors contributed to the data analysis, drafting of the manuscript, and amending of the paper and are responsible for all aspects of the work. All the data could be accessed by all of the authors to assure the accuracy of the reported data. Tuoxiao Intelligent Technology Company provided the electronic stethoscope equipment and AI algorithm analysis at no cost for this study. The researchers and projects have not received any other commercial funding from the company.

FUNDING

This work was supported by the Program of Shanghai Science and Technology Committee (No. 19441904400). Shanghai Municipal Commission of Economy and Informatization (Shanghai Artificial Intelligence Pilot Application Scenario). Scientific Research Project of Shanghai Pudong New Area, Health and Family Planning Commission (PW2017E-1). Science and Technology Support Project in Biomedical Field of Science and Technology Innovation Action Plan of Shanghai Science and Technology Commission (19441909000). Science and Technology Development Fund of Pudong New Area, Shanghai, China (PKX2019-S2).

REFERENCES

1. Pervaiz F, Chavez MA, Ellington LE, Grigsby M, Gilman RH, Miele CH, et al. Building a Prediction Model for Radiographically Confirmed Pneumonia in Peruvian Children: From Symptoms to Imaging. *Chest.* (2018) 154:1385–94. doi: 10.1016/j.chest.2018.09.006
2. Cohen N, Capua T, Lahat S, Glatstein M, Sadot E, Rimon A. Predictors for hospital admission of asymptomatic to moderately symptomatic children after drowning. *Eur J Pediatr.* (2019) 178:1379–84. doi: 10.1007/s00431-019-03429-1
3. Murayama Y, Shioya H, Tadaki H, Miyamoto M, Yoshihara S, Tabata H, et al. Objective evaluation of wheezing in normal infants. *Pediatr Int.* (2019) 61:956–61. doi: 10.1111/ped.13994
4. Tabata H, Hirayama M, Enseki M, Nukaga M, Hirai K, Furuya H, et al. A novel method for detecting airway narrowing using breath sound spectrum analysis in children. *Respir Investig.* (2016) 54:20–8. doi: 10.1016/j.resinv.2015.07.002
5. Hafke-Dys H, Breborowicz A, Kleka P, Kocinski J, Biniakowski A. The accuracy of lung auscultation in the practice of physicians and medical students. *PLoS ONE.* (2019) 14:e0220606. doi: 10.1371/journal.pone.0220606
6. Gottlieb ER, Aliotta JM, Tammaro D. Comparison of analogue and electronic stethoscopes for pulmonary auscultation by internal medicine residents. *Postgrad Med J.* (2018) 94:700–3. doi: 10.1136/postgradmedj-2018-136052
7. Bardou D, Zhang K, Ahmad SM. Lung sounds classification using convolutional neural networks. *Artif Intell Med.* (2018) 88:58–69. doi: 10.1016/j.artmed.2018.04.008
8. McCollum ED, Park DE, Watson NL, Buck WC, Bunthi C, Devendra A, et al. Listening panel agreement and characteristics of lung sounds digitally recorded from children aged 1-59 months enrolled in the Pneumonia Etiology Research for Child Health (PERCH) case-control study. *BMJ Open Respir Res.* (2017) 4:e000193. doi: 10.1136/bmjresp-2017-000193
9. Pasterkamp H, Brand PL, Everard M, Garcia-Marcos L, Melbye H, Priftis KN. Towards the standardisation of lung sound nomenclature. *Eur Respir J.* (2016) 47:724–32. doi: 10.1183/13993003.01132-2015
10. Serbes G, Sakar CO, Kahya YP, Aydin N. Feature extraction using time-frequency/scale analysis and ensemble of feature sets for crackle detection. *Conf Proc IEEE Eng Med Biol Soc.* (2011) 11:3314–7. doi: 10.1109/IEMBS.2011.6090899
11. Kandaswamy A, Kumar CS, Ramanathan RP, Jayaraman S, Malmurugan N. Neural classification of lung sounds using wavelet coefficients. *Comput Biol Med.* (2004) 34:523–37. doi: 10.1016/S0010-4825(03)00092-1
12. Shi Y, Wang G, Niu J, Zhang Q, Cai M, Sun B, et al. Classification of Sputum Sounds Using Artificial Neural Network and Wavelet Transform. *Int J Biol Sci.* (2018) 14:938–45. doi: 10.7150/ijbs.23855
13. Grzywalski T, Piecuch M, Szajek M, Breborowicz A, Hafke-Dys H, Kocinski J, et al. Practical implementation of artificial intelligence algorithms in

pulmonary auscultation examination. *Eur J Pediatr.* (2019) 178:883–90. doi: 10.1007/s00431-019-03363-2

14. Legget ME, Toh M, Meintjes A, Fitzsimons S, Gamble G, Doughty RN. Digital devices for teaching cardiac auscultation - a randomized pilot study. *Med Educ Online.* (2018) 23:1524688. doi: 10.1080/10872981.2018.1524688
15. Manfredi A, Cassone G, Cerri S, Venerito V, Fedele AL, Trevisani M, et al. Diagnostic accuracy of a velcro sound detector (VECTOR) for interstitial lung disease in rheumatoid arthritis patients: the InSPIRAtE validation study (INterStitial pneumonia in rheumatoid ArThritis with an electronic device). *BMC Pulm Med.* (2019) 19:111. doi: 10.1186/s12890-019-0875-x
16. Barraza JAM, Benardis CNS, Jeria RSA, Sepulveda DHA, Diaz IS, Navarrete PJB. Concordance in discriminating recordings of different lung sounds between physiotherapists. *Respir Care.* (2020) 65:177–82. doi: 10.4187/respcare.06624
17. Global Initiative For Asthma. (2020). https://ginasthma.org/reports/ (accessed June 22, 2020).
18. Bernardi S, Giudici F, Leone MF, Zuolo G, Furlotti S, Carretta R, et al. A prospective study on the efficacy of patient simulation in heart and lung auscultation. *BMC Med Educ.* (2019) 19:275. doi: 10.1186/s12909-019-1708-6
19. Ramanathan A, Zhou L, Marzbanrad F, Roseby R, Tan K, Kevat A, et al. Digital stethoscopes in paediatric medicine. *Acta Paediatr.* (2019) 108:814–22. doi: 10.1111/apa.14686
20. Kevat AC, Kalirajah A, Roseby R. Digital stethoscopes compared to standard auscultation for detecting abnormal paediatric breath sounds. *Eur J Pediatr.* (2017) 176:989–92. doi: 10.1007/s00431-017-2929-5
21. Palaniappan R, Sundaraj K, Sundaraj S. A comparative study of the SVM and K-nn machine learning algorithms for the diagnosis of respiratory pathologies using pulmonary acoustic signals. *BMC Bioinformatics.* (2014) 15:223. doi: 10.1186/1471-2105-15-223

Conflict of Interest: H-YZ was employed by Tuoxiao Intelligent Technology Company.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Pediatrics

PERSPECTIVE
published: 30 March 2021
doi: 10.3389/fped.2021.647458

One-Size-Fits All: A Scalable Solution to Formal Telemedicine Provider Training to Support the COVID-19 Pandemic Response

Dana A. Schinasi[1,2]*, *Yuemi An-Grogan*[3], *Rebecca Stephen*[1,2], *Aric Shimek*[2], *Marisa Furney*[2] *and M. Katie Bohling*[2]

[1] Department of Pediatrics, Northwestern University Feinberg School of Medicine, Chicago, IL, United States, [2] Telehealth Programs, Ann & Robert H. Lurie Children's Hospital of Chicago, Chicago, IL, United States, [3] Department of Emergency Medicine, McGovern Medical School at UTHealth, The University of Texas Health Science Center at Houston, Houston, TX, United States

Introduction: Formalized training in telemedicine addresses barriers to provider adoption and engagement and assures a level of competence for independent practice. We previously developed a blended-model training program, customizable according to role and specialty; this method of training was not feasible in the pandemic response. We describe the development and implementation of a multi- and interdisciplinary telemedicine provider training program enabling the rapid scaling of telemedicine at our institution.

Methods: An existing curriculum was pared down to a 1-h session delivered synchronously, covering the foundational components of telemedicine practice. Supplemental materials were available for asynchronous learning via the hospital intranet. Completion of training was required of all clinicians who practice telemedicine.

Results: We conducted 35 sessions for 1,070 providers over 12 weeks. Attendees included clinicians across numerous roles and specialties. Additional resources were created and available through the Telemedicine Virtual Handbook and housed in specific toolkits.

Discussion: Telemedicine training is necessary for consistent, competent practice of telemedicine in pediatrics. We describe a training process that can be easily replicated and rapidly deployed to providers of telemedicine across roles and disciplines. Combining a mandatory and brief synchronous provider training session with a repository of online resources creates a foundation for consistent practice, while allowing for more individualized resources accessible on demand. Standardized telemedicine training followed by mechanisms for ongoing professional practice evaluation allow institutions to ensure consistent and competent practice of telemedicine. Further study is needed to determine the best modality for training, and optimal assessment tools according to professional role.

Keywords: telemedicine, telehealth, COVID-19, training, education

OPEN ACCESS

Edited by:
Tzielan Lee,
Stanford University, United States

Reviewed by:
Lindsay Stevens,
Stanford University, United States
Neel Naik,
Weill Cornell Medical Center,
United States

***Correspondence:**
Dana A. Schinasi
dschinasi@luriechildrens.org

Specialty section:
This article was submitted to General Pediatrics and Pediatric Emergency Care, a section of the journal Frontiers in Pediatrics

Received: *29 December 2020*
Accepted: *08 March 2021*
Published: *30 March 2021*

Citation:
Schinasi DA, An-Grogan Y, Stephen R, Shimek A, Furney M and Bohling MK (2021) One-Size-Fits All: A Scalable Solution to Formal Telemedicine Provider Training to Support the COVID-19 Pandemic Response. Front. Pediatr. 9:647458. doi: 10.3389/fped.2021.647458

INTRODUCTION

Formalized training of providers in telemedicine is endorsed by the American Telemedicine Association (1), though is not yet standardized nor consistent across institutions. A formalized training program has the potential to address key issues previously cited as barriers to provider adoption and engagement in telemedicine, including ease of use and perceived usefulness of this modality of care delivery (2–5). Additionally, providers familiar with technology are more inclined to use telemedicine (6), a barrier which is overcome with exposure and hands-on training (7, 8). Health care providers tend to be reluctant to accept change (9), and the formal opportunity to have questions answered and concerns addressed by program leaders in real time through synchronous training may be a valuable means to overcome this. Additionally, training allows consistency in adherence to federal, state, and local standards, and ensures that providers are compliant in their practice. Finally, formal telemedicine training can be a pre-requisite to assignment of hospital telemedicine privileges; it has been our experience that formal telemedicine privileges help to expedite credentialing of our telemedicine providers externally with partner hospitals. Still, there are several deterrents to formal training in telemedicine: training requires specific resources in the form of time, personnel, and financial commitment, which may deter organizations from developing required, formalized programs.

There are currently over 30 training and certificate programs in telemedicine in the United States (10–12), with varying content and without standardization. Presently, academic programs lack guidelines for training, certification, and accreditation, although the American Association of Medical Colleges published its Telehealth Competencies (13) in September 2020, signaling an important step in the right direction. Development of a core set of competencies and standards is also underway at various health care organizations and national collaboratives. Still, with the recognition that *web*side delivery of care differs from care delivered in-person at the *bed*side, there are foundational components that each telemedicine provider should have a basic knowledge of and demonstrate competence in. These foundational components were determined based on our institutional experience and informed by existing literature (1), and include: local context and programmatic goals; legal and risk considerations; workflows; clinical considerations, including physical examination techniques and charting requirements; virtual presence, including webside manner overview; and technology overview, including hardware, software, and troubleshooting.

Adults learn best by experiential learning modalities, including small groups, hands-on practice, role-play, and simulation. These blended learning approaches have been increasingly employed in medical education, using a combination of face-to-face and online learning, augmented with other experiential modalities for education (14, 15). At Ann & Robert H. Lurie Children's Hospital of Chicago, medical educators and telemedicine program leaders collaborated to develop a comprehensive blended model training program, incorporating small group work, online content, and simulation-based training. This curriculum is customizable according to provider role and specialty, and its successful completion is a requirement for Telemedicine Privileges through our Medical Staff Office (MSO).

This method of training in telemedicine was not feasible during the pandemic response. COVID-19 necessitated widespread rapid deployment of a telemedicine curriculum to enable competent and independent practice of telemedicine, a modality of care that had not been widely practiced by pediatric providers at our institution previously. As we endeavored to rapidly train hundreds of providers during the pandemic response, we needed to adapt our existing training requirements to meet their basic educational and operational needs. Here, we describe the development and implementation of an easily reproducible and scalable telemedicine provider training curriculum reaching across the numerous specialties, roles, and practice settings at our children's hospital.

Curriculum Development and Deployment

The existing customizable Telemedicine Provider Training curriculum was developed following Kern's six-step model for curriculum development: (1) problem identification and general needs assessment, (2) targeted needs assessment, (3) goals and objectives, (4) educational strategies, (5) implementation, and (6) concepts for evaluating the effectiveness of the curriculum (16). The educational effectiveness of this curriculum was assessed using checklists for observed simulations and anonymous web-based surveys for self-reported knowledge and attitudes assessment, finding improvement in knowledge and attitudes following training, specifically regarding workflow and processes, provider roles, and medicolegal issues; these results are yet unpublished.

Given the large scale and abbreviated timeframe to deploy telemedicine in response to the COVID-19 pandemic, we needed to adapt our existing training requirements to meet their basic educational and operational needs. Our approach in paring down the targeted training to a 1-h session covering key foundational components delivered synchronously to all clinicians regardless of role, discipline, or setting started with areview of each of the previous curricula utilized for existing programs, peeling away their specific workflows and clinical considerations. Through this exercise, we honed in on the foundational components relevant to all disciplines, roles, and practice settings, and used these to scaffold the 1-h Telemedicine Provider Training. We then layered in updated regulations, technology standards, and workflows related to our institutional ramp-up in response to the pandemic. Individual hands-on practice and additional role-specific workflow and operational discussions were at the discretion of individual service lines, based on their telemedicine utilization and plans. We then developed an institutional "Telemedicine Virtual Handbook" and published it on the Lurie Children's intranet as a dynamic, asynchronous resource with further detail on topics introduced in the structured training. In-person training was offered in the hospital conference center, where in-person attendance was capped to ensure compliance with safe social distancing recommendations. A virtual attendance option was available for those who were unable to safely attend in-person.

Synchronous Training

We conducted 35 sessions and trained 1,070 providers over 12 weeks; 27 sessions were conducted with 791 providers trained in the first 4 weeks following the declaration of the national emergency. Those in attendance included a mix of physicians, advanced practice providers, psychologists, social workers, clinical nutritionists, genetic counselors, case managers, and more. They spanned the departments of Pediatrics (general and subspecialty), Surgery (general and subspecialty), Psychiatry, Rehabilitation Services (physical, occupational, and speech therapy), and Radiology. As resident and fellow trainees re-joined the clinical workforce, they, too, received formal telemedicine training. In total, 595 providers received Disaster Telemedicine Privileges through the MSO, which were immediately released, and lasted 120 days.

Specific content included within each of the foundational components of the synchronous telemedicine training are reviewed here. First, definitions and *local context* are provided, along with the sharing of institutional telehealth vision and programmatic goals. Federal, state, and local *legal considerations* are reviewed next to ensure that telemedicine providers are up to date on current policies and standards on provision of care and reimbursement for telemedicine services. *Risk management* is a previously cited concern to provider adoption of telemedicine; it is an essential component of training as it relates to scope of practice, malpractice coverage, limitations of physical assessment, and a review of resources or policies for action in the event of witnessing a situation concerning for child maltreatment. A review of *clinical considerations* includes an introduction to the observational physical examination, an overview of workflows, and an introduction of charting requirements. The *virtual presence* component reviews best practices for webside manner, introduces privacy and confidentiality as it relates to telemedicine, and conveys standards for professional appearance during an encounter. Regardless of specific technology (hardware and software) investment, the basic principles of *telemedicine technology training* are the same. These include an overview of equipment sanctioned for use; software platform(s) for video visit, image-sharing, and communication; discussion of network connections; and introduction of troubleshooting tips and resources.

Asynchronous Training

Additional resources were created on the hospital SharePoint site, a customizable cloud-based content collaboration and management platform that houses the Lurie Children's intranet (17). These resources are located in the Telemedicine Virtual Handbook page of the intranet and are housed in specific toolkits. The *Provider Toolkit* includes electronic health record guides and tip sheets, a physical examination tip sheet, a library of videos developed by local colleagues on various telemedicine physical examination components, a visit checklist, guides for accessing interpreting services, as well as sample materials (e.g., patient/family pre-visit letter). The *Technical Toolkit* includes guides and tip sheets for troubleshooting hardware and software. The *Scheduling Toolkit* includes training videos for appointment schedulers as well as guides for helping patients and families prepare for their visit, including obtaining and troubleshooting internet access. The *Webside Manner Toolkit* houses best practices for on-camera presentation and overall virtual experience. Additional resources housed on the Telemedicine Virtual Handbook include mechanisms for support, important announcements, opportunities for information sharing, as well as a repository for resources for program evaluation and quality improvement. The Telemedicine Virtual Handbook remains a dynamic resource, easily accessible through the hospital intranet, with updates and additional content added as needed.

Ongoing Quality Assessment

Telemedicine is an additional modality to support and augment clinical practice; as such, measures to assess the quality of care delivered should align with those quality measures for in-person practice. This can be readily accomplished in concert with an assignment of distinct Telemedicine Privileges through the MSO. In accordance with Joint Commission requirements, once privileges are attained, telemedicine providers enter the Focused Professional Practice Evaluation (FPPE) process, to assure the privilege-specific competence of the individual practitioner (18); at our institution, this entails a discrete number of encounters reviewed by the division head or medical director. Once the FPPE requirements are satisfied for telemedicine, the Ongoing Professional Practice Evaluation (OPPE) is overseen by the individual department or division clinical leadership, according to their usual practice. Additional measures for evaluation of quality were suggested according to established frameworks for telemedicine evaluation and measurement (19, 20), and are incorporated at the discretion of clinical leadership. Domains include activity data, medical/clinical knowledge, interpersonal/communication skills, professionalism, and systems-based practice. Ongoing evaluation is paramount to ensure that telemedicine programs reach patients equitably, are high-quality, and cost-effective.

DISCUSSION

Telemedicine training is necessary for consistent, competent practice of telemedicine in pediatrics. We describe a training process that can be easily replicated and rapidly deployed to telemedicine providers across roles and specialties. Combining a mandatory and brief synchronous provider training session with a growing repository of online resources creates a foundation of consistent practice, while also allowing for more detailed and individualized resources that can be accessed on-demand. In our experience, standardized telemedicine training followed by mechanisms for ongoing evaluation has allowed our institution to ensure consistent and competent practice of telemedicine; collection of data geared toward evaluation of the curriculum is warranted and is an area of future research. While further study is needed to determine the best modality for training and the optimal assessment tools according to professional role, a workforce trained in telemedicine is best poised to advocate for meaningful and lasting changes to improve access to care for our patients and families.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

DS and YA-G developed the curriculum, drafted the initial manuscript, reviewed, and revised the manuscript. RS, AS, and MF reviewed and revised the manuscript. MB developed the curriculum and reviewed and revised the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

REFERENCES

1. McSwain SD, Bernard J, Burke Jr BL, Cole SL, Dharmar M, Hall-Barrow J, et al. American telemedicine association operating procedures for pediatric telehealth. *Telemedicine and e-Health.* (2017) 23:699–706. doi: 10.1089/tmj.2017.0176
2. Hopp F, Whitten P, Subramanian U, Woodbridge P, Mackert M, Lowery J. Perspectives from the Veterans Health Administration about opportunities and barriers in telemedicine. *J Telemed Telecare.* (2006) 12:404–9. doi: 10.1258/135763306779378717
3. Rogove HJ, McArthur D, Demaerschalk BM, Vespa PM. Barriers to telemedicine: survey of current users in acute care units. *Telemed J E Health.* (2012) 18:48–53. doi: 10.1089/tmj.2011.0071
4. Sisk B, Alexander J, Bodnar C, Curfman A, Garber K, McSwain SD, et al. Pediatrician attitudes toward and experiences with telehealth use: results from a national survey. *Acad Pediatr.* (2020) 20:628–35. doi: 10.1016/j.acap.2020.05.004
5. Moore MA, Coffman M, Jetty A, Petterson S, Bazemore A. Only 15% of FPs report using telehealth; training and lack of reimbursement are top barriers. *Am Fam Physician.* (2016) 93:101.
6. Holden RJ, Karsh BT. The technology acceptance model: its past and its future in health care. *J Biomed Inform.* (2010) 43:159–72. doi: 10.1016/j.jbi.2009.07.002
7. Cappi V, Artioli G, Ninfa E, Ferrari S, Guarnieri MC, Martucci G, et al. The use of blended learning to improve health professionals' communication skills: a literature review. *Acta Biomed.* (2019) 90(4-S):17–24. doi: 10.23750/abm.v90i4-S.8330
8. Wang JJ, Lavigueur O, Sheridan M, Stern E. Implementation of a simulation-based telemedicine curriculum. *Med Educ.* (2017) 51:1178–9. doi: 10.1111/medu.13433
9. Gupta DM, Boland RJ Jr, Aron DC. The physician's experience of changing clinical practice: a struggle to unlearn. *Implement Sci.* (2017) 12:28. doi: 10.1186/s13012-017-0555-2
10. URAC. Digital/Telehealth Programs. Available online at: https://www.urac.org/accreditations-certifications/programs/digital-telehealth-programs/ (accessed December 22, 2020).
11. National Consortium of Telehealth Resource Centers. Available online at: https://www.telehealthresourcecenter.org/ (accessed December 22, 2020).
12. California Telehealth Resource Center. Available online at: https://www.caltrc.org/knowledge-center/training/ (accessed December 22, 2020).
13. AAMC Telehealth Competencies. September, 2020. Available online at: https://www.aamc.org/media/47796/download (accessed December 20, 2020).
14. Lindquist LA, Gleason KM, McDaniel MR, Doeksen A, Liss D. Teaching medication reconciliation through simulation: a patient safety initiative for second year medical students. *J Gen Intern Med.* (2008) 23:998–1001. doi: 10.1007/s11606-008-0567-3
15. Zendejas B, Brydges R, Wang AT, Cook DA. Patient outcomes in simulation-based medical education: a systematic review. *J Gen Intern Med.* (2013) 28:1078–89. doi: 10.1007/s11606-012-2264-5
16. Thomas PA, Kern DE, Hughes MT, Chen BY. *Curriculum Development for Medical Education: A Six-Step Approach.* Baltimore, MD: Johns Hopkins University Press (2015).
17. SharePoint®. Available online at: https://support.microsoft.com/en-us/office/what-is-sharepoint-97b915e6-651b-43b2-827d-fb25777f446f (accessed December 22, 2020).
18. The Joint Commission. (2020). Focused Professional Practice Evaluation (FPPE) – Understanding the Requirements. Available online at: https://www.jointcommission.org/standards/standard-faqs/critical-access-hospital/medical-staff-ms/000001485/ (accessed December 20, 2020).
19. National Quality Forum. (2017). Creating a Framework to Support Measure Development for Telehealth. Available online at: https://www.qualityforum.org/ProjectDescription.aspx?projectID=83231 (accessed November 29, 2020).
20. Chuo J, Macy ML, Lorch SA. Strategies for evaluating telehealth. *Pediatrics.* (2020) 146:e20201781. doi: 10.1542/peds.2020-1781

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Pediatrics

BRIEF RESEARCH REPORT
published: 07 April 2021
doi: 10.3389/fped.2021.647937

Check for updates

Attitudes and Perceptions of Telemedicine in Response to the COVID-19 Pandemic: A Survey of Naïve Healthcare Providers

Dana A. Schinasi[1,2]*, *Carolyn C. Foster*[1,2,3], *M. Katie Bohling*[2], *Leonardo Barrera*[3] and *Michelle L. Macy*[1,2,3]

[1] *Department of Pediatrics, Northwestern University Feinberg School of Medicine, Chicago, IL, United States,* [2] *Telehealth Programs, Ann & Robert H. Lurie Children's Hospital of Chicago, Chicago, IL, United States,* [3] *Mary Ann & J. Milburn Smith Child Health Outcomes, Research, and Evaluation Center, Ann & Robert H. Lurie Children's Hospital of Chicago, Chicago, IL, United States*

Introduction: Expansion of telemedicine enabled healthcare access during the COVID-19 pandemic. In response to in-person visit restrictions, our institution trained >1,000 clinicians in telemedicine. Little is known about telemedicine-naïve pediatric healthcare provider's perceptions as they adopted telemedicine practice.

Methods: We conducted a cross-sectional survey of clinicians after expanding telemedicine practice at an independent children's hospital. The survey assessed experience with, concerns about, and intentions to continue telemedicine. Outpatient providers were included if they were first trained for telemedicine in response to COVID-19 and conducted at least one video visit, 3/21/2020–6/30/2020. Descriptive statistics were calculated; perceptions were compared across telemedicine activity level quartiles (based on proportions of visits delivered by video in June 2020) using Fisher's exact tests.

Results: Of 609 survey responses, 305 (50.1%) met inclusion criteria, representing various roles and disciplines. Over half (54.1%) conducted >20 video visits 3/21/2020–6/30/2020. More than 75% of providers found telemedicine easy to learn. Providers with greater proportions of video visits in a typical week in June reported greater ease of incorporating telemedicine into clinical practice and greater intention to continue telemedicine practice in 6 months. Nearly all providers endorsed concerns. Patient care experiences reinforced technology-related concerns and alleviated liability and privacy concerns. Payer reimbursement was the leading influencer of anticipated future use of telemedicine.

Discussion: Providers who conducted more telemedicine encounters reported greater ease of incorporating telemedicine into practice. Provider concerns were influenced by patient care experiences. Targeted training and quality improvement strategies are needed to sustain a robust post-pandemic telemedicine program.

Keywords: telemedicine, telehealth, COVID-19, pediatric, children's hospital, healthcare provider

OPEN ACCESS

Edited by:
Tzielan Lee,
Stanford University, United States

Reviewed by:
Kristin Ray,
University of Pittsburgh, United States
Rajdeep Pooni,
Stanford University, United States

Correspondence:
Dana A. Schinasi
dschinasi@luriechildrens.org

Specialty section:
This article was submitted to General Pediatrics and Pediatric Emergency Care, a section of the journal Frontiers in Pediatrics

Received: *30 December 2020*
Accepted: *12 March 2021*
Published: *07 April 2021*

Citation:
Schinasi DA, Foster CC, Bohling MK, Barrera L and Macy ML (2021) Attitudes and Perceptions of Telemedicine in Response to the COVID-19 Pandemic: A Survey of Naïve Healthcare Providers. Front. Pediatr. 9:647937. doi: 10.3389/fped.2021.647937

INTRODUCTION

Few pediatric providers had telemedicine experience prior to 2020 (1, 2). The COVID-19 pandemic forced clinicians to reconsider how to safely deliver care. The declaration of a national emergency in March 2020 resulted in loosening of national privacy policies and easing of state-level restrictions around provision of care and reimbursement for telemedicine (4–6). Stay-at-home orders issued to mitigate spread of COVID-19 necessitated widespread rapid deployment of telemedicine services throughout the U.S healthcare system (3). Beginning on March 21, 2020, the stay-at-home order in Illinois (7) fueled demand for telemedicine as an alternative to in-person care. Our institutional experience prior to COVID-19 aligns with previously reported barriers to telehealth adoption, including insufficient payment, inability to bill for services (2), lack of training, cost of equipment, and concerns about potential liability (8).

While Ann & Robert H. Lurie Children's Hospital of Chicago has had a dedicated telemedicine department since 2014, fewer than sixty providers had completed the required formal training to deliver care via telemedicine by the start of 2020. Telemedicine services were contained in dedicated programs that serviced unique patient populations such as neurocritical care, infectious diseases, and emergency care. The required Telemedicine Provider Training curriculum covered the foundational components of telemedicine and was tailored to provider-specific needs within each program. Before the COVID-19 pandemic, telemedicine service lines had been of limited interest to most specialties due to poor reimbursement and restrictions related to provision of telemedicine, such as the state requirement for another healthcare provider to be present at the patient site to serve as a tele-presenter. Therefore, most clinicians practicing in the outpatient settings affiliated with Lurie Children's were telemedicine-naïve, with no prior experience in this model of care delivery before the pandemic. The gubernatorial Executive Order enacted on March 19, 2020 in response to the public health emergency eased reimbursement regulations for telemedicine video and telephone visits alike.

Prior surveys of pediatric clinician attitudes on telemedicine have been conducted in similar pre-COVID settings where actual telemedicine use among providers was low. Results of a 2016 national survey on pediatricians' experiences with and attitudes toward telehealth found that 15% of pediatricians reported any telehealth use in the 12 months prior to the survey (2). With this study, we sought to examine attitudes and perceptions of those clinicians who had experience delivering care via newly adopted telemedicine practice in response to the COVID-19 pandemic. In this brief research report, we present results of a survey of telemedicine providers at our institution conducted within 3 months of their Telemedicine Provider Training and compare their attitudes relative to their self-reported telemedicine visit activity levels in June 2020. We hypothesized that attitudes and perceptions of telemedicine in the new "COVID-era" may be different as more pediatric providers have experience with telemedicine.

METHODS

Study Design

We conducted a brief cross-sectional survey to assess perceptions of telemedicine among clinicians who completed their Telemedicine Provider Training and delivered outpatient care via video visits between March 21 and June 30, 2020. This study was deemed exempt by our Institutional Review Board.

Setting

Ann & Robert H. Lurie Children's Hospital of Chicago is the largest independent quaternary care children's hospital in Illinois with more than 1,665 physicians and allied health professionals in 70 pediatric specialties (9). More than 220,000 children receive medical care at Lurie Children's each year, across the emergency department (ED), ambulatory, and inpatient settings. Lurie Children's Emergency Care Center is a Level 1 Pediatric Trauma Center, serving more than 56,000 ill and injured children per year. The hospital has 365 total pediatric beds, including 64 in the neonatal intensive care unit, 60 in the pediatric intensive care unit, and 12 in inpatient psychiatry.

Telemedicine Training

Prior to being credentialed in telemedicine, all clinicians providing patient care or family support via telemedicine at our institution are required to complete formal training. Resident physicians at our institution did not participate in telemedicine during the study period. For those physicians in fellowship training, the decision to include them in their divisional telemedicine response was at the discretion of individual program leadership. Certain divisions required each of their providers to complete Telemedicine Provider Training in anticipation of use, regardless of whether explicit plans for telemedicine were yet in place. The training was delivered as a 1-h session delivered synchronously and was an institutional requirement for Telemedicine Privileges through our Medical Staff Office. Within the first 12 weeks following the declaration of national emergency, synchronous Telemedicine Provider Training was completed by 1,069 physicians, advanced practice providers, social workers, therapists, counselors, and other clinicians at Lurie Children's. The training covered foundational components of telemedicine including: local context and program goals; legal and risk considerations; high-level workflows; clinical considerations, including physical examination tips and charting requirements; virtual presence, including webside manner overview; technology overview, including hardware, software, and troubleshooting.

Survey Development

Survey items were developed by a team experienced in telemedicine and health services research. The survey was designed to gather information about provider experiences with telemedicine, their attitudes toward telemedicine, and their intentions to continue delivering care via telemedicine. Responses from a pilot survey administered in March 2020 to previously naïve telemedicine providers at our institution were used to inform the content of this survey. The survey questions were entered into the Qualtrics XM survey platform (Qualtrics, Provo, UT). This survey was pilot tested with five individuals with expertise in evaluation and refined based on their feedback.

In the survey, "telemedicine" was defined for respondents as "real-time, face-to-face video encounter between a patient/family and a healthcare provider using a secure, HIPAA-compliant platform." To capture outpatient clinic activity and telemedicine experience, the survey asked respondents "how many total outpatient visits did you complete in a typical week before the COVID-19 stay-at-home order," "how many total outpatient visits did you complete in a typical week in June 2020," and "provide your best estimate of the percentage of your outpatient visits in a typical week in June 2020 within each of the following categories": "telephone consults," "telemedicine (video) visits" and "in-person visits." Respondents were asked to enter numbers totaling 100%.

To identify attitudes toward adoption of telemedicine, the survey asked "how easy or difficult it was to: (1) learn how to conduct a visit using telemedicine, and (2) incorporate telemedicine into my clinical practice;" responses were captured according to a 5-point Likert scale ("extremely easy" to "extremely difficult"). Clinicians were also queried on their intention to continue to use telemedicine in the future.

A series of questions related to concerns about telemedicine began by asking providers to select all items that cause them at least some concern from a list generated by providers at the start of the telemedicine COVID-19 response. The list of concerns included: "(1) patient privacy, (2) liability associated with telemedicine, (3) reliability of internet connections to support telemedicine, (4) families won't be able to access video services due to lack of digital devices, cellular data, or Wi-Fi, (5) limitations in the physical assessment of a patient by video, and (6) quality of audio or video will be poor." A free-response option was also provided. For each selected item, a subsequent question asked respondents to indicate how concerned they are about each item today: "a little concerned," "somewhat concerned," "very concerned," or "extremely concerned." Respondents were also asked to indicate whether or not a patient care experience has influenced their level of concern. For each of the concerns they had selected they were provided the following response options: "I had a patient care experience that decreased this concern," "I have not had any patient care experiences that change my concern," and "I had a patient care experience that increased this concern."

Providers then were asked "How did the 1-h Telemedicine Provider Training impact your overall level of concern about delivery care via telemedicine, if at all?" We also queried providers about their desire for additional training on (1) how to use the telemedicine technology, (2) webside manner or how to conduct a telemedicine visit generally, (3) how to help patient families connect through telemedicine, (4) something else with a free-text response option.

Providers were asked if they anticipated providing patient care via telemedicine in 6 months. Response options included "definitely yes," "probably yes," "might or might not," "probably not," and "definitely not;" affirmative responses (definitely or probably yes) and negative responses (definitely or probably not) were grouped for analysis. Providers were asked to rank four influencers of the continued provision of patient care via telemedicine in 6 months: division continues to offer, payers continue to reimburse, family interest, and personal preference; another response was also available. We created a categorical variable of the top influencer based on the item each provider selected as most influential. Demographic characteristics included years in clinical practice (categorical) and their area of practice/clinical background. Area of clinical practice was aggregated into the following categories: pediatric subspecialist including all medial subspecialties, general pediatrics, pediatric surgery including general surgery and surgical subspecialties, psychiatry/psychology, habilitation/rehabilitation services, clinical nutrition, genetic counseling, and other/no response.

Survey Distribution

Anonymous survey links were distributed via email on July 8, 2020 through the hospital distribution list; reminders were sent on July 15, 2020 and targeted requests were made via email to division leadership and providers who had completed a feedback form prior to their initial training. The survey was closed to responses on August 8, 2020.

Study Population

All 1,069 clinicians who completed formal training at our institution were considered eligible for this study. Screening questions were used to identify providers who practiced in the ambulatory setting, had not provided telemedicine care prior to March 2020 (telemedicine-naïve), and who had conducted at least one video visit in response to the COVID-19 pandemic. We excluded responses from individuals who did not provide service to patients via video visits during the period between March 21, 2020 and June 30, 2020 and those who did not progress through the entire survey.

Analysis

Descriptive statistics were calculated including medians and interquartile ranges (IQR) for continuous data and proportions for categorical data. We characterized respondents by their telemedicine activity and categorized each provider into quartiles based on their self-reported percentage of care delivered by video visits in a typical week in June 2020. We then compared perceptions of telehealth across telemedicine activity quartiles using Fisher's exact tests. We report on perceived concerns and the change in concern based on clinical experiences, desire for additional training, intentions to continue to provide telemedicine care in 6 months, and influencers of continued provision of telemedicine. Responses were downloaded from Qualtrics and entered into Stata version 15.1 (StataCorp LLC, College Station, TX) for analysis. Free text responses to the desire for additional training were reviewed and thematically coded by one investigator (MM) and affirmed by another investigator (DS). Discrepancies were resolved through discussion.

RESULTS

Surveys were distributed via institution-wide and division-specific email lists. Survey links were opened by 609 staff members; 126 respondents were not eligible (93 respondents did not provide ambulatory care and 33 did not complete training). There were 483 eligible responses from 1,069 trained providers (response rate 45%). We excluded 178 surveys from our analyses (42 from providers who reported completing no video visits, 89 from providers who did not respond to the question about the number of completed telemedicine video visits, and 47 with incomplete responses to other questions relevant to our analyses). Characteristics of the 305 respondents included in the analysis and their clinical practice are presented in **Table 1**. The analyzed respondents represented a variety of disciplines and roles including physicians; advanced practice nurses ($n = 43$); physical therapists, occupational therapists, speech therapists ($n = 37$); social workers ($n = 7$); clinical nutritionists ($n = 9$); genetic counselors ($n = 6$); and nurses ($n = 5$). Twenty-one respondents reported that they did not complete any outpatient visits prior to the stay at home order, and 3 reported that they did not complete any visits during a typical week in June; these include academic clinicians who spend the majority of their time in research, surgeons, and other specialists who provide a mix of inpatient and outpatient care. The largest numbers of respondents reported being in practice for 15 years or more (45.3%) and conducting >20 video visits (54.1%).

Respondent attitudes toward telemedicine relative to percent of visits conducted via video in a typical week in June 2020 are shown in **Table 2**. There were similar perceptions of ease of learning to conduct a telemedicine visit across the different quartiles of video visit activity during a typical week ($p = 0.51$). However, there was an association between the ease of incorporating telemedicine into clinical practice and the quartiles of video visit activity with 53.3% in the lowest activity quartile, 67.1 and 68.8% in the middle quartiles, and 82.9% in the highest activity quartile reporting it was very easy or easy to incorporate telemedicine into clinical practice ($p = 0.006$). Providers' intention to continue to provide care via telemedicine into the next 6 months increased incrementally by video visit activity quartile, ranging from 60.0% for the lowest activity quartile to 92.1% for the highest activity quartile ($p < 0.0001$).

The median number of concerns selected was 4 (IQR 3, 4) out of 7 possible listed concerns. Six of the 305 respondents (2.0%) selected no telemedicine concerns. Of the 299 providers indicating at least one concern, 68 (22.7%) reported that a patient care experience with telemedicine decreased their level of concern, whereas 225 (75.3%) reported that a patient care experience with telemedicine increased their level of concern. The telemedicine training curriculum decreased concerns for 101 (33.8%), increased concerns for 5 (1.7%), and had no change on concerns for 193 (64.5%).

The number of providers selecting each telemedicine-specific concern from the list of fixed-choice responses is presented in **Table 3**. The greatest numbers of providers selected technology-related concerns including: reliability of internet ($n = 250$, 82.0%), limitations to physical assessment by video ($n = 225$, 73.8%), family access to video services ($n = 217$, 71.1%), and poor quality of audio or video ($n = 191$, 62.6%). Less than half of responding providers reported concerns about liability ($n = 111$, 36.4%) and patient privacy ($n = 52$, 17.0%). More than half of providers who selected a technology-related concern indicated that concern had been increased by a patient care experience. Approximately 15% of providers had patient care experiences that alleviated their concerns about reliability of internet and family access to video services. Most providers had no patient care experiences that changed their liability and privacy concerns. Additional training was desired on how to help patients' families connect through telemedicine ($n = 124$), webside manner or how to conduct a telemedicine visit in generally ($n = 48$), how to use the telemedicine technology ($n = 42$), and how to document a telemedicine encounter ($n = 41$). Other training was

TABLE 1 | Respondent characteristics.

	$N = 305$	
Clinical role/Training		
Pediatric subspecialist	101	33.1%
Nursing/APN	48	15.7%
PT/OT/Speech therapist	37	12.1%
Pediatric surgery	27	8.9%
Psychology	26	8.5%
General pediatrics	25	8.2%
Psychiatry	16	5.2%
Clinical nutrition	9	3.0%
Social work	7	2.3%
Other/No response	9	3.0%
Years in practice		
<5	61	20.0%
5–9	51	16.7%
10–14	53	17.4%
>14	138	45.3%
Missing	2	1%
Median number of visits in a typical week prior to Stay at Home order		
(March 21, 2020) (IQR) ($n = 275$)	15	(8, 30)
Median number of visits in a typical week in June, 2020		
Including in-person, telephone, and video (IQR) ($n = 273$)	15	(7, 25)
Total number of video visits since Stay at Home order		
(March 21, 2020–June 30, 2020)		
1–5	47	15.4%
6–20	93	30.5%
>20	165	54.1%
Total number of telephone visits since Stay at Home order		
(March 21, 2020–June 30, 2020)		
0	60	19.7%
1–5	89	29.2%
6–20	93	30.5%
>20	62	20.3%
Missing	1	<1%
Proportion visits by video in a typical week in June, 2020		
1st Quartile: <10%	75	24.6%
2nd Quartile: 10–23%	76	24.9%
3rd Quartile: 24–70%	78	25.6%
4th Quartile: >70%	76	24.9%

TABLE 2 | Attitudes toward telemedicine relative to percent of visits conducted by video in a typical week in June.

	Quartile 1: <10% of visits were video	Quartile 2: 10–23% of visits were video	Quartile 3: 24–70% of visits were video	Quartile 4: 71–100% of visits were video	
In your experience, how easy or difficult was it to learn how to conduct a visit using telemedicine?					
Easy or very easy	57 (76.0%)	57 (75.0%)	62 (79.5%)	66 (86.8%)	$P = 0.51$
Neither easy nor difficult	12 (16.0%)	11 (14.5%)	12 (15.4%)	7 (9.2%)	
Difficult or very difficult	6 (8.0%)	8 (10.5%)	4 (5.1%)	3 (4.0%)	
In your experience, how easy or difficult was it to incorporate telemedicine into your clinical practice?					
Easy or very easy	40 (53.3%)	51 (67.1%)	53 (68.8%)	63 (82.9%)	$P = 0.006$
Neither easy nor difficult	12 (16.0%)	9 (11.8%)	10 (13.0%)	2 (2.6%)	
Difficult or very difficult	23 (30.7%)	16 (21.1%)	14 (18.2%)	11 (14.5%)	
Thinking ahead 6 months, do you anticipate you will provide patient care via telemedicine?					
Yes	45 (60.0%)	61 (80.3%)	71 (91.0%)	70 (92.1%)	$P < 0.001$
Unsure	18 (24.0%)	9 (11.8%)	4 (5.1%)	5 (6.6%)	
No	12 (16.0%)	6 (7.9%)	3 (3.9%)	1 (1.3%)	

selected by 27 and free responses included a desire for training of administrative staff to schedule telemedicine visits ($n = 7$), billing ($n = 6$), and sharing of patient education materials ($n = 6$). Free-text responses that related to technology ($n = 10$), webside manner ($n = 5$), and family support ($n = 9$) are included in the presentation of the fixed choice response results related to additional training above.

Most respondents ($n = 247$, 81.0%) anticipated continued practice of telemedicine 6 months after the survey, 36 respondents (11.8%) indicated they may or may not and 22 respondents (7.2%) indicated they did not anticipate continued practice of telemedicine in 6 months. Payer reimbursement was most commonly selected influencer of plans to continue the practice of telehealth ($n = 120$, 45.5%), followed by offering of telemedicine by the respondent's specialty and family preference ($n = 62$, 23.5% for each), and provider preference ($n = 20$, 7.6%). The relationship between anticipated continued telemedicine practice and selected influencers of continued practice are presented in **Table 4**.

DISCUSSION

Pediatric providers previously naïve to telemedicine overwhelmingly found it easy to learn and many found telemedicine easy to incorporate into clinical practice. We found more overall positive perceptions toward telemedicine with increasing percentage of ambulatory visits conducted by video conferencing. This may signal that telemedicine becomes easier with greater use or that those who had an easier time adopting telemedicine were more likely to incorporate it into their practice. However, within this same group of providers, we identified specific ongoing concerns about telemedicine use. Specifically, providers continued to have concerns about the reliability of internet connection, the quality of video, and the limitations of physical assessment following actual patient care experiences. We also found that some providers' concerns were ameliorated through training, and that additional targeted training was desired on how to help patients' families connect through telemedicine. As a result of these findings, these areas of telemedicine delivery have become targets for education and improvement by our institution. Addressing these concerns is crucial to assuring that we provide on-going high-quality care experiences for patients and providers alike. It is important to note that the pandemic has exposed gaps in internet connectivity nationwide (10), a priority for the Federal Communications Commission to address as they strive to ensure equitable access to health care and education for all Americans.

We also found that providers who were higher utilizers of telemedicine reported greater ease of incorporating telemedicine into practice, and indicated they plan to continue its use. It is possible that some of the providers who anticipated that it would be easy to learn telemedicine were those who conducted a higher proportion of visits via telemedicine. The diffusion of innovation theory suggests that organizational structure and culture will affect health care providers' perceptions of telemedicine, thereby influencing adoption and utilization (11, 12). Similarly, the Technology Acceptance Model (TAM) connects perceived usefulness with ease of use in adoption of new technology (13). TAM is an information systems theory developed to identify how individuals begin to accept and use technological advancements, and within health care provides a better understanding of clinician technology acceptance, informing health care organizations about barriers to embracing new technologies (14). A relationship between telemedicine experience and acceptability has been previously described in providers who care for children with special health care needs (15), as well as in the tele-hospice and tele-psychiatry populations (16). Still, despite the identified relationship between technology acceptance and adoption by health care providers, there is a need to better understand the various factors contributing to this relationship (17). As such, our survey results support the need for a more targeted framework to better define this relationship. Numerous medical education frameworks already exist for achieving mastery of essential clinical skills (18, 19), and

TABLE 3 | Impact of patient care experience on telemedicine concerns.

Question stem:		**Please indicate whether or not a patient care experience has influenced your level of concern for each of the concerns you selected.**		
Below are a list of several concerns of providers prior to our deployment of telemedicine in response to COVID-19 at Lurie Children's in mid-March, 2020. Please select the all of items that cause you at least some concern.	**N* selecting concern**	**Concern decreased because of patient care experience**	**No change in concern based on patient care experience**	**Concern increased because of patient care experience**
Reliability of internet connections to support telemedicine	250	36 (14.5%)	51 (20.5%)	162 (65.0%)
Limitations in the physical assessment of patient by video	225	23 (10.3%)	84 (37.5%)	117 (52.2%)
Families won't be able to access video services due to lack of digital devices, cellular data, or WiFi	217	33 (15.3%)	72 (33.3%)	111 (51.4%)
Quality of audio or video will be poor	191	9 (4.8%)	39 (20.6%)	141 (74.6%)
Liability associated with telemedicine	111	11 (9.9%)	91 (82.0%)	9 (8.1%)
Patient privacy (e.g., HIPAA and Protected Health Information)	52	10 (19.2%)	34 (65.4%)	8 (15.4%)
Other concern not listed	40	1 (2.5%)	5 (12.5%)	34 (85.0%)

**one to two respondents did not provide responses to the change in concern based on clinical experience, resulting in a difference between the total sample size, and the sample reported in the change in concern columns.*

TABLE 4 | Top-ranked factors influencing provider intention to continue practicing telemedicine in 6 months.

			Thinking ahead 6 months, do you anticipate you will provide care via telemedicine?					
Top-ranked factor influencing if you will continue to provide patient care via telemedicine 6-months from now.	**$N = 305$**	**%**	**Definitely yes or probably yes $N = 244$**	**%**	**Might or Might not $N = 34$**	**%**	**Probably not or definitely not $N = 20$**	**%**
Whether payers continue to reimburse for telemedicine visits	120	39.3%	104	46.4%	14	41.2%	2	10.0%
Whether my division continues to offer telemedicine visits	62	20.3%	56	25.0%	6	17.7%	0	0
Whether patients' families are interested in telemedicine visits	62	20.3%	46	20.5%	10	29.4%	6	30.0%
My own preference to use telemedicine in my practice	20	6.6%	10	4.5%	3	8.8%	7	35.0%
Other	14	4.6%	8	3.6%	1	2.9%	5	25.0%
No response	27	8.9%	n/a		n/a		n/a	

the field of telemedicine is poised for the merging of technology and education frameworks to achieve this.

Our study has several limitations. Our survey was conducted at a single center; therefore, findings may not be generalizable to settings with different telemedicine training or platforms. Surveys were distributed via mass communication channels to all staff members, including those who do not provide clinical care and those who were not trained in the telehealth pandemic response. We also distributed surveys with anonymous links. Responses represent a subset of individuals who completed telemedicine training and there is potential for response bias. We did not have a mechanism to obtain information from non-respondents and therefore cannot determine if respondents differ from non-respondents. It is possible that providers who completed the survey were representative of the full population. It is also possible that respondents had stronger opinions, either positive or negative, toward telemedicine than non-respondents, but we do not have a way to quantify the impact of response bias on our results. Because of skip and display logic, we do not have a way to compare providers who completed video visits to those who did not. Surveys are also subject to social desirability bias. This bias is minimized by allowing providers to provide anonymous survey responses. Additionally, while all providers were uniformly trained in telemedicine with consistency in standards and technology platforms, integration of telemedicine into ambulatory workflows was at the discretion of individual divisions, some of whom have a medical assistant or nurse to help the provider and others who do not. This data was not collected in our study and is thus a limitation. There are myriad unmeasured factors that could have influenced the ease with which a provider was able to incorporate telemedicine into their practice. This is an area for future research.

The global pandemic exposed providers and patients to telemedicine, many of whom were previously naïve to this modality of care delivery. Our findings support the acceptability of telemedicine in outpatient pediatric care and suggest that with increased experience telemedicine becomes easier to incorporate into practice. Targeted training and quality improvement strategies are needed to sustain a robust post-pandemic telemedicine program. Provider concerns about telemedicine were both reinforced and alleviated by patient care experiences; this lack of distinct directionality is a precursor for future qualitative work, to better describe how provider concerns with telemedicine are either reinforced or alleviated in relation to the patient experience in order to identify areas for additional support. Telehealth programs further can address provider concerns through advocacy for policy change and investment in resources to ensure patients have access to technology needed to utilize telemedicine services.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

DS conceptualized the study, designed the data collection instrument, drafted the initial manuscript, and reviewed and revised the manuscript. CF conceptualized the study, designed the data collection instrument, and reviewed and revised the manuscript. MB conceptualized the study, designed the data collection instrument, and critically reviewed the manuscript for important intellectual content. LB carried out the data analysis and reviewed and revised the manuscript. MM conceptualized the study, designed the data collection instrument, supervised data collection, carried out the data analysis, and reviewed and revised the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

REFERENCES

1. Olson CA, McSwain SD, Curfman AL, Chuo J. The current pediatric telehealth landscape. *Pediatrics.* (2018) 141:e20172334. doi: 10.1542/peds.2017-2334
2. Sisk B, Alexander J, Bodnar C, Curfman A, Garber K, McSwain SD, et al. Pediatrician attitudes toward and experiences with telehealth use: results from a national survey. *Acad Pediatr.* (2020) 20:628–35. doi: 10.1016/j.acap.2020.05.004
3. Keesara S, Jonas A, Schulman K. Covid-19 and health care's digital revolution. *N Engl J Med.* (2020) 382:e82. doi: 10.1056/NEJMp2005835
4. *H.R. 6074 – Coronavirus Preparedness and Response Supplemental Appropriations Act.* (2020). Available online at: https://www.congress.gov/bill/116th-congress/house-bill/6074 (accessed September 13, 2020).
5. U.S. Department of Health & Human Services. *Notification of Enforcement Discretion for Telehealth Remote Communications During the COVID-19 Nationwide Public Health Emergency.* (2020). Available online at: https://www.hhs.gov/hipaa/for-professionals/special-topics/emergency-preparedness/notification-enforcement-discretion-telehealth/index.html (accessed September 13, 2020).
6. *Illinois Executive Order 2020-09: Executive Order to Expand Telehealth Services and Protect Health Care Providers in Response to COVID-19.* (2020). Available online at: https://www2.illinois.gov/Pages/Executive-Orders/ExecutiveOrder2020-09.aspx (accessed September 13, 2020).
7. Illinois Executive Order 2020-10. *Executive Order in Response to COVID-19.* (2020). Available online at: https://www2.illinois.gov/Pages/Executive-Orders/ExecutiveOrder2020-10.aspx (accessed September 13, 2020).
8. Moore MA, Coffman M, Jetty A, Petterson S, Bazemore A. Only 15% of FPs report using telehealth; training and lack of reimbursement are top barriers. *Am Fam Physician.* (2016) 93:101.
9. *Ann & Robert H. Lurie Children's Hospital of Chicago.* Available online at: https://www.luriechildrens.org/en/who-we-are/facts-figures/ (accessed December 24, 2020).
10. *Federal Communications Commission.* Available online at: https://www.fcc.gov/keep-americans-connected (accessed December 29, 2020).
11. Rogers, Everett M, *Diffusion of Innovations.* New York, NY: Free Press of Glencoe (1962).
12. Walker J, Whetton S. The diffusion of innovation: factors influencing the uptake of telehealth. *J Telemed Telecare.* (2002) 8(Suppl. 3):73–5. doi: 10.1258/13576330260440934
13. Holden RJ, Karsh BT. The technology acceptance model: its past and its future in health care. *J Biomed Inform.* (2010) 43:159–72. doi: 10.1016/j.jbi.2009.07.002
14. Yarbrough AK, Smith TB. Technology acceptance among physicians: a new take on TAM. *Med Care Res Rev.* (2007) 64:650–72. doi: 10.1177/1077558707305942
15. Karp WB, Grigsby RK, McSwiggan-Hardin M, Pursley-Crotteau S, Adams LN, Bell W, et al. Use of telemedicine for children with special health care needs. *Pediatrics.* (2000) 105(4 Pt 1):843–7. doi: 10.1542/peds.105.4.843
16. Whitten PS, Mackert MS. Addressing telehealth's foremost barrier: provider as initial gatekeeper. *Int J Technol Assess Health Care.* (2005) 21:517–21. doi: 10.1017/S0266462305050725
17. Ruiz Morilla MD, Sans M, Casasa A, Giménez N. Implementing technology in healthcare: insights from physicians. *BMC Med Inform Decis Mak.* (2017) 17:92. doi: 10.1186/s12911-017-0489-2
18. Branzetti J, Gisondi MA, Hopson LR, Regan L. Aiming beyond competent: the application of the taxonomy of significant learning to medical education. *Teach Learn Med.* (2019) 31:466–78. doi: 10.1080/10401334.2018.1561368
19. Frank JR, Mungroo R, Ahmad Y, Wang M, De Rossi S, Horsley T. Toward a definition of competency-based education in medicine: a systematic review of published definitions. *Med Teach.* (2010) 32:631–7. doi: 10.3109/0142159X.2010.500898

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

ORIGINAL RESEARCH
published: 13 April 2021
doi: 10.3389/fped.2021.648631

Pediatric Subspecialty Adoption of Telemedicine Amidst the COVID-19 Pandemic: An Early Descriptive Analysis

*James Xie [1,2], Priya Prahalad [2,3], Tzielan C. Lee [2,4], Lindsay A. Stevens [2,5] and Kara D. Meister [6]**

[1] Division of Pediatric Anesthesiology, Department of Anesthesiology, Perioperative and Pain Medicine, Lucile Packard Children's Hospital—Stanford Children's Health, Stanford University School of Medicine, Stanford, CA, United States, [2] Information Services Department, Stanford Children's Health, Stanford, CA, United States, [3] Division of Pediatric Endocrinology and Diabetes, Department of Pediatrics, Lucile Packard Children's Hospital—Stanford Children's Health, Stanford University School of Medicine, Stanford, CA, United States, [4] Division of Pediatric Rheumatology, Department of Pediatrics, Lucile Packard Children's Hospital—Stanford Children's Health, Stanford University School of Medicine, Stanford, CA, United States, [5] Division of General Pediatrics, Department of Pediatrics, Lucile Packard Children's Hospital—Stanford Children's Health, Stanford University School of Medicine, Stanford, CA, United States, [6] Division of Pediatric Otolaryngology, Department of Otolaryngology—Head and Neck Surgery, Lucile Packard Children's Hospital—Stanford Children's Health, Stanford University School of Medicine, Stanford, CA, United States

OPEN ACCESS

Edited by:
Priya Sara Verghese, Ann & Robert H. Lurie Children's Hospital of Chicago, United States

Reviewed by:
Michelle Macy, Ann & Robert H. Lurie Children's Hospital of Chicago, United States
Lyndsay Harshman, The University of Iowa, United States

****Correspondence:***
Kara D. Meister
meister4@stanford.edu

Specialty section:
This article was submitted to Pediatric Nephrology, a section of the journal Frontiers in Pediatrics

Received: *01 January 2021*
Accepted: *16 March 2021*
Published: *13 April 2021*

Citation:
Xie J, Prahalad P, Lee TC, Stevens LA and Meister KD (2021) Pediatric Subspecialty Adoption of Telemedicine Amidst the COVID-19 Pandemic: An Early Descriptive Analysis. Front. Pediatr. 9:648631. doi: 10.3389/fped.2021.648631

Telemedicine has rapidly expanded in many aspects of pediatric care as a result of the COVID-19 pandemic. However, little is known about what factors may make pediatric subspeciality care more apt to long-term adoption of telemedicine. To better delineate the potential patient, provider, and subspecialty factors which may influence subspecialty adoption of telemedicine, we reviewed our institutional experience. The top 36 pediatric subspecialties at Stanford Children's Health were classified into high telemedicine adopters, low telemedicine adopters, and telemedicine reverters. Distance from the patient's home, primary language, insurance type, institutional factors such as wait times, and subspecialty-specific clinical differences correlated with differing patterns of telemedicine adoption. With greater awareness of these factors, institutions and providers can better guide patients in determining which care may be best suited for telemedicine and develop sustainable long-term telemedicine programming.

Keywords: telemedicine, telehealth, pediatric, subspecialty, access, COVID-19

INTRODUCTION

The COVID-19 pandemic has fueled the rapid implementation and adoption of telemedicine (TM) in pediatric care. In a pandemic, TM offers a unique venue to preserve patient access to care, while also providing a real-time benefit to public health via infection control by limiting patients' exposure to one another and providers (1, 2). Policymakers recognized the need and deregulated TM, accelerating its adoption and resulting in a national "telemedicine test case" (3). However, little is known about what kinds of pediatric patients are best served by digital modalities, which pediatric subspecialties are best suited to the adoption of TM, and what barriers might exist in the perpetuation of TM in pediatric subspecialty care. The rapid implementation of TM in response to the COVID-19 pandemic has provided a unique situation to study barriers, facilitators, and operational processes of TM in various pediatric subspecialties (4). As such, there have been a number of publications summarizing the experiences in various pediatric subspecialties such as endocrinology, medical genetics, and orthopedics (5–7). It is assumed that the effectiveness and durability of a TM program varies widely by pediatric specialty, patient population, and the preferences of patients and providers. To our knowledge, there have not been any publications summarizing a single institution's experiences across different pediatric subspecialties.

It is also known that differences in patient demographics such as race, language, insurance status, and neighborhood broadband status may impact the use of health-related technologies including patient portals and TM (8, 9). Inequities in accessing TM have also been reported in adult patients during the COVID-19 pandemic, with poorer, non-English-speaking, and Latinx patients having less TM use (10). To better delineate the potential patient, provider, and subspecialty factors influencing subspecialty adoption of TM, we studied a single institution's experience during the COVID-19 pandemic. We hypothesized that because subspecialties differ in the nature of the clinical encounter and needs, subspecialities within a single institution may have different TM adoption rates, and these differences may continue and evolve throughout the pandemic. Secondarily, we hypothesized that TM use may be driven by non-specialty factors including patient factors such as patient's preferred language (English speaking patients may be more likely to adopt to TM), insurance type (patients with non-public insurance may be more likely to adopt TM), and distance to the clinic (patients living farther away may be more likely to adopt TM), as well as institutional factors such as wait times to make appointments (subspecialties with long appointment wait times may be more likely to adopt TM).

MATERIALS AND METHODS

Setting

Lucile Packard Children's Hospital/Stanford Children's Health is located in the San Francisco Bay Area, California. The quaternary academic teaching hospital, Lucile Packard Children's Hospital (LPCH), is located in Palo Alto, California, and is associated with Stanford School of Medicine. Stanford Children's Health (SCH) is comprised of more than 65 affiliated outpatient clinics and locations. Our institution was fortunate to have an existing TM platform, which although it had not previously been widely adopted, was quickly able to scale up and to have clinicians trained to use the platform in a short period of time. This led to a consistent adoption model across our institution.

Since our institution is in the San Francisco Bay Area, a local Shelter-in-Place (SIP) order went into effect on March 16, 2020, followed by a California SIP on March 19, 2020. An institution-wide request to convert appropriate in-person encounters to TM encounters was issued starting March 15, 2020. The hospital and providers opted to limit in-person visits when not necessary, and many patients and families did not want to be exposed unnecessarily. For the majority of the study period, Santa Clara County, the county in which Stanford is situated, remained at the highest risk tier of purple with only a brief decrease to the second highest tier in September, 2020. No specific restrictions were imposed on patients and families desiring to seek medical care during the study period.

Data Acquisition

Data for outpatient clinical encounters was queried from the electronic medical record, ambulatory access dashboards, and billing databases at LPCH/SCH. TM encounter data from ambulatory clinic visits from January 1, 2020, through November 15, 2020, was obtained with associated data on each patient's primary language, home zip code, insurance type, clinic specialty, and provider identification number. Of note, a pediatric patient's language is recorded with the parent or caregiver's preferred language. A linear distance from the center of the patient's home zip code to the Stanford, CA zip code (94305) was calculated to estimate proximity to SCH, where the majority of clinics are located. Wait times for clinic appointments were averaged over the study period to account for changes in wait times during the pandemic.

Statistical Analysis

To compare TM adoption patterns across subspecialties, three groups were defined by using a "simple majority" cutoff of 50% of visits being telehealth: (1) Low TM adopters (clinics that never increased share of TM $>$ 50% vs. in-person visits in 2020); (2) High TM adopters (clinics that increased share of TM $>$ 50% vs. in-person and remained $>$ 50% for the rest of the year); and (3) TM reverters (clinics that increased TM $>$ 50% vs. in-person but fell back to $<$ 50% TM shortly thereafter).

Demographic and clinical characteristics were statistically analyzed. Analysis was performed on a visit-level basis (i.e., each TM visit was weighted the same even if the same patient had multiple visits). Descriptive statistics were used to examine and highlight trends. Numerical data was expressed as mean and standard deviation, and categorical variables were expressed as absolute frequencies and percentages. The proportion of patients with public vs. managed care insurance was compared for the top four language groups of our patients. In order to compare TM adoption groups, we applied paired t-test for numerical parameters and Chi Square test with Yates' continuity correction for categorical variables. One-way ANOVA with Tukey's Honestly Significant Difference (HSD) *post-hoc* test was used when the means of more than two groups were being analyzed. A $p < 0.05$ was considered statistically significant.

RESULTS

Subspecialties With TM Visits

Across our institution, TM visits increased in quantity for every subspecialty during 2020. A summary of in-person vs. TM visits for 36 subspecialties and general pediatrics at SCH in 2020 is depicted in **Figure 1**. Prior to March 2020, there were very few TM visits at our institution (i.e., <1% of all clinic encounters, from January 2016 to February 2020 there were 6,305 TM visits from 2,344 unique patients). From March 2020 to November 2020, there were 123,416 TM visits from 72,819 unique patients. April 2020 saw the highest total number of TM visits at 14,938;

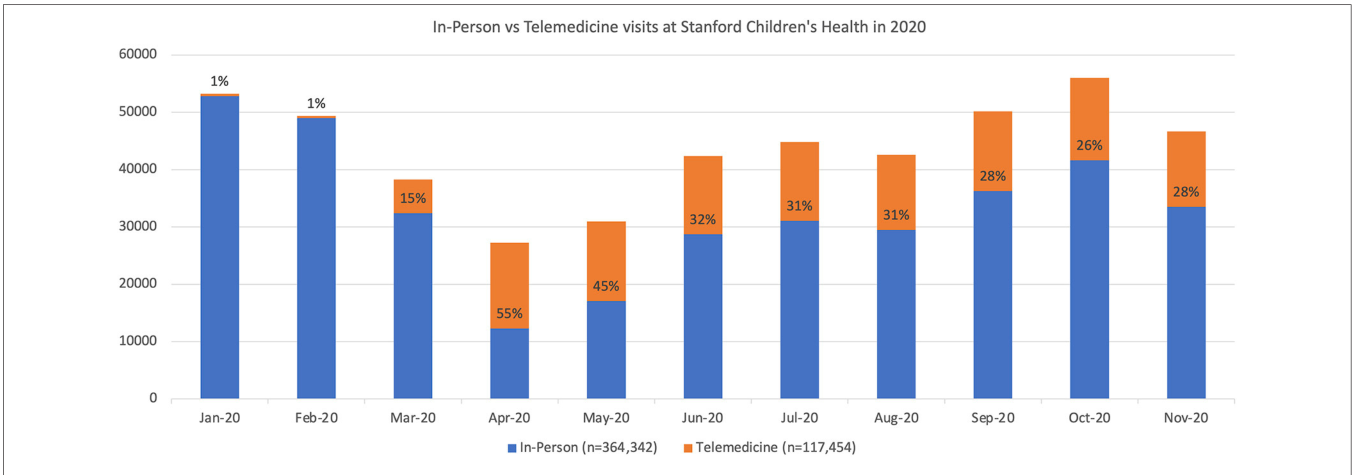

FIGURE 1 | Percentage of In-person vs. TM visits at Stanford Children's Health in 2020.

April 2020 was also unique in that TM visits exceeded in-person visits ($n = 12{,}302$) across our institution. Peak TM monthly percentages ranged from 18.2% (Cardiology, April 2020) to 100% (Weight Management, April 2020).

There were 28 subspecialties with >50% TM visits in March/April/May 2020. Of these, 12 subspecialties maintained >50% TM visits for the remainder of 2020. These subspecialties were considered "high TM adopters." There were nine subspecialties with <50% TM visits in March/April/May 2020 and beyond; these were considered "low TM adopters." There were 16 subspecialties that returned to <50% TM visits after May 2020; these subspecialties were considered "TM reverters." These subspecialties are listed in **Table 1**.

Patient Insurance Among Subspecialty TM Visits

The proportion of visits with public insurance for low TM adopters, high TM adopters, and TM reverters is shown in **Table 2**. Low TM adopters had a lower percentage (21.7%) of public insurance compared to high TM adopters (25.7%), $\chi^2 = 165.3$, $p < 0.01$, Odds ratio (OR) of 1.25 (95% CI: 1.21–1.30) of having managed care if a patient was in the low TM adopter group relative to high TM group, and a lower percentage of public insurance compared to TM reverters (33.3%), $\chi^2 = 900.4$, $p < 0.01$, OR = 1.80 (95% CI: 1.73–1.87). The difference between high TM adopters and TM reverters was also significant $\chi^2 = 468.9$, $p < 0.01$, OR = 1.44 (95% CI: 1.39–1.49).

Primary Language Among Subspecialty TM Visits

There were statistically different rates of English-preferred language patients vs. non-English-preferred language patients among the three groups of subspecialty TM adoption. The largest differences were seen between the low TM adopters and high TM adopters and the low TM adopters and TM reverters. Low TM adoption was associated with a higher percentage (95.1%) of English-preferred language patients when compared to high TM adopters (90.4%),$\chi^2(1, N = 53{,}258) = 563.17$, $p < 0.01$, OR = 2.06 (95% CI: 1.93–2.19), and TM reverters (87.7%), $\chi^2(1, N = 24{,}838) = 961.79$, $p < 0.01$, OR = 2.72 (95% CI: 2.55–2.91).

Primary Language by Insurance Type

Across TM use at our institution, insurance type differs by preferred language as summarized in **Table 3**. 97.5% of managed care patients were English-preferred language patients while 70.8% of public insurance patients were English-preferred language patients. Spanish-preferred language patients had a significantly higher percentage of patients with public health insurance (90.8% with public insurance) compared to English-preferred language patients (20.2% with public insurance), $\chi^2[(1, N = 92{,}280) = 22{,}200$, $p < 0.001]$.

Distance to Home Comparison Among Subspecialty TM Visits

The linear distance from patient's home zip code to Stanford, CA was used as an approximation of travel burden. The average distances had a right-skewed distribution: low TM adopters had a mean distance of 39.1 miles, median 24.2 miles, SD 127.5 miles; high TM adopters had a mean distance of 53.1 miles, median 21.0 miles, SD 157.5 miles; TM reverters had a mean distance of 64.9 miles, median 27.1 miles, $SD = 213.5$ miles. A one-way ANOVA showed the differences in mean distance traveled from home to clinic was significant $[F_{(2)} = 165.74, p < 0.001]$. *Post-hoc* analyses using the Tukey HSD *post-hoc* test indicated that the mean distance traveled from home to clinic was significantly lower in the low TM adopters ($M = 39.07$) than in the high TM adopters ($M = 53.09$) and the TM reverters ($M = 64.92$).

Clinic Wait Time Among Subspecialties

When compared to low TM adopters ($M = 5.31$ days, $SD = 4.91$), high TM adopters ($M = 18.33$ days, $SD = 15.06$) had a longer average number of days from referral to first visit scheduled $[t_{(15)} = 2.33, p = 0.03]$.

TABLE 1 | Pediatric subspecialty telemedicine use by adoption pattern.

Subspecialty	Peak TM %	Peak TM month	Month when TM returned to <50%
Low TM adopters: Subspecialties with <50% TM visits March/April/May 2020 and beyond			
Adolescent medicine	20.7%	May-20	
Cardiology	18.2%	April-20	
Hand surgery	28.6%	May-20	
Hematology	27.4%	April-20	
Oncology	25.1%	April-20	
Ophthalmology	28.0%	April-20	
General pediatrics	46.3%	April-20	
Plastic surgery	46.8%	April-20	
Stem cell transplant	26.7%	April-20	
Subspecialty	**Peak TM %**	**Peak TM month**	
High TM adopters: Subspecialties which maintained >50% TM visits for rest of 2020			
Developmental behavioral pediatrics	98.3%	May-20	
Diabetes	95.1%	April-20	
Eating disorders	97.7%	April-20	
Gastroenterology	80.7%	April-20	
Gender	98.4%	April-20	
Genetics	84.6%	April-20	
Immune behavioral health	95.4%	April-20	
Liver transplant	73.6%	May-20	
Neurology	96.4%	April-20	
Pain medicine	98.6%	April-20	
Psychiatry	99.0%	July-20	
Subspecialty	**Peak TM %**	**Peak TM month**	**Month when TM returned to <50%**
TM reverters: Subspecialties that returned to <50% TM visits beyond May 2020			
Allergy and immunology	57.0%	April-20	May-20
Cardiovascular transplant	71.2%	April-20	May-20
Cystic fibrosis	75.7%	April-20	May-20
Dermatology	98.2%	April-20	August-20
Endocrinology	91.3%	April-20	November-20
General surgery	75.0%	April-20	May-20
Gynecology	71.6%	April-20	June-20
Infectious diseases	72.2%	April-20	June-20
Nephrology	96.6%	April-20	June-20
Neuro-oncology	57.1%	April-20	May-20
Neurosurgery	68.6%	April-20	September-20
Orthopedics and sports medicine	63.2%	April-20	May-20
Otolaryngology	71.5%	April-20	May-20
Pulmonology	94.7%	April-20	June-20
Rheumatology	94.8%	April-20	July-20
Urology	57.8%	April-20	May-20

There were 36 subspecialities examined across our institution. The subspecialties were divided into three cohorts based on rate of TM adoption. Subspecialties which maintained >50% TM visits for the remainder of 2020 were considered "high TM adopters." Subspecialties which did not reach >50% TM visits during any month in 2020 were considered "low TM adopters." There were 16 subspecialties that initially had >50% TM visits in early 2020, but then returned to <50% TM visits beyond May 2020; these subspecialties were considered "TM reverters".

DISCUSSION

The COVID-19 pandemic forced the use of TM in many pediatric subspecialties during the early months of the pandemic, including some subspecialties for which TM was previously seen as unviable. The proportion of TM visits in clinics with pre-pandemic adoption of TM also rose rapidly. However, some subspecialties were low utilizers of TM, and others shifted back to majority in-person visits relatively quickly. Understanding the patient factors, provider/institutional factors, and subspecialty

TABLE 2 | Patient factors among pediatric subspecialty TM visits.

	Low TM adopters *n* (%)	High TM adopters *n* (%)	TM reverters *n* (%)
Managed Care	22,467 (78.3)	38,845 (74.3)	16,344 (66.7)
Public Insurance	6,222 (21.7), **(a) $p < 0.01$**	13,466 (25.7)	8,154 (33.3), **(a) $p < 0.01$**
English Language	27,563 (95.1), **(b) $p < 0.01$**	48,145 (90.4)	21,776 (87.7), **(b) $p < 0.01$**
Non-English Language	1,424 (4.9)	5,113 (9.6)	3,062 (12.3)
	Mean (miles)	**Mean (miles)**	**Mean (miles)**
Distance to home	39.07, **(c) $p < 0.001$**	53.09, **(c) $p < 0.001$**	64.92, **(c) $p < 0.001$**

(a) Low TM adopters were more likely to have managed care insurance than high TM adopters [OR = 1.25 (95% CI: 1.21–1.30), $p < 0.01$], or TM reverters [OR = 1.80 (95% CI: 1.73–1.87], $p < 0.01$]. (b) Low TM adopters were more likely to be English speaking than high TM adopters [OR = 2.06 (95% CI: 1.93–2.19), $p < 0.01$] or TM reverters [OR = 2.72 (95% CI: 2.55–2.91), $p < 0.01$]. (c) There was a significant difference among the three groups (low TM adoption, sustained high TM adoption, and TM adopters that reverted back to >50% in-person visits) for linear distance between the patient's zip code and Stanford, CA, $p < 0.001$, with low TM adopters having the shortest mean distance.

TABLE 3 | Preferred language and insurance type.

Patient's preferred language	Managed care *n* (%)	Public insurance *n* (%)
English	91,433 (80%)	23,245 (20%)
Spanish	847 (9%) **(a) $p < 0.001$**	8,318 (91%)
Chinese (Mandarin or Cantonese)	654 (57%) **(b) $p < 0.001$**	498 (43%)
Other language	800 (51%) **(c) $p < 0.001$**	771 (49%)

Insurance type	English *n* (%)	Spanish *n* (%)	Chinese (Mandarin or Cantonese) *n* (%)	Other language *n* (%)
Managed care	91,433 (97.5%)	847 (0.9%)	654 (0.7%)	800 (0.9%)
Public insurance	23,245 (70.8%)	8,318 (25.3%)	498 (1.5%)	771 (2.4%)

Patient's preferred language relative to patient's insurance type for all telemedicine encounters. (a) Primarily English-speaking patients have a significantly higher percentage of patients with managed care insurance than Spanish-speaking patients [$\chi^2(1, N = 92,280) = 22,200$, $p < 0.001$], (b) Mandarin/Cantonese-speaking patients [$\chi^2(1, N = 92,087) = 367.5$, $p < 0.001$], or (c) those patients speaking other languages [$\chi^2(1, N = 92,233) = 782.9$, $p < 0.001$].

clinical factors which may drive TM use will enable institutions to develop more effective digital health programs. Our data demonstrates there are multiple factors which correlate with whether a subspecialty adopts and sustains high rates of TM encounters.

Overall, there was an initial reduction in total visit numbers at our institution, as reflected in **Figure 1**. The decrease in visits, especially in March/April 2020, is likely multifactorial and likely includes a combination of: (1) families not wanting to be exposed to COVID-19, (2) less exposure to common infections requiring care, (3) SIP/social distancing protocols, and (4) downstream effects of decreased referrals from community providers as fewer patients were being seen by general practitioners.

Patient factors, including insurance type, preferred language, and distance from home to clinic, were different between low TM adopter subspecialties and other subspecialties. For insurance type, although there are statistically significant differences among the three TM adoption pattern groups, none of the odds ratios are >2, suggesting a relatively weak association. Of note, California has had payor parity for telemedicine since 2019 following the signing of AB744 which mandates that payors reimburse healthcare providers for telehealth services "on the same basis and to the same extent" as they cover in-person services (11). This may explain why the proportion of patients with public insurance remained approximately consistent with our institution's internal data on payor mix prior to the COVID-19 pandemic.

While it is not possible to directly attribute TM adoption rates to patients' preferred language, our findings showed a lower percentage of non-English-preferred language patients in clinics with low TM adoption. Only 4.9% of TM visits in low adoption specialties were with non-English-preferred language patients. This is lower than expected compared to the pre-pandemic language mix in those clinics. This may indicate that when given the option for in-person visits or TM, non-English-preferred language patients chose in-person. This finding may also be related to the need for TM-enabled interpreter services and the need to set up a third-party interpreter during a TM visit. In-person visits have a more established interpreter workflow and thus perhaps fewer non-English-preferred language patients were being seen via TM in the low TM adoption group. Equitable accessibility for all patients is challenging (12, 13). Families need solutions in their preferred language, at their level of health literacy, and digital literacy. Patients experiencing healthcare disparities show less engagement in telehealth, including use of patient portals and TM visits (14, 15). Despite being situated in the Silicon Valley, our institution still sees some of the most explicit examples of the "digital divide" in our families (16).

Similarly, low TM adoption was associated with a shorter mean distance from home to the clinic. This finding could reflect that subspecialties with a regional catchment (e.g., cardiology, hematology, and oncology) remained low TM adopters due to the inherent proximity of their patients. Clinics that maintained high TM rates were able to see more patients farther away. For the clinics that reverted back to >50% in-person visits, the visits that remained TM may have been for patients who live farther away. This may suggest that patients were more willing to travel to an in-person encounter when the distance, and corresponding burdens of travel and time, was less. Conversely, in the high TM adopters and remaining TM visits in the reverter group, the potential disadvantages of TM (unfamiliarity, technology, and accessibility needs) may have been outweighed by the convenience and option to not travel. Patients in rural counties have been shown to be more likely than their urban counterparts to use TM for pediatric rheumatology care (17), high risk obstetrics (18), and otolaryngology (19); similarly, TM for pediatric neurosurgery care has been shown to be feasible and save families substantial travel time, travel cost, and time away from work (20). Among pediatric Medicaid beneficiaries, TM use is more likely in rural children (12). In addition, rural pediatricians have also expressed enthusiasm about telehealth strategies to improve access to subspecialty care (21).

Provider/institutional factors, such as wait time, also may influence long-term TM adoption (22). As we embarked on evaluating the changes in TM adoption in our subspecialty clinics, we hypothesized that clinics with longer wait times may be more likely to continue with TM to help improve access to care. In our data, subspecialties that were high TM adopters had longer times between referral to first visit than low TM adopters. This suggests that subspecialties with a longer average wait time to be seen were more inclined to transition to TM and sustain TM appointments beyond May 2020. As TM can maximize usage of physical space and provider productivity, it is logical that institutions may prioritize digital health as an avenue to increase access, especially in those subspecialties with more constrained schedules. Alternatively, the finding that high TM adopters had longer times between referral to first visit may indicate that patients were willing to transition to TM rather than cancel or reschedule a long-awaited appointment in these subspecialties.

Provider willingness to adopt and sustain TM, providers' comfort with resuming in-person visits, adaptability of scheduling algorithms, technical readiness, and other factors not captured in the presented data should also be considered (23). Our institution was fortunate to deploy a multi-lingual TM platform within our EHR-embedded patient portal across subspecialties and had institutional on-demand technical support and training for TM encounters. The method by which appointments were converted from in-person to TM was variable by pediatric specialty. Scheduling algorithms and call centers differ between subspecialties at our institution, making access a significant potential confounder to TM adoption between subspecialties.

There are likely inherent differences in the clinical encounters of different subspecialties which strongly influenced TM adoption. These include visits with a linked or connected service or study, specific physical examination techniques or perceived reliance upon the physical examination (e.g., slit lamp exam for ophthalmology, joint exam for rheumatology), proportion of patients with high-risk diagnoses (oncology, stem cell transplant), and the appropriateness and ratio of new vs. established encounters. At our institution, high TM adopters were non-surgical subspecialties with the exception of liver transplant (which includes a large number of pre-transplant and post-transplant medical visits and has a long-standing TM program for patients, local physicians, and transplant coordinators). In our early experience, those patients needing a linked or connected service, such as the cardiology patient needing an echocardiogram or the hand surgery patient needing an x-ray, had lower utilization of TM appointments. In addition, those specialties that rely heavily on the physical examination were slower to adopt the TM platform. Adoption in rheumatology and otolaryngology TM visits were seemingly born out of necessity—both specialties had very few or no TM encounters prior to the COVID-19 pandemic, because the physical exam is crucial to decision making. Within otolaryngology, there may be subspecialties that are more amenable to TM, such as the evaluation of tonsillar hypertrophy which can be visualized with basic video tools, rather than middle ear pathology, which requires specialized equipment for examination.

There are several limitations to the presented data, most notably in aspects of healthcare delivery which are not included in our dataset. Analysis of the in-person visits before and during the study period, as well as the visit types (new vs. established) would be helpful to provide granularity and examine the influence of encounter types on TM adoption. There may be a baseline difference between subspecialties in the proportion of new vs. established visits offered via TM. Unfortunately, subspecialty clinics have significant variability in differentiating between new and follow-up encounters, so we were unable to account for these differences. Moreover, by using visit-level data in our analysis, there will be a natural representation bias, skewing the demographic data toward patients who had multiple visits via TM (although as we show in our results, the 123,416 TM visits from March 2020 to November 2020 represented 72,819 unique patients). Our categorization schema for low vs. high TM adoption relies on a simple majority, as definitions of operationally or clinically significant rates of TM adoption are currently lacking. In the analysis of distance to clinic, a linear distance was used between the patient's zip code and Stanford, CA. This approach should be treated as a rough approximation as it does not reflect estimated driving time and is calculated by zip codes which cover larger geographies in rural areas. Importantly, we do not discuss any patient preference or patient experience data, and how that may have influenced TM rates over the course of the year. Early data from our institution suggests there are novel concerns in patient acceptability of pediatric TM experiences, such as the role for the caregiver (24). Similarly, provider experience data and no-show/late cancellation data by subspecialty would be necessary in developing a robust TM program. With regards to clinical appropriateness, we do not have any data on conversions to in-person visit or admission within an interval of the TM visit, which could be indicative of duplicative care or an inappropriate initial triage to TM. In some instances, TM was used in triage to determine if an in-person visit was necessary despite shelter-in-place guidance. In short, the data presented may be beneficial in delineating which subspecialties are best suited to developing sustained TM programs and exploring factors driving TM persistence, but it cannot robustly determine whether the clinical goals of patient care and patient/provider experiences are being met.

There has undoubtedly been progress in TM and digital health in pediatric subspecialty care driven by adaptation to the constraints of the COVID-19 pandemic. To solidify this progress, institutions must further define goals for TM adoption for each subspecialty to address. Some aspects may be consistent across subspecialties, such as ensuring equity in access for patients of all languages and socioeconomic backgrounds or defining criteria for essential in-person visits. Other aspects of TM adoption may be subspecialty specific, such as how to handle reliance upon physical examination or the need for a connected services (25). Subspecialty programs with low TM adoption may look toward innovations to help overcome barriers, such as a digital stethoscope in cardiology, but this should be done in the context of overall appropriateness of TM to the subspecialty and the patients it serves. High TM adopters may also benefit from re-evaluating the patient populations, diagnoses, and experiences of their patients to better design workflows and fine-tune clinical encounters for TM. Overall, clinical appropriateness criteria for TM and in-person visits will need to be validated prospectively. This could help guide an institutions' approach to ambulatory care models for pediatric subspecialty care models. By looking at these characteristics, a model could be created to predict volume and using some of these factors that may drive resource allocation for program development. By continually analyzing patient-based and systems-based data, we can optimize the positive impact of TM across pediatric subspecialty care.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

JX: concept, data retrieval, data analysis, data interpretation, review and editing of manuscript, and final approval of manuscript. PP: concept, data interpretation, and final approval of manuscript. TL: concept, data retrieval, data interpretation, and review and editing of manuscript, and final approval of manuscript. LS: concept, data interpretation, and final approval of manuscript. KM: concept, data retrieval, data analysis, data interpretation, drafting of initial manuscript, review and editing of manuscript, and final approval of manuscript. All authors contributed to the article and approved the submitted version.

ACKNOWLEDGMENTS

The authors acknowledge the expertise of Lisa J. Chamberlin, MD, MPH, for her guidance and feedback regarding social determinants of health as related to telehealth access in pediatric subspecialty care.

REFERENCES

1. Latifi R, Doarn CR. Perspective on COVID-19: Finally, Telemedicine at Center Stage. *Telemed J E Health.* (2020) 26:1106–9. doi: 10.1089/tmj.2020.0132
2. Keesara S, Jonas A, Schulman K. Covid-19 and health care's digital revolution. *N Engl J Med.* (2020) 382:e82. doi: 10.1056/NEJMp2005835
3. Telemedicine in the Era of COVID-19-ClinicalKey. Available online at: https://www.clinicalkey.com/#!/content/playContent/1-s2.0-S221321982030249X?returnurl=null&referrer=null (cited May 23, 2020).
4. Olson CA, McSwain SD, Curfman AL, Chuo J. The current pediatric telehealth landscape. *Pediatrics.* (2018) 141:e20172334. doi: 10.1542/peds.2017-2334
5. Regelmann MO, Conroy R, Gourgari E, Gupta A, Guttmann-Bauman I, Heksch R, et al. Pediatric endocrinology in the time of COVID-19: considerations for the rapid implementation of telemedicine and management of pediatric endocrine conditions. *Horm Res Paediatr.* (2020) 93:343–50. doi: 10.1159/000513060
6. Cohen AJ, Shur N, Starin D, MacLeod E, Roshan Lal T, Leon E, et al. Pediatric medical genetics house call: Telemedicine for the next generation of patients and providers. *Am J Med Genet C Semin Med Genet.* (2021) 187:55–63. doi: 10.1002/ajmg.c.31882
7. Chaudhry H, Nadeem S, Mundi R. How satisfied are patients and surgeons with telemedicine in orthopaedic care during the COVID-19 pandemic? A Systematic Review and Meta-analysis. *Clin Orthop.* (2021) 479:47–56. doi: 10.1097/CORR.0000000000001494
8. Perzynski AT, Roach MJ, Shick S, Callahan B, Gunzler D, Cebul R, et al. Patient portals and broadband internet inequality. *J Am Med Inform Assoc.* (2017) 24:927–32. doi: 10.1093/jamia/ocx020
9. Gilson SF, Umscheid CA, Laiteerapong N, Ossey G, Nunes KJ, Shah SD. Growth of ambulatory virtual visits and differential use by patient sociodemographics at one urban Academic Medical Center during the COVID-19 pandemic: retrospective analysis. *JMIR Med Inform.* (2020) 8:e24544. doi: 10.2196/24544
10. Eberly LA, Kallan MJ, Julien HM, Haynes N, Khatana SAM, Nathan AS, et al. Patient Characteristics associated with telemedicine access for primary and specialty ambulatory care during the COVID-19 pandemic. *JAMA Netw Open.* (2020) 3:e2031640. doi: 10.1001/jamanetworkopen.2020.31640
11. Lagasse J. *Telehealth Laws and Regulations in 2019 Have Set the Stage for Increased Access and Use.* Healthcare Finance. Available online at: https://www.healthcarefinancenews.com/news/telehealth-laws-and-regulations-2019-have-set-stage-increased-access-and-use (cited Febuary 11, 2021).
12. Ray KN, Mehrotra A, Yabes JG, Kahn JM. Telemedicine and outpatient subspecialty visits among pediatric medicaid beneficiaries. *Acad Pediatr.* (2020) 20:642–51. doi: 10.1016/j.acap.2020.03.014
13. Ray KN, Ashcraft LE, Mehrotra A, Miller E, Kahn JM. Family perspectives on telemedicine for pediatric subspecialty care. *Telemed E Health.* (2017) 23:852–62. doi: 10.1089/tmj.2016.0236
14. Walker DM, Hefner JL, Fareed N, Huerta TR, McAlearney AS. Exploring the digital divide: age and race disparities in use of an inpatient portal. *Telemed E Health.* (2020) 26:603–13. doi: 10.1089/tmj.2019.0065

15. Nouri S, Khoong E, Lyles C, Karliner L. Addressing equity in telemedicine for chronic disease management during the Covid-19 pandemic. *NEJM Catal Innov Care Deliv.* (2020). doi: 10.1056/CAT.20.0123
16. Davidson E. *The Burdens of Aspiration: Schools, Youth, and Success in the Divided Social Worlds of Silicon Valley*. New York, NY: New York University Press (2011). 249 p.
17. Kessler EA, Sherman AK, Becker ML. Decreasing patient cost and travel time through pediatric rheumatology telemedicine visits. *Pediatr Rheumatol Online J.* (2016) 14:54. doi: 10.1186/s12969-016-0116-2
18. Whittington JR, Magann EF. Telemedicine in High-Risk Obstetrics. *Obstet Gynecol Clin North Am.* (2020) 47:249–57. doi: 10.1016/j.ogc.2020.02.007
19. Kokesh J, Ferguson AS, Patricoski C. The Alaska experience using store-and-forward telemedicine for ENT care in Alaska. *Otolaryngol Clin North Am.* (2011) 44:1359–74, ix. doi: 10.1016/j.otc.2011.08.010
20. Hayward K, Han SH, Simko A, James HE, Aldana PR. Socioeconomic patient benefits of a pediatric neurosurgery telemedicine clinic. *J Neurosurg Pediatr.* (2020) 25:204–8. doi: 10.3171/2019.8.PEDS1925
21. Ray KN, Demirci JR, Bogen DL, Mehrotra A, Miller E. Optimizing telehealth strategies for subspecialty care: recommendations from rural pediatricians. *Telemed E Health.* (2015) 21:622–9. doi: 10.1089/tmj.2014.0186
22. Hofstetter PJ, Kokesh J, Ferguson AS, Hood LJ. The impact of telehealth on wait time for ENT specialty care. *Telemed E Health.* (2010) 16:551–6. doi: 10.1089/tmj.2009.0142
23. Brophy PD. Overview on the challenges and benefits of using telehealth tools in a pediatric population. *Adv Chronic Kidney Dis.* (2017) 24:17–21. doi: 10.1053/j.ackd.2016.12.003
24. Pooni R, Pageler NM, Sandborg C, Lee T. Pediatric subspecialty telemedicine use from the patient and provider perspective. *Pediatr Res.* (2021). doi: 10.1038/s41390-021-01443-4
25. Tomines A. Pediatric telehealth. *Adv Pediatr.* (2019) 66:55–85. doi: 10.1016/j.yapd.2019.04.005

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Pediatrics

ORIGINAL RESEARCH
published: 23 April 2021
doi: 10.3389/fped.2021.648536

Check for updates

Implementation and Outcomes of a Telehealth Neonatology Program in a Single Healthcare System

Lory J. Maddox[1,2]*, *Jordan Albritton*[1,3], *Janice Morse*[2,4], *Gwen Latendresse*[2], *Paula Meek*[2] *and Stephen Minton*[5]

[1] Intermountain Connect, Intermountain Healthcare, Salt Lake City, UT, United States, [2] College of Nursing, University of Utah, Salt Lake City, UT, United States, [3] RTI International, Research Triangle Park, Durham, NC, United States, [4] University of Alberta, Edmonton, AB, Canada, [5] Neonatal TeleHealth Intermountain Healthcare, Salt Lake City, UT, United States

Background: Intermountain Healthcare, an early adopter and champion for newborn video-assisted resuscitation (VAR), identified a reduction in facility-level transfers and an estimated savings of $1. 2 million in potentially avoided transfers in a 2018 study. This study was conducted to increase understanding of VAR at the individual, newborn level.

Study Aim: To compare transfers to a newborn intensive care unit (NICU), length of stay (LOS), and days of life on oxygen between newborns managed by neonatal VAR and those receiving standard care (SC).

Methods: This retrospective, nonequivalent group study includes infants born in an Intermountain hospital between 2013 and 2017, 34 weeks gestation or greater, and requiring oxygen support in the first 15 minutes of life. Data came from billing and clinical records from Intermountain's enterprise data warehouse and chart reviews. We used logistic regression to estimate neonatal VAR's impact on transfers. Negative binomial regression estimated the impact on LOS and days of life on supplemental oxygen.

Results: The VAR intervention was used in 46.2 percent of post-implementation cases and is associated with (1) a 12 percentage points reduction in the transfer rate, $p = 0.02$, (2) a reduction in spoke hospital (SH) LOS of 8.33 h ($p < 0.01$) for all transfers; (3) a reduction in SH LOS of 2.21 h ($p < 0.01$) for newborns transferred within 24 h; (4) a reduction in SH LOS of 17.85 h ($p = 0.06$) among non-transferred newborns; (5) a reduction in days of life on supplemental oxygen of 1.4 days ($p = 0.08$) among all transferred newborns, and (6) a reduction in days of life on supplemental oxygen of 0.41 days ($p = 0.04$) among non-transferred newborns.

Conclusion: This study provides evidence that neonatal VAR improves care quality and increases local hospitals' capabilities to keep patients close to home. There is an ongoing demand for support to rural and community hospitals for urgent newborn resuscitations, and complex, mandatory NICU transfers. Efforts may be necessary to encourage neonatal VAR since the intervention was only used in 46.2 percent of this study's potential cases. Additional work is needed to understand the short- and long-term impacts of Neonatal VAR on health outcomes.

Keywords: telehealth, newborn, resuscitation, implementation, telemedicine, transfers, length of stay, video-assisted resuscitation

OPEN ACCESS

Edited by:
Mark Lo,
University of Washington,
United States

Reviewed by:
Daniele Trevisanuto,
University Hospital of Padua, Italy
Naveed Hussain,
University of Connecticut Health Center, United States

Correspondence:
Lory J. Maddox
lory.maddox@imail.org

Specialty section:
This article was submitted to Neonatology, a section of the journal Frontiers in Pediatrics

Received: *31 December 2020*
Accepted: *09 March 2021*
Published: *23 April 2021*

Citation:
Maddox LJ, Albritton J, Morse J, Latendresse G, Meek P and Minton S (2021) Implementation and Outcomes of a Telehealth Neonatology Program in a Single Healthcare System. Front. Pediatr. 9:648536. doi: 10.3389/fped.2021.648536

INTRODUCTION

Over 40 years ago, video technology was used to reduce newborn mortality and morbidity in high-risk maternal-newborn populations geographically separated from neonatologists (1). Over the past decade, the use and effectiveness of synchronous audio-video communications in pediatric care, newborn care, and support for newborn resuscitations has increased (2–4). Consumer demand, medical need, and federal reimbursement represent an acceptance of telemedicine and telehealth services (5–7). In the face of the overwhelming demand for telehealth services during the global pandemic, program evaluation becomes increasingly important despite the challenges of rapid cycle development, implementation, and success measures.

Telehealth video-assisted resuscitation (VAR) programs vary in implementation, and there is limited evidence of the impact of these programs. Three of the earliest VAR programs began in 2013. Randall Children's Hospital supported five low-risk maternity centers and participated in about two percent of all births (8, 9). The Mayo clinic also began using telehealth technology to support six spoke sites (10). Intermountain Healthcare conducted its first neonatal video consult in 2013. By early 2016, it had deployed the neonatal video consult service to over 16 hospitals in the Intermountain West.

Early in the implementation, NICU hub neonatologists and spoke sites shared anecdotal stories of successful VAR, preventing transfers, and increasing confidence in their ability to conduct a newborn resuscitation. This study was informed from early implementation success stories, Intermountain and UC Davis studies on reduced transfer rates, and improved resuscitation quality reported by Randall Children's Hospital and the Mayo Clinic (9, 11–13). This study's primary aim was to determine the influence of a neonatologist VAR on transfers to a NICU, birth facility length of stay, This study's primary aim was to determine the influence of a neonatologist VAR on transfers to a newborn intensive care unit (NICU), birth facility length of stay, and days of life on supplemental oxygen.

MATERIALS AND METHODS

In 2013, Intermountain piloted an innovative program to provide neonatal VAR to remote hospitals in Southwest Utah 54 and 118 miles away from the hub neonatal intensive care unit (NICU) in St. George, Utah. Over the next 3 years, this program was expanded to four NICU hubs and 16 spoke sites in Utah and its immediate borders. The Utah neonatal VAR project developed technical solutions, assessed clinical feasibility, conducted the implementation, and evaluated operational and clinical solutions. Two individuals on this paper were part of the implementation team, LM as operations manager and SM as neonatal telemedicine medical director.

Telehealth systems often operate with a "hub and spoke" model. In the case of Intermountain's newborn VAR program, the neonatologist staffed tertiary NICUs as the hub providing care via telehealth to smaller regional or community hospitals, the spokes. The newborn and family receive in-person care at the spoke facility. A single NICU hub will support multiple spoke hospitals as part of their regionalized maternal-newborn care system (14). This manuscript will refer to the NICUs as hubs, and local nursery's as the spokes.

Telehealth Equipment

Design considerations for the neonatal environment include the diversity of newborn warmers, incubator designs, and the limited space around a warmer–approximately 48 inches deep and 25 inches wide. No telehealth equipment could be permanently attached to newborn warmers since warmers are FDA-regulated devices and are frequently moved throughout nurseries and hospitals.

Telehealth equipment was internally developed by the Intermountain telehealth technology team using currently available technology. The telehealth equipment included a palm-size Axis pan-tilt-zoom camera, a dedicated computer, and a monitor secured to the newborn area headwall or used as a mobile telehealth workstation (**Figure 1**). Microsoft video conferencing applications were customized to allow room selection, remote audio-video controls, and role-based access. Synchronous audio-video consults were conducted on Intermountain's intranet and approved by compliance and information systems security teams.

Each NICU hub had at least two telehealth-enabled workstations. Hardwired synchronous audio-video conferencing equipment was installed in delivery rooms, cesarean section operating rooms, and nursery locations in spoke hospitals. A mobile solution involved a palm-sized Axis camera, a Dell All-In-One computer, and Intermountain's customized video conferencing software. This allowed clinicians at spoke sites to access neonatologists for telehealth consults for at-risk neonates anywhere in their facility. Once the neonatologist was notified about the baby's location, the neonatologist could initiate a video connection, remotely control the camera using pan-tilt-zoom features, and adjust the audio for the spoke site hospital and themselves. These design features allowed the spoke site clinicians to focus on the newborn resuscitation, not the telehealth technology solution.

Clinical Usability

Telehealth technologies were used to help spoke sites with simulation training, consults, and VAR, developing an early version of newborn resuscitation telemedicine program (NRTP) (5, 14–17). Clinical staff at spoke sites were asked to notify the neonatologists as early as possible, often before delivery, to allow time to establish a video connection. Indications for early notification for neonatologists were drawn from obstetrical high-risk categorization for mothers and fetuses (17, 18). Early notification provided time for neonatologists at the hub site to establish a video connection with the spoke site, discuss, and prepare clinical staff for the neonate's birth just as they would in an in-person delivery.

Systemwide implementation began after clinical feasibility, standardized telehealth equipment, and workflows had been established. At the end of 2016, there were 126 newborn

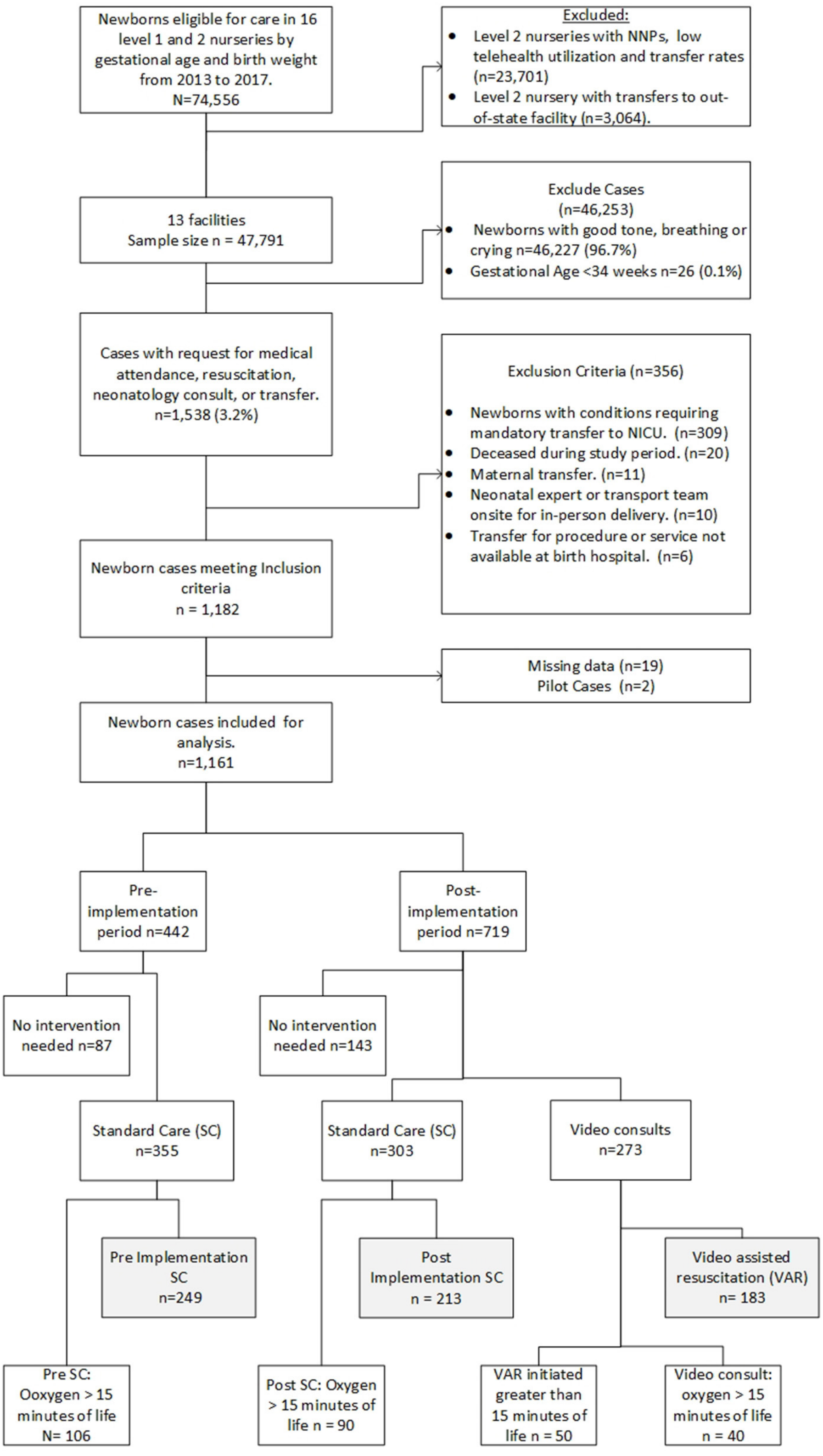

FIGURE 1 | Sample collection.

telehealth in-room solutions and 14 mobile carts for newborn VAR; consults were being conducted at 16 spoke site locations. Hub site NICUs had at least two telehealth workstations to ensure that neonatologists had easy access to support emergent events.

STUDY DESIGN

In this retrospective, non-equivalent, pre-post telehealth implementation study, we analyzed a subset of newborns with no mandatory previously determined transport requirements. The study sample includes newborns with a gestational age of at least 34 weeks with oxygen administered within the first 15 min of life, born between 2013 and 2017. The newborns had a telephone or video neonatology consult or were transferred to a tertiary and quaternary NICU. Records obtained from the enterprise data warehouse (EDW) did not always include a scanned document indicating "resuscitation," so manual chart review was completed. Chart reviews included minutes of life to oxygen administration, VAR or standard care, and days of life on supplemental oxygen.

Initiation of oxygen, resuscitation measures, or transfers were based upon medical necessity. These are clinical decisions not based on parental concern or ability to pay for services. Therefore, randomization to a control group is not possible. Intermountain Healthcare and the University of Utah Institutional Review Board approved this study.

Data Collection and Analysis

Three groups were identified during data abstraction and initial analysis. Group 1 ($n = 183$) includes VAR conducted by the neonatologist after program implementation. Group 2 ($n = 213$) consisted of post-implementation standard care (SC) when neonatology consults were via telephone. Group 3 ($n = 249$), consisted of SC pre-implementation period. Two of the 16 spoke sites were excluded due to low telehealth and transfer rates. A third spoke site was excluded because newborns were transferred to an out-of-state NICU where follow-up chart review is not possible. Newborn diagnoses codes were used to exclude newborns with conditions requiring a mandatory transport to a quaternary or tertiary NICU. Additional exclusion criteria include newborns deceased during the study period, newborns transferred for maternal transports, newborns managed by in-person neonatology advanced practice practitioners, neonatologists, or transport team present at delivery, or mandatory transfers for service or procedure not available at the birthing hospital (**Figure 2**). Exclusion criteria were applied to generate a more homogenous population for this study. Additionally, we excluded cases ($n = 50$) where the VAR began more than 15 min after birth; in these cases, it was decided that it was unlikely that the neonatologist would have a significant impact on the resuscitation event. We conducted a sensitivity analysis to test the results and included cases with VAR >15 min of life.

All newborns were born in an Intermountain facility. Therefore, data from maternal and neonatal billing codes, diagnoses, clinical event data, and newborn gestational age, weight, gender, and Apgar scores were available to the researchers from the electronic medical record (EMR) and the EDW. Data on type of neonatology consult, minutes of life oxygen administered, and days of life on supplemental oxygen were abstracted from chart reviews, recorded in REDCap, and stored in a password-protected database. Consult types were determined from billing data and verified during chart review. Transfers and LOS data was determined from clinical events recorded in the EDW. Data discrepancies between billing data and chart review were reconciled after reviewing with the research team. A master data set combined all data sources.

Statistical Analysis

We summarized characteristics for newborns with oxygen initiated in the first 15 min of life ($n = 645$) and the maternal and newborn diagnoses for the study population. All t-tests and p values are bivariate and presented for informational purposes only. There was no statistical difference in gestational age, weight, and gender for the newborns between the study groups. All newborns in this study had a 1-min Apgar score of <7. The mean 1-min Apgar score was 4.1 with a standard deviation of 2.4 in the VAR group and was significantly lower than the post-implementation SC group (mean = 5.0, SD 2.6), $p < 0.001$, and pre-implementation SC group (mean = 4.7, SD = 2.9) $p = 0.03$ (**Table 1** Newborn sample characteristics and **Table 2** Maternal and newborn diagnoses).

We used logistic regression to identify factors associated with a neonatology consult (**Table 3** Factors associated with neonatology consult before or within 15 min of birth). In this study, it was vital to parse neonatology VAR's effect, the independent variable, from the pre-and post-implementation period and confounding variables. Thus, in the main analyses, we controlled for factors significantly associated with early notification and other variables deemed important based on clinical expertise. Control variables included time (pre or post-implementation period, newborn gestational age, gender, multiple gestation, 1-min Apgar scores, maternal chorioamnionitis, pregnancy-induced hypertension, eclampsia, pre-eclampsia, hemorrhage, intrapartum abnormal fetal heart tones, newborn meconium, umbilical cord or placenta complications, and nursery level. All statistical tests are conducting with Microsoft ExcelPro 16.0 and Stata 15.1.

We used regression analyses to evaluate the impact of VAR on key outcomes. Because of the emphasis on the first few minutes, hours, and days of life, the data collected to evaluate clinical outcomes are not normally distributed. We used logistic regression to estimate the impact of VAR on transfer rates. Count variables were overdispersed, meaning the variance in the data is greater than the mean. Thus, we used negative linear regression to determine the neonatology VAR program's effects on newborn LOS and days of life on supplemental oxygen.

A pre-study statistical power analysis was performed for sample size estimation. The power analysis was based on data from an internal pilot study comparing the overall length of stay rates between pre-and post-implementation of the VAR program. The pilot study's effect size was 0.19, considered a small effect size, and was based on nursery level and newborns' gestational age but did not account for maternal or newborn risk factors. The sample

FIGURE 2 | Wall mounted newborn telehealth station at spoke site.

TABLE 1 | Newborn sample characteristics.

	Post-implementation			Pre-implementation	
	Video assisted resuscitation ($n = 183$)	**Standard care ($n = 213$)**	***P***	**Standard care ($n = 249$)**	***P***
Gestational age, mean (SD)	38.2 (2.01)	38.1 (2.0)	0.58	38.4 (1.8)	0.40
Gestational age category, *n* (%)[A]			0.36		0.07
34 0/7–35 6/7 weeks	32 (17.5)	40 (15.2)		26 (10.4)	
36 0/7–37 6/7 weeks	39 (21.3)	73 (27.8)		75 (30.1)	
38 0/7–39 6/7 weeks	73 (39.9)	90 (34.2)		95 (38.2)	
40 weeks or greater	39 (21.3)	60 (22.8)		53 (21.3)	
Birth weight (grams)					
Mean (SD)	3,145 (599)	3,116 (587)	0.62	3,211 (510)	0.23
Gender			0.51		0.11
Female	62 (33.9)	97 (36.9)		103 (41.4)	
Male	121 (66.1)	166 (63.1)		146 (58.6)	
APGAR, mean (SD)					
1 min[B]	4.1 (2.4)	5.0 (2.6)	<0.001	4.7 (2.9)	0.03
5 min[B]	6.7 (1.8)	6.8 (1.9)	0.75	6.7 (2.2)	0.99
10 min[C]	7.4 (1.4)	7.4 (1.6)	0.64	7.3 (2.0)	0.85

Results from t-tests with the assumption of unequal variances unless otherwise specified.
[A]*Fishers exact test for categorical variables.*
[B]*VC, $n = 180$, Pre-UC, $n = 246$.*
[C]*VC, $n = 74$, Post-UC, $n = 95$, Pre-UC $n = 132$.*

size for this study was determined to be 565 cases with an alpha = 0.05, power = 0.80, a two-sided t-test.

RESULTS

In the logistic regression model, the VAR group had a significant decrease in the transfer rate of 12 percentage points, $p = 0.02$, SE = 0.05. For all transfers, the neonatology VAR intervention was associated with decreased LOS of 8.33 h, $p < 0.001$, SE = 1.3. For newborns remaining at the spoke facility, VAR was associated with a LOS reduction of 17.9 h, $p = 0.06$, SE = 9.5. For newborns transferred within 24 h, VAR was associated with a reduced LOS by 2.21 h, $p < 0.01$, SE = 0.60.

Neonatal VAR influenced days of life on supplemental oxygen. For newborns transferred to a NICU, neonatal VAR was associated with a reduction in days of life on supplemental oxygen by 1.41 days, $p = 0.08$, SE = 0.80. Newborns that were not transferred spent an average of 9.84 h less (0.41 days), $p = 0.04$, SE = 0.20, than the standard care groups.

(**Table 4** VAR influence on transfers, birth facility length of stay, and days on supplemental oxygen).

The sensitivity analysis, including 50 additional cases with VAR conducted later than 15-min of life, produced similar results to those just reported. The VAR group transfer rate increased to 14 percentage points, $p < 0.01$, SE = 0.04. For all transfers, the neonatology VAR intervention was associated with decreased LOS of 7.03 h, $p < 0.001$, SE = 1.24. For newborns remaining at the spoke facility, VAR was associated with a LOS reduction of 16.71 h, $p = 0.07$, SE = 9.05. For newborns transferred within 24 h, VAR was associated with a reduced LOS by 1.74 h, $p < 0.01$, SE = 0.58.

For newborns transferred to a NICU, neonatal VAR was associated with reduced days of life on supplemental oxygen by 1.39 days, $p = 0.76$, SE = 0.07. There was no change in days of life on supplemental oxygen for newborns remaining at the spoke site.

DISCUSSION

Intermountain Healthcare's neonatology service was an early adopter and champion for VAR. This program was implemented to provide expert support for high-risk births and post-delivery care to reduce unnecessary transfers (15). Guidelines to request additional medical assistance from an on-call pediatrician or another qualified medical provider were in place before the neonatology VAR program. During program implementation, spoke sites were encouraged to follow existing guidelines to request on-call medical attendance. Once the on-call provider was notified, the neonatologists would be called for an anticipated VAR. Frequently, the neonatology video consult would be established before the in-person medical provider's arrival. Establishing a video connection before birth allowed the neonatologist to receive a report, anticipate clinical scenarios, review resuscitation protocols, and emergency resuscitation equipment with the spoke site team (5, 15, 19).

In this study, acute maternal diagnoses of chorioamnionitis, pregnancy-induced hypertension, eclampsia, pre-eclampsia, hemorrhage, intrapartum abnormal fetal heart tones, and fetal meconium, umbilical cord, or placenta complications were most frequently associated with a request for a neonatology VAR before or within 15 min of birth. An acute maternal, intrapartum, or fetal event's urgency may explain the higher frequency of these

TABLE 2 | Maternal and newborn diagnoses.

	Post-implementation			Pre-implementation	
	VAR (*n* = 183)	SC (*n* = 213)	*P*	SC (*n* = 249)	*P*
Maternal diagnoses, *n* (%)					
Chorioamnionitis	59 (32.2)	39 (18.3)	<0.001	58 (23.3)	0.04
Infection	24 (13.1)	26 (12.2)	0.95	9 (3.6)	<0.001
Hypertension, Pregnancy induced, Pre-eclampsia, eclampsia	45 (24.6)	30 (14.1)	<0.01	42 (16.9)	0.05
Mood and anxiety disorders	24 (13.1)	34 (16.0)	0.69	31 (12.5)	0.84
Diabetes mellitus (gestational, type 1 and 2)	17 (9.3)	30 (14.1)	0.56	29 (11.7)	0.05
Metabolic disorders other than diabetes	21 (11.5)	27 (12.7)	0.82	95 (38.2)	<0.001
Anemia or blood disorders	17 (9.3)	13 (6.1)	0.28	21 (8.4)	0.76
Obesity	8 (4.4)	18 (8.5)	0.15	17 (6.8)	0.27
Respiratory Disorders	6 (3.3)	12 (5.6)	0.49	20 (8.0)	0.03
Substance Abuse	5 (2.7)	9 (4.2)	0.30	5 (2.0)	0.63
Uterine bleeding, complications of labor	11 (6.0)	4 (1.9)	0.04	8 (3.2)	0.18
Fetal diagnosis, *n* (%)					
Multiple Gestation	27 (14.8)	20 (9.4)	0.11	8 (3.2)	<0.001
Small for dates	13 (7.1)	22 (10.3)	0.25	68 (27.3)	<0.001
Large for dates	14 (7.7)	15 (7.0)	0.82	6 (2.4)	0.09
Polyhydramnios	7 (3.8)	7 (3.3)	0.81	4 (1.6)	0.30
Oliogohydramnios	1 (0.6)	4 (1.9)	0.22	5 (2.0)	0.38
Intrapartum diagnosis, *n* (%)					
Abnormal fetal heart tracings	67 (36.6)	53 (24.9)	0.01	66 (26.5)	0.03
Abnormal presentation	57 (31.2)	46 (21.6)	0.03	42 (16.9)	0.00
Nuchal cord	50 (27.3)	44 (20.7)	0.12	54 (21.7)	0.18
Meconium associated with birth	40 (21.9)	28 (13.2)	0.02	43 (17.3)	0.24
Umbilical cord complications	18 (9.8)	17 (8.0)	0.52	59 (23.7)	0.00
Instrumental delivery	8 (4.4)	6 (2.8)	0.41	12 (4.8)	0.83
Placenta Previa, abruption, hemorrhage	16 (8.7)	8 (3.8)	0.04	16 (6.4)	0.38
General anesthesia	1 (0.6)	2 (0.9)	0.65	1 (0.4)	0.83
Narcotic use within four hours of delivery	1 (0.6)	3 (1.4)	0.38	3 (1.2)	0.46
Newborn diagnosis, *n* (%)					
Respiratory	146 (79.8)	166 (77.9)	0.65	181 (72.7)	0.09
Sepsis, actual, and rule-out	71 (38.8)	66 (31.0)	0.11	71 (28.5)	0.03
Fluid, electrolyte, and metabolic imbalances	58 (31.7)	59 (27.7)	0.39	63 (25.3)	0.15
Hypoxia	46 (25.1)	57 (26.8)	0.71	50 (20.1)	0.22
Pneumothorax	14 (7.7)	13 (6.1)	0.54	34 (13.7)	0.04
Cardiovascular disorders – other than congenital	17 (9.3)	18 (8.5)	0.77	36 (14.5)	0.09
Emphysema	–	2 (0.9)	0.15	34 (13.7)	<0.001
Abnormal movements, seizure assessment	6 (3.3)	9 (4.2)	0.62	31 (12.4)	0.001
Pneumonia	7 (3.8)	13 (6.1)	0.30	22 (8.8)	0.03
Hypoglycemia	18 (9.8)	24 (11.3)	0.64	20 (8.0)	0.52
Hypovolemia	22 (12.0)	17 (8.0)	0.19	14 (5.6)	0.02

diagnoses in the VAR group. Ideally, these mothers would be transferred before birth to a regional maternity center equipped to manage these high-risk patients. However, maternal transfers are not possible when mothers with these conditions present to community and rural hospitals in advanced labor. Neonatal VAR acts as a safety net for these high-risk newborns by providing similar standards of care as the NICU hub (15, 20). Chronic maternal conditions such as hypertension, diabetes, or mood and anxiety disorders were higher in the post-implementation, standard care group. Pediatricians and family practice clinicians may feel more comfortable managing these patients without neonatal expert support at birth.

Outcomes

Transfers, spoke site LOS, and days on supplemental oxygen were used as outcome measures to evaluate this neonatal VAR

TABLE 3 | Control factors for regression analyses.

	AME[A]	SE[B]	95% CI		*P*
			LL	UL	
Post implementation (Time period)	0.48	0.03	3.38	5.48	<0.001
Maternal factors					
Chorioamnionitis	0.11	0.04	0.29	1.29	<0.01
Infection	−0.03	0.33	−0.69	0.63	0.93
Hypertension, Pregnancy-induced, Pre-eclampsia, eclampsia	0.11	0.04	0.23	1.34	<0.01
Uterine bleeding, complications of labor	0.97	0.63	−0.25	2.20	0.12
Fetal factors					
Multiple gestation	0.11	0.05	0.10	1.46	0.02
Intrapartum factors					
Abnormal fetal heart tracing	0.05	0.03	−0.14	0.79	0.18
Meconium associated with birth	0.06	0.04	−0.17	0.99	0.17
Umbilical cord complications	0.06	0.05	−0.28	1.13	0.23
Placenta Previa, abruption, hemorrhage	0.09	0.06	−0.24	1.57	0.14
Newborn factors					
Gestational age	0.01	0.01	−0.08	0.18	0.47
Apgar, 1 min	−0.02	0.01	−0.24	−0.06	<0.01

Number of observations = 639.
[A]Average marginal effects.
[B]Standard error.

TABLE 4 | VAR influence on transfers, birth facility length of stay, and days on supplemental oxygen.

Outcome metrics	Number of observations	AME	SE	*P*
Percentage point reduction in transfers*	639	−0.12	0.05	0.02
Reduced LOS in hours for all transferred newborns	311	−8.33	1.33	<0.01
Reduced LOS in hours for newborns remaining at the birthing facility	328	−17.85	9.47	0.06
Reduced LOS in hours for newborns transferred within 24 h	273	−2.21	0.60	<0.01
Reduced days on supplemental oxygen, transferred	216	−1.41	0.80	0.08
Reduced days on supplemental oxygen, not transferred	303	−0.41	0.20	0.04

Linear regression was used to assess the effect of the VAR intervention on these outcomes unless noted otherwise.
*All models used the same control factors listed in **Table 3**.*
**Logistic regression analysis was used to determine transfer rates.*

program (19). Direct measurements of resuscitation quality were not available in the newborn record. We identified a relatively homogenous group of newborns and chose transfers, LOS, and days on supplemental oxygen outcomes as indirect measures of the influence of VAR on resuscitation quality. This study is one of the earliest to report LOS and days on supplemental oxygen for neonatal VAR interventions at spoke sites.

In this study, neonatal experts were called to assist with the most acute maternal, fetal, and newborn conditions. Although higher-risk newborns are represented in the VAR group, VAR is associated with fewer transfers and supports prior studies that telehealth consults are associated with reduced transfer rates (11, 13). Additionally, VAR newborns transferred within the first 24 h of life had a LOS reduction of 2.21 h. A benefit of telehealth is that patients can be more efficiently triaged to the appropriate level of care when specialists are involved with their care (15, 21).

Reductions in days of life on supplemental oxygen were also associated with VAR. Results from a simulation study using video consults for pre-transport evaluation found that neonatologists used less invasive respiratory support, i.e., continuous positive airway pressure (CPAP) vs. intubation, for transport (22). Neonatologists' tendency to use non-invasive ventilation techniques may contribute to fewer days on supplemental oxygen in the VAR group. Neonatology support for pre-transport stabilization and preference for CPAP vs. intubation for mild to moderate respiratory distress may also account for shorter LOS at spoke sites.

The sensitivity analysis we conducted suggests that neonatal VAR gains are the most beneficial when the VAR occurs at birth or within the first 15 min of life. When the neonatal expert is waiting for birth, they can receive a report and prepare bedside teams for a high-risk birth. The benefits of an early VAR intervention and the opportunity for "just in time" education offset the 20 percent of all medical attendance requests at birth that did not require NRP interventions.

The informal training spoke sites receive from ongoing communication and relationships with neonatal experts helps build knowledge and skills acquired during NRP certification.

These ongoing synchronous audio-video interactions build upon existing telehealth-based simulation education and NRTP to improve clinical outcomes (11, 23–25). We were encouraged that our VAR rate was 46.2 percent, higher than the expected 34.5 percent rate reported by Fang et al. (26), reporting that 65.5 percent of users "did not use service because they did not have a clinical need." This study was not designed to explain why the spoke site chose (1) not to contact a neontologist for a VAR, (2) delay the consult until a transfer was required, or (3) why the NICU hub and spoke sites used the telephone. These questions deserve future study, especially in the post COVID-19 period, when telehealth is the only plausible alternative to in-person care. The rapid adoption and implementation of telehealth during the COVID-19 pandemic and improved outcomes demonstrated in this study may persuade medical providers to increase telemedicine usage (27).

Paradoxically, the combination of increased neonatal video consults and steady transfer rates in the UC group led to an overall increase in neonatal consults in the post-implementation period. When establishing a neonatal VC program for newborn resuscitation and initial stabilization, there may be a period of increased neonatology workload. A telehealth service introduces new technology, workflows, and uncertain demand. Sample selection for this study provides a guideline for estimating demand for future neonatal video consult programs. Considerations for estimating the frequency of neonatal VC include:

1. Pre-transport stabilization cases for all premature and required newborn transfers.
2. Cases in which medical attendance at birth was requested or newborn resuscitation measures were performed.
3. Current transfer rates.

Estimates for neonatal video consult programs should allow for a period of technology deployment, testing, education, and early program adoption when both standard care transfers and VAR overlap.

Limitations and Future Directions

This study's retrospective design limits this study with sample selection from a single healthcare system and newborns >34 weeks gestation requiring oxygen within the first 15 min of life. Differences in spoke sites were controlled by nursery level, not by the implementation date. Since implementation occurred over a 16-month timeline, early spoke sites had more time to use telehealth during this study period. We used regression modeling to control for confounding variables associated with non-randomized studies.

Due to technology limitations and retrospective chart review, it was not feasible to determine each video consult's length of time. We may be missing data in the pre-implementation period since neonatology consults were not always documented. In some instances, resuscitation events were reconstructed during chart review. VAR within 15 min of life was chosen as the cut-off period, with approximately 80 percent of all VAR occurring before or within the first 15 min of life. We recognize that there may not be a difference between a VAR at 14 or 16 min but had to establish the study population. Newborns with a VAR >15 min of life were not included in this study. However, they were included in the sensitivity analysis which produced similar results.

Randomized controlled trials are challenging in real-world clinical settings, especially when an intervention, VAR, reduces transfers, facilitates timely triage, reduces LOS, and reduces days on supplemental oxygen. When and where VAR is available, we must ensure equitable access to high-quality neonatology care regardless of geographical location (15). Future studies should include prospective, observational, and ethnographic studies that emphasize decision-making to activate neonatology support in the delivery room. Team building and communication skills are critical areas of decision-making and can be studied in a simulated or clinical setting. Telehealth fundamentally changes communication styles and perceptions when the specialist is visible to the entire spoke site team, parents, and loved ones in the delivery room. Video recording of newborn resuscitation events affords clinicians the opportunity for an objective review of their performance like an elite athletes' review of their performance and provides an opportunity for coaching. In addition to using outcomes for quality improvement, transfer, LOS, and days of life on supplemental oxygen can be quantified for payers, hospitals, patients, and communities to describe a comprehensive neonatal VAR and NRTP valuation.

CONCLUSION

Improvements in care processes and outcomes provide evidence that neonatal VAR improves care quality. Neonatal VAR also helps increase the capabilities of local hospitals and keeps patients in their communities. There is an ongoing demand for support to rural and community hospitals for urgent newborn resuscitation, and complex, mandatory NICU transfers. Still, efforts may be necessary to encourage the use of neonatal VAR as the intervention was only used in 46.2 percent of potential cases in this study. Additional work is needed to understand the short- and long-term impacts of Neonatal VAR on health outcomes.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Intermountain Healthcare and the University of Utah. Written informed consent from the participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

LM, JA, JM, and SM conceived this study. LM and JA obtained and analyzed the data and contributed equally to this work. GL, PM, and JM supervised this study and share senior authorship. SM is last author and medical director for this program. All authors read, edited, and approved the final manuscript.

FUNDING

Partial funding provided to LM by Intermountain Healthcare educational program and nursing research grant.

ACKNOWLEDGMENTS

This study and the research behind it would not have been possible without the expertise and support of the entire telehealth team at Intermountain Healthcare as well as mentoring by senior authors. This research was conducted to fulfill degree requirements and may appear in print as: Maddox, Lory J. (2020) An analysis of telehealth neonatology consults on neonate management in level 1 and 2 nurseries. [Dissertation]. [Salt Lake City (UT)]: University of Utah.

REFERENCES

1. Jones PK, Halliday HL, Jones SL. Prediction of neonatal death or need for interhospital transfer by prenatal risk characteristics of mother. *Med Care*. (1979) 17:796–806. doi: 10.1097/00005650-197908000-00002
2. McCauley K, Kreofsky BL, Suhr BL, Fang JL. Developing a newborn resuscitation telemedicine program: a follow-up study comparing two technologies. *Telemed e-Health*. (2019) 26:589–96. doi: 10.1089/tmj.2018.0319
3. Nadar M, Jouvet P, Tucci M, Toledano B. Impact of synchronous telemedicine models on clinical outcomes in pediatric acute care settings: a systematic review. *Pediatr Crit Care Med*. (2018) 19:e662–71. doi: 10.1097/PCC.0000000000001733
4. Tomines A. Pediatric telehealth: approaches by specialty and implications for general pediatric care. *Adv Pediatr*. (2019) 66:55–85. doi: 10.1016/j.yapd.2019.04.005
5. Donohue LT, Hoffman KR, Marcin JP. Use of telemedicine to improve neonatal resuscitation. *Children*. (2019) 6:E50. doi: 10.3390/children6040050
6. Fang J. *Telemedicine for Newborn Resuscitation*. (2017). doi: 10.1542/peds.141.1_MeetingAbstract.520
7. Sauers-Ford HS, Marcin JP, Underwood MA, Kim JH, Nicolau Y, Uy C, et al. The use of telemedicine to address disparities in access to specialist care for neonates. *Telemed e-Health*. (2018) 25:775–80. doi: 10.1089/tmj.2018.0095
8. Scheans P. Telemedicine for neonatal resuscitation. *Neonatal Netw*. (2014) 33:283–7. doi: 10.1891/0730-0832.33.5.283
9. Scheans P, McElwain L. Telemedicine for neonatal resuscitation. *J Obstetr Gynecol Neonatal Nurs*. (2015) 44:S23. doi: 10.1111/1552-6909.12696
10. Fang JL, Collura CA, Johnson RV, Asay GF, Carey WA, Derleth DP, et al. Emergency video telemedicine consultation for newborn resuscitations: the mayo clinic experience. *Mayo Clin Proc*. (2016) 91:1735–43. doi: 10.1016/j.mayocp.2016.08.006
11. Albritton L, Maddox L, Dalto J, Ridout E, Minton S. The effect of a newborn telehealth program on transfers avoided: a multiple-baseline study. *Health Aff*. (2018) 37:1990–6. doi: 10.1377/hlthaff.2018.05133
12. Colby CE, Fang JL, Carey WA. Remote video neonatal consultation: a system to improve neonatal quality, safety and efficiency. *Resuscitation*. (2014) 85:e29–30. doi: 10.1016/j.resuscitation.2013.11.003
13. Haynes SC, Dharmar M, Hill BC, Hoffman KR, Donohue LT, Kuhn-Riordon KM, et al. The impact of telemedicine on transfer rates of newborns at rural community hospitals. *Acad Pediatr*. (2020) 20:636–41 doi: 10.1016/j.acap.2020.02.013
14. *Toward Improving the Outcome of Pregnancy III*. Dimes M.o, editor (2010).
15. Olson CA, McSwain SD, Curfman AL, Chuo J. The current pediatric telehealth landscape. *Pediatrics*. (2018) 141:e20172334. doi: 10.1542/peds.2017-2334
16. Leone TA. Using video to assess and improve patient safety during simulated and actual neonatal resuscitation. *Semin Perinatol*. (2019) 43:151179. doi: 10.1053/j.semperi.2019.08.008
17. American College Obstetricians and Gynecologists. Levels of maternal care. *Am J Obstet Gynecol*. (2015) 212:259–71. doi: 10.1016/j.ajog.2014.12.030
18. American Academy of Pediatrics Committee on Fetus and Newborn. Levels of neonatal care. *Pediatrics*. (2012) 130:587–97. doi: 10.1542/peds.2012-1999
19. Makkar A, McCoy M, Hallford G, Escobedo M, Szyld E. A hybrid form of telemedicine: a unique way to extend intensive care service to neonates in medically underserved areas. *Telemed J E Health*. (2018) 24:717–21. doi: 10.1089/tmj.2017.0155
20. Hoffman AM, Bushey JA, Ocheltree TW, Smith MD. Historical perspectives: telemedicine in neonatology. *Neoreviews*. (2019) 20:e113–23. doi: 10.1542/neo.20-3-e113
21. Marcin JP, Shaikh U, Steinhorn RH. Addressing health disparities in rural communities using telehealth. *Pediatr Res*. (2016) 79:169–76. doi: 10.1038/pr.2015.192
22. Umoren RA, Gray MM, Schooley N, Billimoria Z, Smith KM, Sawyer TL. Effect of video-based telemedicine on transport management of simulated newborns. *Air Med J*. (2018) 37:317–20. doi: 10.1016/j.amj.2018.05.007
23. Escobedo MB, Shah BA, Song C, Makkar A, Szyld E. Recent recommendations and emerging science in neonatal resuscitation. *Pediatr Clin North Am*. (2019) 66:309–20. doi: 10.1016/j.pcl.2018.12.002
24. Beck JA, Jensen JA, Putzier RF, Stubert LA, Stuart KD, Mohammed H, et al. Developing a newborn resuscitation telemedicine program: a comparison of two technologies. *Telemed J E Health*. (2018) 24:481–8. doi: 10.1089/tmj.2017.0121
25. Makkar A, Siatkowski RM, Szyld E, Ganguly A, Sekar K. Scope of telemedicine in neonatology. *Chinese J Contempor Pediatr*. (2020) 22:396–408.
26. Fang, J. L., Asiedu, G. B., Harris, A. M., Carroll, K., and Colby, C. E. A Mixed-Methods Study on the Barriers and Facilitators of Telemedicine for Newborn Resuscitation. *Telemed J E Health*. (2018) 24:811–7. doi: 10.1089/tmj.2017.0182
27. Hollander JE, Carr BG. Virtually perfect? Telemedicine for covid-19. *N Engl J Med*. (2020) 382:1679–81. doi: 10.1056/NEJMp2003539

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Pediatrics

BRIEF RESEARCH REPORT
published: 19 May 2021
doi: 10.3389/fped.2021.638070

Rapid Implementation and Evaluation of Virtual Health Training in a Subspecialty Hospital in British Columbia, in Response to the COVID-19 Pandemic

Kasra Hassani[1*], *Theresa McElroy*[1,2,3], *Melissa Coop*[1], *Joelle Pellegrin*[1], *Wan Ling Wu*[1], *Rita D. Janke*[1] *and L. Kit Johnson*[1]

[1] Child Health British Columbia (BC), Provincial Health Services Authority, Vancouver, BC, Canada, [2] Department of Occupational Science and Occupational Therapy, Faculty of Medicine, University of British Columbia, Vancouver, BC, Canada, [3] British Columbia Children's Hospital Research Institute, Vancouver, BC, Canada

Introduction: Adoption of virtual health (VH) solutions in healthcare has been challenging; this changed rapidly after implementation of physical distancing measures due to the COVID-19 pandemic. In response to the pandemic, British Columbia's Children's and Women's sub-specialty hospitals rapidly trained and scaled up support to equip staff and clinicians to use VH.

Methods: Ninety-minute live online training workshops and frequently updated online support materials were offered for 6 weeks. Training was monitored *via* feedback collected at training sessions and a brief post-training survey. After training completion, a second survey was circulated to measure utilization outcomes and experiences with VH.

Results: Eight hundred and ninety-five participants representing 82% of staff requiring support were trained through 101 sessions; 348 (38.9%) and 272 (30.4%) responses were collected for the monitoring and outcome surveys, respectively. Overall, 89% agreed that training was relevant to their needs; participants indicated average 58.1% (SD = 26.6) and 60.6% (SD = 25.2) increase in knowledge and confidence in VH after training; 90.1% had booked or conducted VH sessions. Increase in confidence was more pronounced in participants with lesser previous exposure to VH, but number of sessions conducted post-training and percentage of successful sessions were independent of previous exposure. For future training and support, participants suggested subject-tailored trainings, asynchronous trainings, and availability of experienced users.

Discussion: Training is key to success of VH implementation. Moving forward, core competencies in VH should be developed to support standardization and allow for evaluation and quality improvement. Incorporation of VH training in continuous professional development and onboarding is also highly recommended.

Keywords: implementation, evaluation, telehealth, training, capacity building, virtual health

OPEN ACCESS

Edited by:
Mark Lo,
University of Washington,
United States

Reviewed by:
Kelly Schieltz,
The University of Iowa, United States
Tina Gustin,
Old Dominion University, United States

***Correspondence:**
Kasra Hassani
hassani.kasra@gmail.com

Specialty section:
This article was submitted to General Pediatrics and Pediatric Emergency Care, a section of the journal Frontiers in Pediatrics

Received: *05 December 2020*
Accepted: *06 April 2021*
Published: *19 May 2021*

Citation:
Hassani K, McElroy T, Coop M, Pellegrin J, Wu WL, Janke RD and Johnson LK (2021) Rapid Implementation and Evaluation of Virtual Health Training in a Subspecialty Hospital in British Columbia, in Response to the COVID-19 Pandemic. Front. Pediatr. 9:638070. doi: 10.3389/fped.2021.638070

INTRODUCTION

Despite a global movement toward digital technologies, adoption of virtual health (VH) solutions has been challenging and slow (1–4). This trend changed rapidly after the implementation of physical distancing measures due to the COVID-19 pandemic. VH became necessary for safe and timely patient care, and many barriers to its scale-up were overcome (5–8).

VH, also referred to as virtual care, telehealth, or telemedicine, is any non-face-to-face activity to deliver care. It encompasses both patient–provider and provider–provider encounters. The benefits of VH are especially pronounced during infectious disease outbreaks such as the COVID-19 pandemic, e.g., remote triaging, remote diagnosis, and consultations (7, 9, 10). However, the promise of VH includes opportunities such as (1) innovative health service delivery through virtual care technologies, e.g., virtual visits, digital messaging, remote or real-time monitoring; (2) providing care closer to home, e.g., local and regional health care teams, continuing education; and (3) increasing children's access to the output of research and technology. VH is considered a more patient-centered model, increasing access, offering comfort and convenience of being in the community, and reducing the cost and burden of travel to receive care (11, 12).

Implementing VH can pose numerous challenges. The health system's inertia toward new models of care, lack of technology infrastructure, regulatory and legal issues, lack of financial incentives, and low tech-literacy have historically slowed implementation of VH (2). Furthermore, despite recommendations for VH training and core competencies (13, 14), formal VH training programs are not widely established or studied (4, 9, 11, 15). For patients, lack of access to technology and connectivity, privacy and security concerns, and low tech-literacy hinder utilization of VH (11, 12, 16). Some of these challenges, such as reluctance and inertia, and to some extent financial incentives, have been overcome due to the necessity created by COVID-19; others remain, particularly addressing training and education needs (16).

In response to the COVID-19 pandemic and the British Columbia (BC) public health officer's call to stay at home, BC's Children's and Women's (C&W) hospitals rapidly implemented VH solutions and training across clinics and programs. Non-emergency patient visits ceased, while clinics rapidly trained and scaled up support to equip the staff and clinicians to use VH. This paper explores the development, implementation, and evaluation of the training module designed to support staff to use VH and offers lessons learned on development and implementation of VH for healthcare providers.

METHODS

Training Content

The live online training workshop included the following content: (1) introduction to VH, including definition, types, and advantages and disadvantages; (2) clinical requirements for conducting virtual sessions, such as confirming patient identity, ensuring privacy, appropriate etiquette, and documentation; (3) the operational procedures for scheduling a VH visit, including collecting informed consent before the visit; (4) equipment required and available, and how to test before a visit; (5) an introduction to the two VH platforms Skype for Business and Zoom for Healthcare, including how to schedule a visit, how to use the software platforms on desktop and mobile devices, and how to troubleshoot common audio and video issues during a visit. Training slides and online resource documents were available to the participants before the training. Content was updated during implementation as per feedback by participants, input from collaborators, or evolving context (e.g., software updates, new operational procedures).

Train-the-Trainer Model

Fifteen Child Health BC staff members, including 10 trainers, were redeployed from their primary roles and were trained to facilitate the live-online modules by the Child Health BC Manager of VH. Redeployed Child Health BC staff included provincial leads, research associates, and program coordinators and managers. All redeployed staff had 1–5 years previous experience in using VH platforms, although not necessarily for VH visits. Trainers practiced offering the training to one another. Those who joined the team later were trained by shadowing the live sessions followed by practice, and all had access to a training module lesson plan.

Training Implementation

The training initiative's format was (1) 90-min live-online training workshops including question-and-answer sessions and post-session follow-up when required, and (2) online support materials such as Frequently Asked Questions (FAQs) and How To's for various topics and audiences.

Training was delivered *via* Skype for Business. Several sessions were scheduled for each day. Each session had a maximum class size of 12, later increased to 18, to encourage opportunity for interaction and ensure that support could be provided. Participants needed to take the training session only once. Each session included a lead trainer who delivered the content, a technical support trainer who assisted participants with technical issues and monitored the chat box, and a scheduled on-call trainer who would step in in case of technical difficulties or sudden change in the schedule of one of the trainers.

The project was managed through an Agile approach (17) and the training team met daily to discuss progress, logistics, and to incorporate the recently collected feedback into the training content.

Recruitment

All C&W staff and clinicians who needed VH to continue patient care were encouraged to participate in the training; this included but was not limited to booking clerks, physicians, nurses, allied health staff, and nursing and administrative leads. Participants were invited to register *via* emails and reminders from their group leads and institutional communications.

Monitoring and Evaluation

Monitoring

Training quality was monitored through informal feedback collected from participants by trainers during the session and a short post-training survey administered to participants through REDCap (18). Feedback collected during the session included suggestions for improvement in terms of training scheduling, content, and delivery, and questions not already addressed in the training. The post-training survey included two Likert-scale statements "The training was RELEVANT to my learning needs" and "I have the KNOWLEDGE and SKILLS to be successful in supporting or conducting a virtual health visit," followed by two open-ended questions "What can we do to improve the training?" and "Please tell us of any additional support you need to support or conduct virtual health visits." Data collection took place from March 27 to May 8, 2020 inclusive and feedback was added to a master list to provide project coordinators with quick access. The training leadership team reviewed the feedback weekly and incorporated the needed changes. Urgent feedback was raised and discussed at daily team meetings.

Outcome Evaluation

Two weeks after training program completion, a follow-up REDCap survey was sent to all participants. Focusing on short-term outcomes after the training initiative, the survey asked about changes in knowledge and confidence in VH, frequency of engagement in VH activities since the training, barriers and facilitators of conducting virtual sessions, and perspectives for the future. Specifically, participants were asked "How much did your SKILLS/CONFIDENCE for utilizing Virtual Health for patient visits increase following the training?" and responded using a visual analog scale (VAS) ranging from 0 to 100 with response anchors including not at all (0), moderately (50), and greatly (100). The survey remained open for 2 weeks and one reminder was sent *via* email after the first week.

Data Analysis

Both quantitative and qualitative data were collected and analyzed. Quantitative data included responses to multiple-choice and VAS survey questions as well as overall administrative data. Quantitative data were analyzed using basic descriptive and inferential statistics in RStudio (19). Qualitative data included responses to open-ended questions in the monitoring and outcome surveys. To analyze the qualitative data, thematic analysis was applied to the dataset manually.

Privacy Statement

As their primary purpose was monitoring and evaluation of an ongoing initiative, the study was exempted from Research Ethics Board review. Both surveys were reviewed and approved by the Provincial Health Services Authority Privacy Office.

RESULTS

Live-Online Training

The training was live for 6 weeks. During this time, 10 trainers trained 895 participants through 101 training sessions; this represented 82% of C&W staff who required a VH solution to maintain care for patients. Class size varied between 1 and 20 (average = 8.8, SD = 4.5) with 2–6 daily sessions provided on weekdays.

Supporting Materials

The project team created a landing page on the Child Health BC website to consolidate resources for learners, which allowed one-stop access to resources.

Eighteen supporting documents were produced and uploaded to Child Health BC website categorized by platform and audience. Overall, the page was viewed 1,049 times over the training period and the documents were downloaded 544 times.

Monitoring

A total of 348 responses to the monitoring survey were collected throughout the training (38.9% response rate). Overall, 89.0% of the participants agreed or strongly agreed that the training was relevant to their learning needs and 84.4% indicated they had the knowledge and skills to successfully support or conduct a VH visit.

When possible, feedback was integrated in real time, e.g., updating content and FAQs for both platforms. Other feedback, such as the request for recorded sessions, was addressed over time or referred to partner organizations.

Results of the Short-Term Outcomes Survey

Demographics

A total of 272 responses were collected for the follow-up survey (response rate 30.4%). The participants came from diverse clinics on the C&W campus and included a range of roles, such as nursing leadership, direct care staff, allied health members, and physicians. The majority (75.5%) had used VH zero to five times in the year before training, and 40.6% had no previous experience. Less than 10% had previously used VH frequently (21 times or more).

Changes in Knowledge and Confidence in Using VH

Overall, the participants self-reported an average increase of 58.1% (SD = 26.6) in knowledge and 60.6% (SD = 25.2) in confidence after the training. **Figure 1** shows the self-assessed changes in knowledge and confidence for setting up and conducting VH sessions, separated by their previous use of VH in the year before the training. As can be seen in the boxplots, the increase was higher for participants with lesser previous exposure. This was more pronounced for confidence, compared with knowledge. Further analysis of the groups using one-way ANOVA shows that the difference in knowledge gained between groups was not statistically significant [$F_{(2,213)} = 2.879$, $p = 0.058$], but difference in confidence gained was significant [$F_{(3,217)} = 5.738$, $p = 0.00373$].

Training Usefulness and Future Directions

Overall, most participants found instructions on how to set up and conduct Zoom meetings helpful (75%), followed by clinical requirements for conducting VH sessions (44.5%). Suggestions for future training mirrored findings of the post-training monitoring survey, with top suggestions including trainings

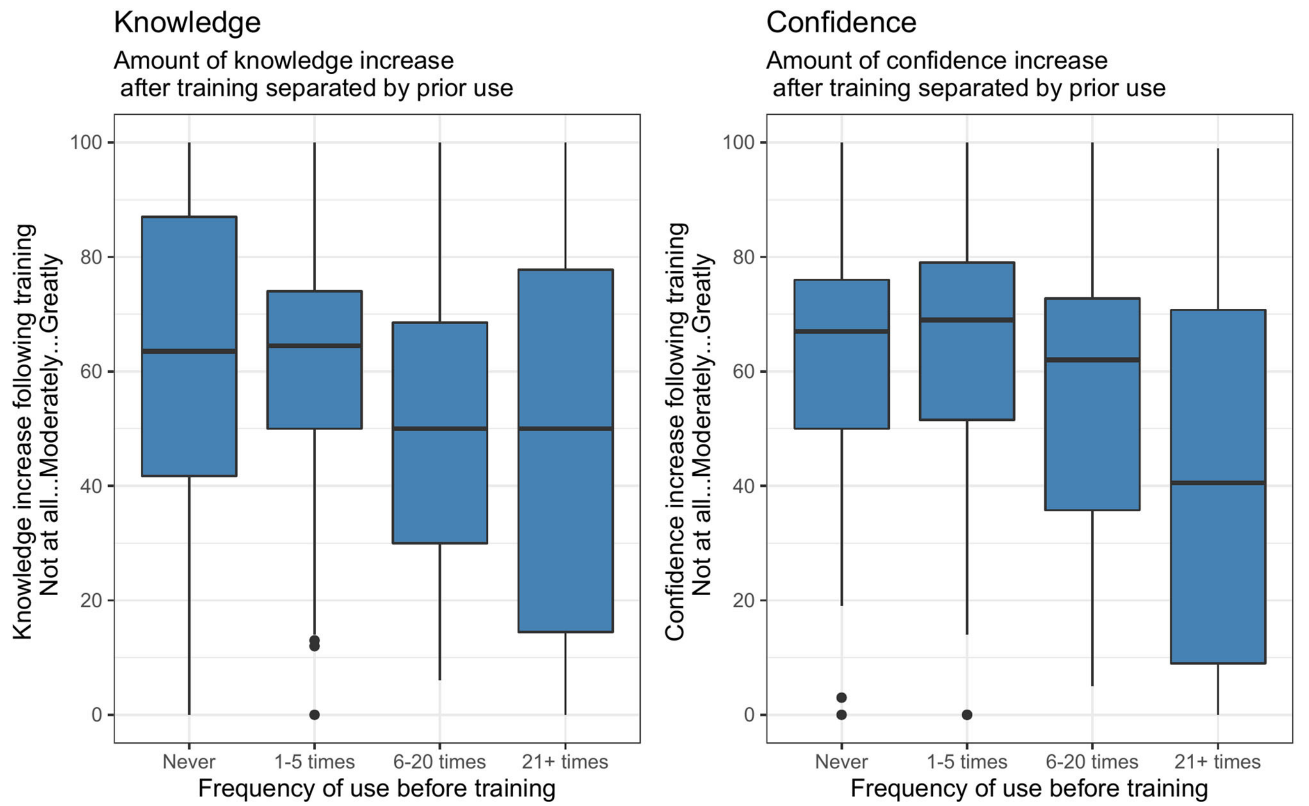

FIGURE 1 | Self-assessed changes in knowledge and confidence post-training, separated by frequency of use in the year before. Changes in knowledge and confidence were more pronounced in those who had had lesser exposure to VH.

tailored by subject (e.g., specific to Zoom, Skype for Business, or other foci like clinical requirements and procedures, booking, and how to use breakout rooms), trainings offered through differing learning modalities, identified super users who could provide continuous support, and live hands-on demonstrations. This was followed closely by asynchronous learning options, such as videos and online courses. In addition, when asked what support was helpful following the trainings, a number of participants mentioned in-person support and access to educational materials.

How the Participants had Used VH After the Training

In response to whether they had used VH in the past few weeks since the training, over 90% of the participants responded positively. This included booking (38.6%) or participating (72.8%) in virtual team meetings, and booking (38.6%) or conducting VH sessions (52.9%). Reasons for not using VH (9.9%) included not having technology or programs set up in clinic, or not being applicable (e.g., bedside nurse).

Among those who had used VH, Zoom was the most commonly used platform, followed by Skype for Business. Other platforms or systems used included telehealth, telephone, Microsoft Teams, doxy.me, and Blue Jeans.

Of the participants who had conducted VH sessions, the majority mentioned that most to all of their sessions were successful (**Table 1**). This was independent of the participants' previous exposure to VH (Fisher's exact test: $p = 0.8563$). Success was defined in the survey as the clinical goals of the session being achieved.

Majority (57.9%) of participants who had used VH post-training had booked or conducted between 10 and 100 sessions (**Table 2**). A smaller percentage (4.1%), including mostly participants who had taken the earlier training, had booked or conducted over 100. The interval between the training and the survey was between 2 and 8 weeks, depending on when the participants had taken the training. This therefore translates to 1–10+ weekly sessions. Previous exposure to VH did not have a significant relationship with number of sessions booked post-training (Fisher's exact test: $p = 0.1606$).

Success of the Sessions: Barriers and Facilitators

Most common facilitators and barriers to the success of the VH sessions are shown in **Figure 2**. Effective platforms, functioning devices, and buy-in from patients were the choices most commonly selected as reasons for success.

> *"Families were more available via video call than to come here from, for example, [remote town]. We reached families that we normally would not."*—Nurse

TABLE 1 | Estimated percentage of successful VH sessions for participants with different previous exposures to VH.

	Estimated percentage of successful VH sessions			
Frequency of using VH before training	0–40%	41–80%	81–100%	Not applicable
0–5 times	5 (2.8%)	48 (27.1%)	106 (59.9%)	18 (10.2%)
6–20 times	2 (4.7%)	15 (34.9%)	22 (51.2%)	4 (9.3%)
21+ times	0 (0%)	6 (27.3%)	13 (59.1%)	3 (13.6%)
Overall	**7 (2.9%)**	**69 (28.5%)**	**141 (58.3%)**	**25 (10.3%)**

Overall, participants mentioned that the majority of their sessions were successful. There was no statistically significant difference between the groups (Fisher's exact test: $p = 0.8563$, alternative hypothesis: two-sided).

TABLE 2 | Estimated number of sessions booked or conducted in the weeks following the training.

	Estimated number of sessions conducted or booked since the training			
Frequency of using VH before training	**0–9**	**10–100**	**100+**	**Many, I don't know**
1–5 times	50 (34.5%)	87 (60%)	5 (3.4%)	3 (2.1%)
6–20 times	11 (32.4%)	17 (50%)	2 (5.9%)	4 (11.8%)
21+ times	5 (33.3%)	8 (53.3%)	1 (6.7%)	1 (6.7%)
Overall	**66 (33.8%)**	**112 (57.9%)**	**8 (4.1%)**	**8 (4.1%)**

Previous exposure to VH did not have a significant relationship with number of sessions booked post-training (Fisher's exact test: $p = 0.1606$, alternative hypothesis: two-sided).

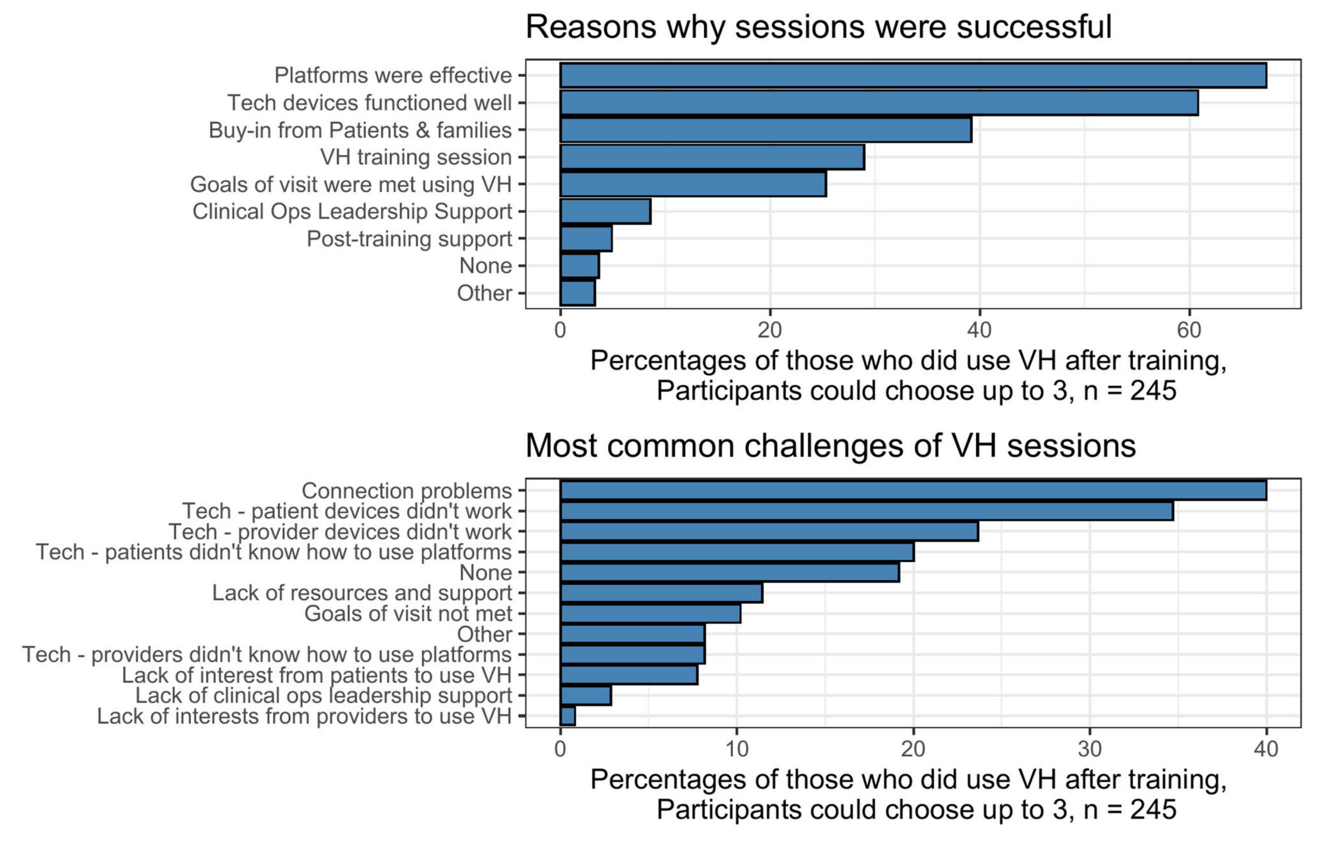

FIGURE 2 | Facilitators and barriers to the success of the VH sessions, as indicated by the participants.

Connection and technology problems were also the main challenges of the sessions. A number of participants also mentioned not having access to equipment, e.g., headphones.

> *"Not having phone/computer speakers available in all the clinic rooms."*—Nurse

A number of practitioners mentioned patient behavioral challenges, which made the session less effective.

> *"Client walking around, not staying in view, children sitting in front of camera even though it was an appointment to interview parents, no one wearing headsets in the house so tinny sounding sound… made for long and frustrating 90-minute experiences for me and added no value to my clinical work."*—Physician

Using VH in the Coming Six Months

Over half of the participants indicated that they expect to regularly use VH in the next six months. This was the case for all participants, regardless of how often they had used VH before (Fisher's exact test: $p = 0.1474$).

> *"It has been very positive for families and me. I think the training provided a good foundation. After that you just have to do it and learn as you go."*—Physician

DISCUSSION

Necessity is a powerful change agent. While the benefits of VH were known before the COVID-19 pandemic (11, 12), the pandemic prompted a rapid shift to VH that would have been highly unlikely in typical circumstances (5, 6, 16). In our context of a Children's and Women's health center, more than half of participants surveyed indicated they would use VH regularly in the next six months despite limited to no exposure to VH before the pandemic. VH became a necessity for the continuation of care.

Lack of provider and staff education has been a key barrier to large-scale adoption of VH (4, 9, 11, 15), and it needed to be addressed rapidly; therefore, our team developed and implemented a training program to support a new virtual model of care. Through its evaluation, opportunities were identified to optimize VH training moving forward. Training options tailored to user needs was a notable theme in the evaluation and should be factored in during curriculum development for continuing professional development (CPD). While we were unable to provide tailored training in the rapid implementation necessitated by the pandemic, it is a promising strategy to maximize efficiency and outcomes of training in time-restrained clinical contexts. The recommendations included platform-specific learning (e.g., Skype for Business vs. Zoom for Healthcare), function-focused (booking vs. clinical use), and skill level (entry vs. follow-up for experienced practitioners). It was also suggested that diverse approaches to training be offered—both synchronous (e.g., webinars, hands-on training with superusers) and asynchronous (e.g., videos, handouts, FAQs) to address differing needs, learning styles, and time availability. Embedding these trainings into the workplace and garnering leadership to support the necessity of CPD in VH were important factors for the high rates of training completion, which should be considered by planners.

One of the significant and immediate outcomes of training was the increase in confidence, a finding also noted by others (11, 20, 21). As might be expected, this was more pronounced with participants who had no previous exposure to VH. However, many indicated that despite gains in knowledge and confidence, they needed further practice. The pandemic context meant that the majority of the participants booked or conducted VH sessions in the relatively short period after the training. Knowledge and confidence were solidified by inevitably practicing through sessions, using the platforms, technical trouble-shooting, and in-house support. This practice has been shown to be important for developing specific skills in VH (4, 20, 22). This learning through direct experience in clinical sessions was perhaps more acceptable in the context of the pandemic, where it was widely acknowledged that everyone was navigating new territory to the best of their ability. Moving forward, building hands-on practice opportunities into CPD is highly recommended.

Most VH sessions post-training were rated as successful. The most prominent facilitators related to success included effectiveness of platforms, devices that functioned well, and buy-in from patients and families. Challenges were most often related to connectivity and technology, either on the provider or the patient end, matters that were beyond control of the parties. These findings regarding barriers and facilitators are not new (11, 12) but compared with former studies, there was a notable shift: fewer structural barriers such as access to platforms, security, leadership support, and reimbursement were noted. This is likely because these barriers were being addressed with an unprecedented speed by leadership and technical teams, a finding noted by other teams who implemented VH during the pandemic (6). Further, there were fewer attitudinal or provider-specific barriers (12); the pandemic context pushed acceptance as there was a wide practical recognition that VH was now necessary for patient care to safely continue.

This Quality Improvement (QI)–focused evaluation highlighted the importance of monitoring and evaluation of the transition to VH. Barriers were quickly identified and were addressed when possible. Future evaluation should include more objective measurements of training effectiveness and monitoring VH usage trends and "success" rates. Success of VH sessions requires definition. In our survey, we used "goals of the session were met;" this definition could become more elaborate to capture different dimensions of a VH visit, such as clinical goals, technological issues, communication, and importantly patient perspectives. Documentation of failed sessions provides foundation for QI. There is also a need for more research focused on effective approaches to VH training and education (4, 9).

Offering more support for patients and families was another important theme; this could include more accessible equipment (e.g., loan programs), working with stakeholders to improve connectivity for remote or vulnerable families, and training and support (e.g., phone-in support line) (16). Patient support resources have been shown to decrease preparation burden for practitioners (11, 13, 14). As part of core competencies, VH training should include how to familiarize patients with VH technology, such as through basic guidelines or checklists, and in addition, techniques to empower patients.

Future training should incorporate core competencies to standardize care delivery through VH and allow for QI (4, 8, 9, 11, 13–15). Such core competencies have been developed in fields such as nursing (8, 13), emergency medicine (14), and behavioral health (23). Core competencies were not covered in detail in our training due to the rapid nature of the project, but should be included in future work. Others have also pointed out the need for curriculum development on regulation of VH, such as policies, procedures, protocols, etiquette, and ethics (8, 13, 15, 22). It is recommended that these curricula should be based on existing competency-based outcome-oriented frameworks such as CanMEDS (24). We also need to consider how to effectively assess VH competency in staff (25), and then provide tailored education and support as part of onboarding and maintenance. This ensures that practice continues to develop and evolve alongside our rapidly changing world.

LIMITATIONS

Data used in this evaluation were from cross-sectional self-report surveys, and therefore are subject to common biases of survey data, such as response bias and confirmation bias. We believe that due to the relatively high response rate (30%), the risk of non-response bias is low. The data are a snapshot in time and have not measured any across-time changes and trends. Finally, the results have not been substantiated with objective data such as number of VH sessions booked and the input from patients and families has not been captured. We aim to address these measurement limitations in future work.

CONCLUSION

The initiative was successful in rapidly preparing staff and providers to provide VH at the onset of the COVID-19 pandemic, where VH use became a necessity. Next steps should include focus on the development of core competencies, diversifying training modalities, incorporation of VH education into onboarding and continuous professional development, and rigorous evaluation.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

KH, TM, and RJ designed the evaluation. KH and TM conducted the monitoring evaluation, analyzed data, and wrote the article. JP, MC, and KJ developed the training. JP, MC, and WW led the training and the training team. All co-authors contributed to the results interpretation and the discussion.

FUNDING

This study was supported by internal funds from Child Health BC. All co-authors are Child Health BC staff members.

ACKNOWLEDGMENTS

We would like to acknowledge the members of the CHBC virtual health training team, Sana Fakih, Zahra Hussein, Lorna Simms, Anya Smith, Shirley de Souza, Terry Chau, and Vida Lopez, and CHBC researchers Sina Waibel and Anya Smith for their feedback on survey design and the article. Special thanks to Provincial Health Services Authority (PHSA) Office of Virtual Health and the Clinical Operations leaders at BC Children's and Women's Hospitals for their partnership in supporting the development of the training. Thank you to Shirley de Souza for her administrative support to the project and much gratitude to the busy clinicians and staff who took the time to provide feedback and help us improve the training. We would also like to thank the BCCHR REDCap team and PHSA Privacy Office for helping us launch the evaluation survey in a short span of time. Finally, we would like to acknowledge the generous support of the BC Children's Hospital Foundation, which provides Child Health BC with the outstanding opportunity to work with our provincial partners to build an accessible system of service for BC's children and youth.

REFERENCES

1. Ray Dorsey E, Topol EJ. State of telehealth. *N Engl J Med.* (2016) 375:154–61. doi: 10.1056/NEJMra1601705
2. Joseph V, West RM, Shickle D, Keen J, Clamp S. Key challenges in the development and implementation of telehealth projects. *J Telemed Telecare.* (2011) 17:71–7. doi: 10.1258/jtt.2010.100315
3. Armfield NR, Edirippulige SK, Bradford N, Smith AC. Telemedicine - is the cart being put before the horse? *Med J Aust.* (2014) 200:530–3. doi: 10.5694/mja13.11101
4. Edirippulige S, Armfield NR. Education and training to support the use of clinical telehealth: a review of the literature. *J Telemed Telecare.* (2016) 23:273–82. doi: 10.1177/1357633X16632968
5. Mann DM, Chen J, Chunara R, Testa PA, Nov O. COVID-19 transforms health care through telemedicine: evidence from the field. *J Am Med Inform Assoc.* (2020) 27:1132–5. doi: 10.1093/jamia/ocaa072
6. Joshi AU, Lewiss RE. Telehealth in the time of COVID-19. *Emerg Med J.* (2020) 37:637–8. doi: 10.1136/emermed-2020-209846
7. Wosik J, Fudim M, Cameron B, Gellad ZF, Cho A, Phinney D, et al. Telehealth transformation: COVID-19 and the rise of virtual

care. *J Am Med Informatics Assoc.* (2020) 27:957–62. doi: 10.1093/jamia/ocaa067
8. Rutledge CM, O'Rourke J, Mason AM, Chike-Harris K, Behnke L, Melhado L, et al. Telehealth competencies for nursing education and practice. *Nurse Educ.* (2021). doi: 10.1097/NNE.0000000000000988. [Epub ahead of print].
9. Chike-Harris KE, Durham C, Logan A, Smith G, DuBose-Morris R. Integration of telehealth education into the health care provider curriculum: a review. *Telemed e-Health.* (2021) 27:137–49. doi: 10.1089/tmj.2019.0261
10. Monaghesh E, Hajizadeh A. The role of telehealth during COVID-19 outbreak: a systematic review based on current evidence. *BMC Public Health.* (2020) 20:1193. doi: 10.1186/s12889-020-09301-4
11. Traube DE, Cederbaum JA, Taylor A, Naish L, Rau A. Telehealth training and provider experience of delivering behavioral health services. *J Behav Heal Serv Res.* (2020) 48:93–102. doi: 10.1007/s11414-020-09718-0
12. Olson CA, Mcswain SD, Curfman AL, Chuo J. The current pediatric telehealth landscape. *Pediatrics.* (2018) 141:e20172334. doi: 10.1542/peds.2017-2334
13. van Houwelingen CTM, Moerman AH, Ettema RGA, Kort HSM, ten Cate O. Competencies required for nursing telehealth activities: a Delphi-study. *Nurse Educ Today.* (2016) 39:50–62. doi: 10.1016/j.nedt.2015.12.025
14. Sharma R, Nachum S, Davidson KW, Nochomovitz M. It's not just facetime: core competencies for the medical virtualist. *Int J Emerg Med.* (2019) 12:8. doi: 10.1186/s12245-019-0226-y
15. Yaghobian S, Ohannessian R, Mathieu-Fritz A, Moulin T. National survey of telemedicine education and training in medical schools in France. *J Telemed Telecare.* (2020) 26:303–8. doi: 10.1177/1357633X18820374
16. Ramirez AV, Ojeaga M, Espinoza V, Hensler B, Honrubia V. Telemedicine in minority and socioeconomically disadvantaged communities amidst COVID-19 pandemic. *Otolaryngol Head Neck Surg.* (2020) 164:91–2. doi: 10.1177/0194599820947667
17. PMI, AgileAlliance. *Agile Practice Guide*. Newtown Square, PA: PMI Book (2017).
18. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform.* (2009) 42:377–81. doi: 10.1016/j.jbi.2008.08.010
19. RStudio Team. *RStudio: Integrated Development for R*. Boston, MA (2016). Available online at: www.rstudio.com
20. Chike-Harris KE, Harmon E, Van Ravenstein K. Graduate nursing telehealth education: assessment of a one-day immersion approach. *Nurs Educ Perspect.* (2020) 41:E35–6. doi: 10.1097/01.NEP.0000000000000526
21. Rutledge C, Hawkins EJ, Bordelon M, Gustin TS. Telehealth education: an interprofessional online immersion experience in response to COVID-19. *J Nurs Educ.* (2020) 59:570–6. doi: 10.3928/01484834-20200921-06
22. Gustin TS, Kott K, Rutledge C. Telehealth etiquette training: a guideline for preparing interprofessional teams for successful encounters. *Nurse Educ.* (2020) 45:88–92. doi: 10.1097/NNE.0000000000000680
23. Hilty DM, Maheu MM, Drude KP, Hertlein KM. The need to implement and evaluate telehealth competency frameworks to ensure quality care across behavioral health professions. *Acad Psychiatry.* (2018) 42:818–24. doi: 10.1007/s40596-018-0992-5
24. Stovel RG, Gabarin N, Cavalcanti RB, Abrams H. Curricular needs for training telemedicine physicians: a scoping review. *Med Teach.* (2020) 42:1234–42. doi: 10.1080/0142159X.2020.1799959
25. van Houwelingen CTM, Ettema RGA, Kort HSM, Ten Cate O. Hospital nurses' self-reported confidence in their telehealth competencies. *J Contin Educ Nurs.* (2019) 50:26–34. doi: 10.3928/00220124-20190102-07

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Pediatrics

ORIGINAL RESEARCH
published: 28 May 2021
doi: 10.3389/fped.2021.645814

Pilot Study of Telehealth Delivered Rehabilitative Exercise for Youth With Concussion: The Mobile Subthreshold Exercise Program (MSTEP)

Sara P. D. Chrisman[1,2], Jason A. Mendoza[1,2,3], Chuan Zhou[1,2], Tonya M. Palermo[1,4], Tierra Gogue-Garcia[1], Kathleen F. Janz[5] and Frederick P. Rivara[1,2,6]*

[1] Center for Child Health, Behavior and Development, Seattle Children's Research Institute, Seattle, WA, United States, [2] Department of Pediatrics, University of Washington, Seattle, WA, United States, [3] Public Health Sciences Division, Fred Hutchinson Cancer Research Center, Seattle, WA, United States, [4] Department of Anesthesiology and Pain Medicine, University of Washington, Seattle, WA, United States, [5] Department of Health and Human Physiology, University of Iowa, Iowa City, IA, United States, [6] Harborview Injury Prevention and Research Center, Seattle, WA, United States

OPEN ACCESS

Edited by:
Tzielan Lee,
Stanford University, United States

Reviewed by:
John Leddy,
University at Buffalo, United States
Kelly McNally,
Nationwide Children's Hospital,
United States

***Correspondence:**
Sara P. D. Chrisman
sara.chrisman@seattlechildrens.org

Specialty section:
This article was submitted to General Pediatrics and Pediatric Emergency Care, a section of the journal Frontiers in Pediatrics

Received: 24 December 2020
Accepted: 08 March 2021
Published: 28 May 2021

Citation:
Chrisman SPD, Mendoza JA, Zhou C, Palermo TM, Gogue-Garcia T, Janz KF and Rivara FP (2021) Pilot Study of Telehealth Delivered Rehabilitative Exercise for Youth With Concussion: The Mobile Subthreshold Exercise Program (MSTEP). Front. Pediatr. 9:645814. doi: 10.3389/fped.2021.645814

Background: Concussion is common, and up to 30% of youth develop persistent symptoms. Preliminary data suggests treatment with rehabilitative exercise is beneficial, but most programs require frequent in-person visits, which is challenging for youth in rural areas, and has been made more difficult for all youth during the COVID-19 pandemic. We have adapted an exercise intervention to be delivered via telehealth using Zoom and personal fitness devices, which could ensure access to this type of treatment.

Objective: The goal of this study was to assess feasibility and acceptability of a telehealth delivered exercise intervention for concussion, the Mobile Subthreshold Exercise Program (MSTEP), and collect pilot data regarding efficacy.

Materials and Methods: All youth received the 6-week MSTEP intervention which included wearing a Fitbit and setting exercise heartrate and duration goals weekly over Zoom with the research assistant. Youth completed standardized measures of concussive symptoms (Health Behavior Inventory, HBI), fear-avoidance (Fear of Pain Questionnaire, FOPQ) and health-related quality of life (Pediatric Quality of life Assessment, PedsQL), as well as a structured qualitative exit interview. We examined change in measures over time using mixed effects modeling, controlling for age, sex, prior concussion and duration of symptoms. We coded qualitative interviews using Thematic analysis.

Results: We recruited 19 subjects, 79% female with average age 14.3 (SD 2.2) and mean duration of symptoms 75.6 days (SD 33.7). Participants wore the Fitbit on 80% of days, and completed 94% of surveys and 96% of Zoom calls. Concussive symptoms (HBI) decreased significantly over the 6 week intervention (−10.6, 95%CI: −16.0 to −5.1) as did fear-avoidance (−21.6, 95%CI: −29.8 to −13.5). PedsQL improved significantly during the same time period (+15.1, 95%CI: 8.6–21.6). Approximately three-quarters (76%) of youth rated their care as "excellent." Participants appreciated the structure of the guided exercise program and the support of the RA. They also enjoyed being able to track their progress with the Fitbit.

Conclusion: This study provides evidence for the feasibility and acceptability of a telehealth delivered rehabilitative exercise intervention for youth with concussion. Further research utilizing a randomized controlled trial is needed to assess efficacy.

Clinical Trial Registration: https://clinicaltrials.gov, identifier: NCT03691363. https://clinicaltrials.gov/ct2/show/NCT03691363

Keywords: brain concussion, child, fear-avoidance, pain, exercise, physical activity, traumatic brain injury, sport

INTRODUCTION

Estimates suggest up to 1.9 million youth sustain a concussion annually in the United States (1). While concussion normally resolves within days to weeks following injury, an estimated 15–30% of youth experience symptoms such as headache, fatigue, dizziness, and difficulty concentrating lasting more than 4 weeks (2, 3), currently referred to as Persistent Post-Concussive Symptoms (PPCS) (3). PPCS can confer marked functional impairment, interfering with academic performance and social interaction, and resulting in negative outcomes such as depression and school failure (4–6). Individuals who develop PPCS represent a small proportion of those injured, yet a disproportionate number of those requiring more intensive interventions and accruing medical expenses (6).

Research suggests a rehabilitative approach with sub-symptom threshold aerobic exercise may provide benefit for PPCS (7–16). Individuals with PPCS tend to have increased symptoms when engaging in physical activity (PA), and these symptoms can lead to avoidance of PA and subsequent disability (17). Studies have reported benefit of rehabilitative exercise for youth with concussion, thought due to retraining the autonomic nervous system, thereby facilitating more rapid recovery (8, 11, 13). Our prior study of an intervention using two in-person visits (Subthreshold Exercise Program, STEP) found benefit for aerobic exercise compared to an active control (stretching) (18). However, requiring in-person visits was challenging for youth who lived far from our urban location, and appeared to impede access.

Interventions delivered via telehealth improve access, generalizability and scalability of care (19). With technology-based interventions, treatment can be offered to youth in their homes, obviating the need to travel to distant clinical locations to receive subspecialty care. During the current COVID-19 pandemic there are additional advantages to delivering an intervention via telehealth, given that being seen in-person confers risk (20). As internet and mobile capacities have expanded, remotely administered telehealth interventions have proved efficacious for treating a broad array of medical issues, and encouraging health promotion (21). Telehealth treatment delivery has been particularly effective for increasing PA when paired with PA trackers (22, 23), and can improve adherence by utilizing more frequent touchpoints with participants (24).

Prior research on exercise as a treatment for PPCS has been grounded in the theory that physiologic change is responsible for treatment effects (8). We propose that positive outcomes associated with encouraging youth to exercise may also be mediated by psychologic change (18). In other words, youth with PPCS may have developed a fear-avoidance response to physical activity, similar to what has been described in youth with chronic pain (25–27). Other researchers have confirmed elevated levels of fear-avoidance in individuals with PPCS (28, 29), and our pilot study of an in-person delivered exercise program for concussion (the Subthreshold Exercise Program, or STEP) (18), demonstrated that fear-avoidance decreased in parallel with concussive symptoms (18). Interventions that encourage youth to exercise despite fears of exacerbating symptoms have been shown to be an effective approach to improving function in individuals with chronic pain (30).

Building from our in-person intervention (STEP), the goal of this study was to adapt the intervention to be delivered via telehealth (the Mobile Subthreshold Exercise Program, MSTEP) and to use mixed methods to assess the feasibility and acceptability of this approach. We also collected pilot data regarding treatment effects on primary outcomes (concussive symptoms and health-related quality of life) and impact on fear-avoidance.

MATERIALS AND METHODS

Overview of Study

Methods were very similar to our previous study (18), but with the transition of all visits to telehealth. Subjects completed on-line surveys at baseline, 3 and 6 weeks via REDCap (31). The 6-week aerobic exercise program was delivered via weekly video conference calls with a research assistant (RA), advancing activity goals weekly. All subjects wore a Fitbit Charge 2 to allow them to track whether they were meeting activity goals. Youth and parents were provided incentives for participation, which were delivered after each task was completed.

Sample

Youth were recruited during 2018–2019 through subspecialty concussion clinics (Sports Medicine and Rehabilitative Medicine) at Seattle Children's Hospital and the University of Washington by contacting families through a variety of means (texting, phone calls, and letters) to invite them to participate, as well as emailing providers in advance of a visit. Inclusion criteria included: (1) age 9–25 years old, (2) concussion occurring 1–9 months prior to the start of the study diagnosed by a clinician trained in concussion management consistent with the 2017 Berlin consensus definition of concussion (32), (3) PPCS as defined by the presence of at least three concussive symptoms rated at least 2 or greater on the Health and Behavior Inventory (HBI) (33), and a total score of 10 or greater. Exclusion criteria included: (1) parent and/or youth not fluent in English, (2) other injuries or medical conditions in addition to concussion that prompted a clinician to recommend against physical activity, (3) daily average of 30 min or greater of moderate to vigorous physical activity at time of enrollment, and (4) already completed a physical therapy intervention to increase aerobic exercise. Youth who chose to engage in the study continued to work with their concussion provider to receive usual care. The study was approved by the Institutional Review Board of Seattle Children's Research Institute. All youth and parents completed written informed consent. This study was registered at Clinicaltrials.gov #NCT03691363.

Mobile Sub-threshold Exercise Program (MSTEP) Intervention

Subjects were asked to complete a home aerobic exercise program daily for 6 weeks. The exercise prescription included recommendations for frequency, duration and intensity in accordance with best practice (7). The initial goal was set at 10 min at a heart rate (HR) of 120 with an expectation that youth would attempt to exercise daily, but might miss 1–2 days per week. Individuals could choose the type of exercise they completed. If symptoms worsened during exercise, youth were instructed to take a break and decrease the heart rate goal utilized until they were able to tolerate 10 min of exercise. Goals were advanced weekly as tolerated to a maximum of 60 min of physical activity per day at a HR of 140. The HR of 140 was chosen as this approximates MVPA for youth (34, 35). The duration of 60 min/day was chosen as this is the US federally recommended level of MVPA for youth (36). Subjects were provided a Fitbit Charge 2 to monitor HR during their home exercise program and met with an RA weekly via video conference (Zoom) to discuss the progress of exercise that week, and advance goals for the next week. Zoom meetings took ∼15 min and were scheduled at a time convenient for the participant.

Assessments

Primary Outcome

The primary goal of the study was to assess feasibility and acceptability of the MSTEP intervention. Parents and youth completed an online survey using a standardized scale of patient satisfaction, the Satisfaction with Study questionnaire, consisting of 8 items such as "How would you rate the quality of care you have received?" and "Would you recommend this study to a friend." They also completed structured qualitative interviews at the end of the study (via phone or video conference), in order to elucidate which parts of the study were most appealing and which could be improved. Interview questions were framed in an open-ended fashion and focused on participant experience with Fitbits, video conference calls and overall study procedures. Interviews were conducted by one of the RAs on the study using a standardized script, and were digitally recorded to allow for review and coding.

Secondary Outcomes

We collected pilot efficacy data regarding outcomes targeted by the intervention, including concussive symptoms, health-related quality of life, sleep, and symptoms of anxiety and depression. All scales were completed by youth via online self-report and included:

- Health and Behavior Inventory: The HBI is a component of the NIH Common Data Elements for research on concussion (37, 38), and is a 20-item instrument that measures the frequency of post-concussive symptoms on a four-point likert scale with higher scores indicating greater symptom severity. The scale yields scores in somatic and cognitive domains demonstrated by factor analysis to be robust across raters and time (Cronbach's alpha = 0.85–0.94) (33). This scale has demonstrated validity and reliability among adolescents and individuals with mild TBI (33, 39–42). Higher scores indicate worse concussion symptoms.
- Pediatric Quality of Life Inventory: The PedsQL is a 23-item 5-point questionnaire that assesses physical, emotional, social, and school functioning, including number of school days missed with established validity and reliability (43). Higher scores indicate better health-related quality of life.
- Fear of pain questionnaire, adapted for concussive symptoms: The FOPQ-C is a 24-item questionnaire, that has been shown to reliably and validly measure pain-related fear in youth (Cronbach's alpha 0.92) (44). Fear of pain is thought to arise from pain catastrophizing in the fear-avoidance model (25, 45). We adapted this measure to be specific to concussive symptoms, changing "pain" in each item to "concussive symptoms." Higher scores indicate more fear and/or avoidance of concussive symptoms.
- Patient Health Questionnire-9: The PHQ-9 is a component of the NIH Common Data Elements for research on concussion. It is a 9-item instrument that measures depressive symptoms on a 4-point likert scale with higher scores indicating greater severity. This scale has demonstrated validity and reliability among adolescents and individuals with concussion (46–50).
- Generalized Anxiety Disorder Scale-7: The GAD-7 is a 7-item standardized anxiety measure that asks youth to rate how often they have been bothered by anxiety symptoms using a 0–3 scale (from "Not at all" to "Nearly every day"), with higher score indicating more severe anxiety. It has been shown to have good reliability, as well as criterion, construct, factorial, and procedural validity for assessing anxiety (51, 52).
- Adolescent Sleep Wake Scale-10 item: The ASWS is a 10-item scale regarding sleep quality that has been shown to have good internal consistency and construct validity (53). Higher scores indicate improved sleep quality.

Covariates

Parents and youth completed additional surveys at the start of the study regarding demographic characteristics including: age, sex, race, ethnicity, parental education, and history of prior mental health diagnoses in youth and family members. Information was also collected regarding injury characteristics: date of injury (used to calculate duration of symptoms), mechanism of injury, primary symptoms experienced, and history of prior concussion.

Analysis

Data were examined for distribution and completeness. Data regarding satisfaction with the intervention were reported descriptively. Recordings of qualitative exit interviews were reviewed and coded iteratively using Thematic analysis to identify parts of the MSTEP intervention that were particularly liked or disliked (54). Changes in quantitative outcomes over time were examined using linear mixed effects regression models with time modeled as a discrete variable, while controlling for covariates of age, sex, duration of symptoms, and history of prior concussion. Subject-specific random intercept was included to account for clustering due to repeated measures within subjects. Fixed effect coefficients were tested using *F*-tests with Kenward–Roger methods for denominator degrees of freedom (55). All analyses were conducted using R statistical software (56).

RESULTS

Sample

We approached 130 individuals, 78 were eligible, 16 declined, 16 were interested but did not follow through and 27 did not respond, leaving 19 who enrolled in the study. One individual withdrew from the study at 3 weeks due to increasing headaches. The sample was three-quarters female, average age 14.5 years (SD = 2.3 years), and majority white (63%, see **Table 1**). Duration of symptoms was about 2 months (average = 75.2 days, SD = 33.7) and all individuals reported headache, with difficulty concentrating and fatigue as the next most common symptoms.

Feasibility and Acceptability

Participants wore the Fitbit on 80% of days and completed 94% of surveys and 96% of Zoom calls. Both youth and parents expressed a high level of satisfaction with the study (see **Table 2**). More than three-quarters of youth and 69% of parents rated the study as "excellent," and the remaining chose "good." All parents and youth expressed that they would recommend the study to a friend. One parent and one youth expressed indifference or mild dissatisfaction on a few of the ratings.

Qualitative Interviews Regarding MSTEP Intervention

Exit interviews were completed by 79% of participants. Dominant themes suggested subjects overall had very positive experiences with the MSTEP intervention, particularly mentioning enjoying wearing the Fitbit, liking the structure of a gradual increase in exercise supported by an RA, and appreciating being able to get back to their sports and other activities (see **Table 3**). A fair number of youth mentioned that

TABLE 1 | Demographics of youth participating in the Mobile Subthreshold Exercise Program (MSTEP) for concussion, Seattle, WA 2018–2019.

Baseline characteristics (*N* = 19)	*N*	(%)
Age		
10–13 y.o.	9	(47.37)
14–20 y.o.	10	(52.63)
Female	14	(73.68)
BMI[a] (kg/m^2)	Mean 23.17	SD (4.56)
Race		
White	12	(63.16)
African–American or Black	3	(15.79)
Asian	3	(15.79)
American Indian or Alaskan Native	1	(5.26)
Native Hawaiian or other Pacific Islander	0	–
Unknown	1	(5.26)
Ethnicity		
Hispanic	0	
Non-Hispanic	18	(94.74)
Unknown	1	(5.26)
Education of consenting parent		
HS or less	0	–
Some college	5	(26.32)
College degree	5	(26.32)
Masters or professional degree	8	(42.11)
Missing	1	(5.26)
Education of other parent		
HS or less	2	(10.53)
Some college	5	(26.32)
College degree	8	(42.11)
Masters or professional degree	3	(15.79)
Family history (parent or sibling)		
Headaches/ migraine	8	(42.11)
Neck/back pain	15	(78.95)
Joint pain	6	(31.58)
ADHD	5	(26.32)
Anxiety	8	(42.11)
Depression	4	(21.05)
Other mental health	2	(10.53)
Drug use/abuse	2	(10.53)
Alcoholism	1	(5.26)
Concussion or other brain injury	3	(15.79)
Duration of symptoms		
<60 days	7	(36.84)
61–95 days	7	(36.84)
96–150 days	5	(26.32)
Mechanism of injury		
MVC[b]	2	(10.53)
Fight/ hit by someone (i.e., assault)	0	–
Fell, not in sports	6	(31.58)
Sport or recreation related	11	(57.90)
+LOC[c]	4	(21.05)
+Memory issues	10	(52.63)

(Continued)

TABLE 1 | Continued

Baseline characteristics (*N* = 19)	*N*	(%)
Symptoms most problematic		
a. Headache	19	(100)
b. Difficulty concentrating	14	(73.68)
c. Fatigue	12	(63.16)
d. Sensitivity to sound	12	(63.16)
e. Sensitivity to light	11	(57.89)
f. Memory issues	11	(57.89)
g. Dizziness	11	(57.89)
h. Balance problems	10	(52.63)
i. Irritability	9	(47.37)
j. Problems sleeping	8	(42.11)
k. Nausea	7	(36.84)
Prior concussion		
0	10	(52.63)
1	3	(15.79)
2	1	(5.26)
3+	5	(26.32)

[a] *BMI, Body mass index = weight in kg/ (height in m)^2.*
[b] *MVC, Motor vehicle crash.*
[c] *LOC, Loss of consciousness.*

their symptoms had improved. A few youth had difficulties with syncing and charging the Fitbit, and a few discussed challenges in determining how many minutes they had achieved at their goal heart rate. Two youth mentioned symptoms worsening.

Outcome Data

Mixed effects regression models indicated concussive symptoms (HBI) improved significantly from baseline to weeks 3 and 6 while health-related quality of life (PedsQL) improved (**Figure 1**, and see **Appendix** for table). Fear-avoidance of concussive symptoms (FOPQ-C) declined significantly over the same time period (**Figure 1**), as did symptoms of anxiety (GAD7) and depression (PHQ9) (**Figure 2**). Sleep (ASWS) significantly improved at 6 weeks compared to baseline (**Figure 2**). Covariates were included in all models (age, sex, history of prior concussion, and duration of symptoms), but they did not affect model fit significantly (in the HBI model, likelihood ratio test comparing models with and without covariate adjustment had $p = 0.22$).

TABLE 2 | Satisfaction with Study ratings for youth and parents participating in the Mobile Subthreshold Exercise Program (MSTEP) for concussion, Seattle, WA 2018–2019.

	Satisfaction with study (Youth *n* = 17, Parent *n* = 16)	
	Youth	**Parent**
How would you rate the quality of care you have received?		
Excellent	13 (76%)	11 (69%)
Good	4 (24%)	5 (31%)
Did you get the kind of care you wanted?		
Yes, definitely	8 (47%)	12 (75%)
Yes, generally	9 (53%)	6 (25%)
To what extent did these services meet your needs?		
Almost all of my needs met	11 (65%)	11 (69%)
Most of my needs met	5 (29%)	4 (25%)
Only a few of my needs met	1 (6%)	1 (6%)
Would you recommend these services to a friend?		
Yes, definitely	11 (65%)	14 (88%)
Yes, I think so	6 (35%)	22 (13%)
How satisfied are you with the amount of help you have received?		
Very satisfied	12 (71%)	13 (81%)
Mostly satisfied	4 (24%)	2 (13%)
Indifferent or mildly dissatisfied	1 (6%)	1 (6%)
Has the care you received helped you?		
Yes, it has helped a great deal	11 (65%)	5 (31%)
Yes, it has helped	6 (35%)	9 (56%)
It didn't really help		1 (6%)
I do not wish to answer		1 (6%)
In an overall general sense, how satisfied are you with the care you have received?		
Very satisfied	14 (82%)	12 (75%)
Mostly satisfied	3 (18%)	4 (25%)
Would you come back to this program?		
Yes, definitely	11 (65%)	13 (81%)
Yes, I think so	5 (29%)	3 (19%)
I do not wish to answer	1 (6%)	

DISCUSSION

Research indicates that exercise is beneficial for treating youth with persistent post-concussive symptoms (PPCS), but prior studies have required multiple in-person visits (7–16). This is the first study to show that a rehabilitative exercise program for concussion (MSTEP) can be feasibly delivered via telehealth, a useful adaptation during a pandemic when in-person care is both challenging to access and higher risk (20). Youth and parents expressed high satisfaction with MSTEP, and would recommend this program to others. Youth in particular enjoyed the structured approach to returning to physical activity and the weekly video conference support from the RA. They also liked wearing the Fitbit, as it provided a means to assess whether they were meeting their activity goals. Technical difficulties were minimal and all were resolved during the study.

In order to adapt the study to be delivered via telehealth, we had to derive an alternate means for providing a tailored exercise program. Most in-person programs utilize a fitness test

TABLE 3 | Qualitative data from exit interviews with youth and parents participating in the Mobile Subthreshold Exercise Program (MSTEP) for concussion, Seattle WA 2018–2019.

Qualitative themes from exit interviews (Number in parentheses represents the number of interviews in which this theme was identified)	Representative quotes
Fitbit	
1. Positive experiences with the Fitbit ($n = 14$)	• "It was really cool to see how many steps I could get in a day, and just like challenging myself with all of it." • "Super easy to wear, just like a watch." • "Easy to use, charged really fast." • "Nice being able to see distance and pacing."
2. Negative experiences with the Fitbit	
a. Need to sync manually ($n = 5$)	• "The automatic syncing didn't really seem to be working. …for the first couple weeks I always forgot that I had to open the app." • "Syncing is poor, doesn't automatically sync."
b. Hard to visualize heart rate ($n = 5$)	• "Liked being able to track heart rate, but hard to see it graphed in the app." • "Doesn't display heart rate information in a way that is easy, hard to see how many minutes, have to kind of 'eyeball it."'
c. Trouble charging ($n = 3$)	• "Hung up by the way it had to charge, needed to have a certain direction." • "Sometimes it would die in the middle of exercise."
d. Difficulty measuring heart rate ($n = 2$)	• "Heart rate didn't seem very accurate, would say it was 100 when it was 150, but most of the time it was pretty close." • "Had to make it tighter to get it to register the HR correctly."
Zoom	
3. Positive experiences with Zoom ($n = 7$)	• "Liked everything about the weekly calls, it always connected and worked." • "Calls were really easy to do, just click the link."
4. Trouble connecting with Zoom ($n = 4$)	• "…The first two calls I was having a lot of problems figuring out how to work Zoom…after that I was able to get it down." • "Originally getting the Zoom app to work was a little complicated, because I don't think it's something that anyone ever uses except for conference calls for work."
Overall	
5. Liked having structure ($n = 8$)	• "It was helpful to have a plan instead of just trying to 'wing it."' • "Before…people told me to exercise, but I didn't know how much or where to start. This made it an easy process, like it was all laid out for me." • "…Before entering into the study I was doing as much exercise as I could until I crashed, which wasn't the best way of doing it. The study kind of helped me get back to the basics and slow down so that I could go up and still feel good."
6. Able to return to usual activities ($n = 8$)	• "Got me back to track practice, really accessible working around my schedule." • "A couple of months ago I couldn't even go to school without headaches, now I can go to school, go to dance without symptoms."
7. Symptom improvement ($n = 6$)	• "…It was a really fun experience, and it helped me get better in some ways…now I never really get blurred vision or dizziness anymore and headaches don't last as long and they're not as painful. " • "Helped me get rid of my concussion symptoms. For 2 months I wasn't getting any better, and then I started seeing results like 2 weeks in."
8. Simplicity of the methods ($n = 6$)	• "Pretty much everything worked pretty well." • "I feel like this is really nice and simple." • "Appreciated how short the calls were (10–15 min)."
9. Appreciated RA support ($n = 4$)	• "I liked that I had someone to talk to." • "Good that we could clarify stuff like if I had a question I could just ask."
10. Advancing science ($n = 3$)	• "I liked the study a lot, I liked being a part of it and doing something that was good for other people, I liked how it all worked and it was just a fun experience." • "Finding out more about concussions could definitely be a step in the right direction because I go to doctors all the time and they're like "Well-concussions are pretty unclear and we don't really know very much about them" and that's not very helpful."
11. Increase in symptoms ($n = 2$)	• "Every time I do activity, the next day or two or three I feel really dizzy" • "Once we got to 150 beats, I started getting more headaches."

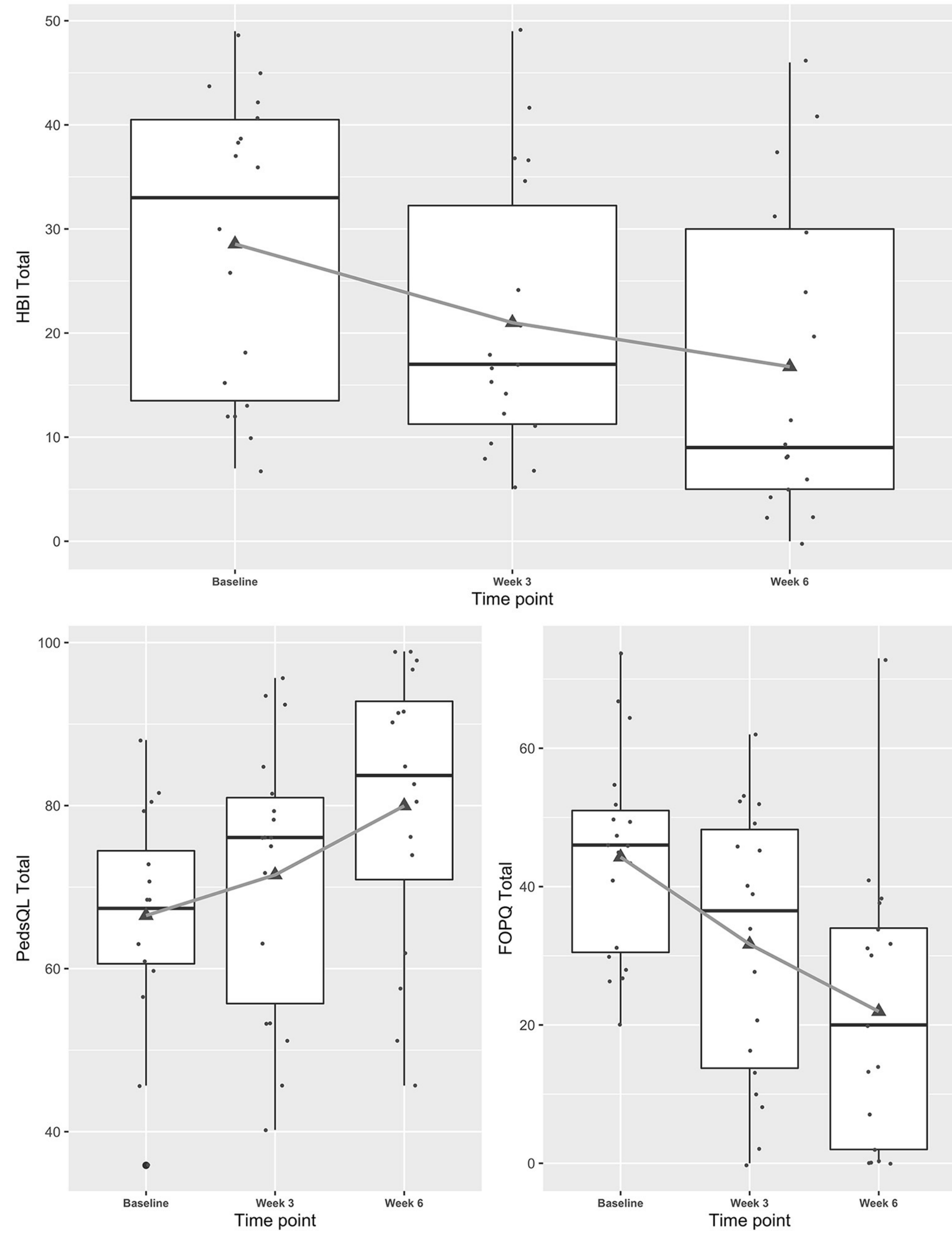

FIGURE 1 | Trajectories of concussive symptoms, health-related quality of life and fear-avoidance for youth participating in a Mobile Subthreshold Exercise Program (MSTEP) for concussion, Seattle, WA 2018–2019.

such as the Buffalo Concussion Treadmill Test to determine a target heart rate (57), which would be challenging to complete remotely as it requires a treadmill that can achieve a high level of grade. To replace this assessment, we designed a program that would target the approximate MVPA for a youth of the average age in the study (HR 140), and then asked participants to adjust the intensity based on their symptoms. Subjects tolerated this level of MVPA well and were comfortable making these adjustments. Only one participant ended up withdrawing from the study, supporting the acceptability of this approach.

Our preliminary analysis of quantitative outcomes suggested significant declines in concussive symptoms (HBI) during the 6-week intervention. Given that youth participants were enrolled following an injury, some level of improvement would be expected during the 6-week study, and the lack of a control group limits interpretation of declines in concussive symptoms. Future research with a randomized controlled trial

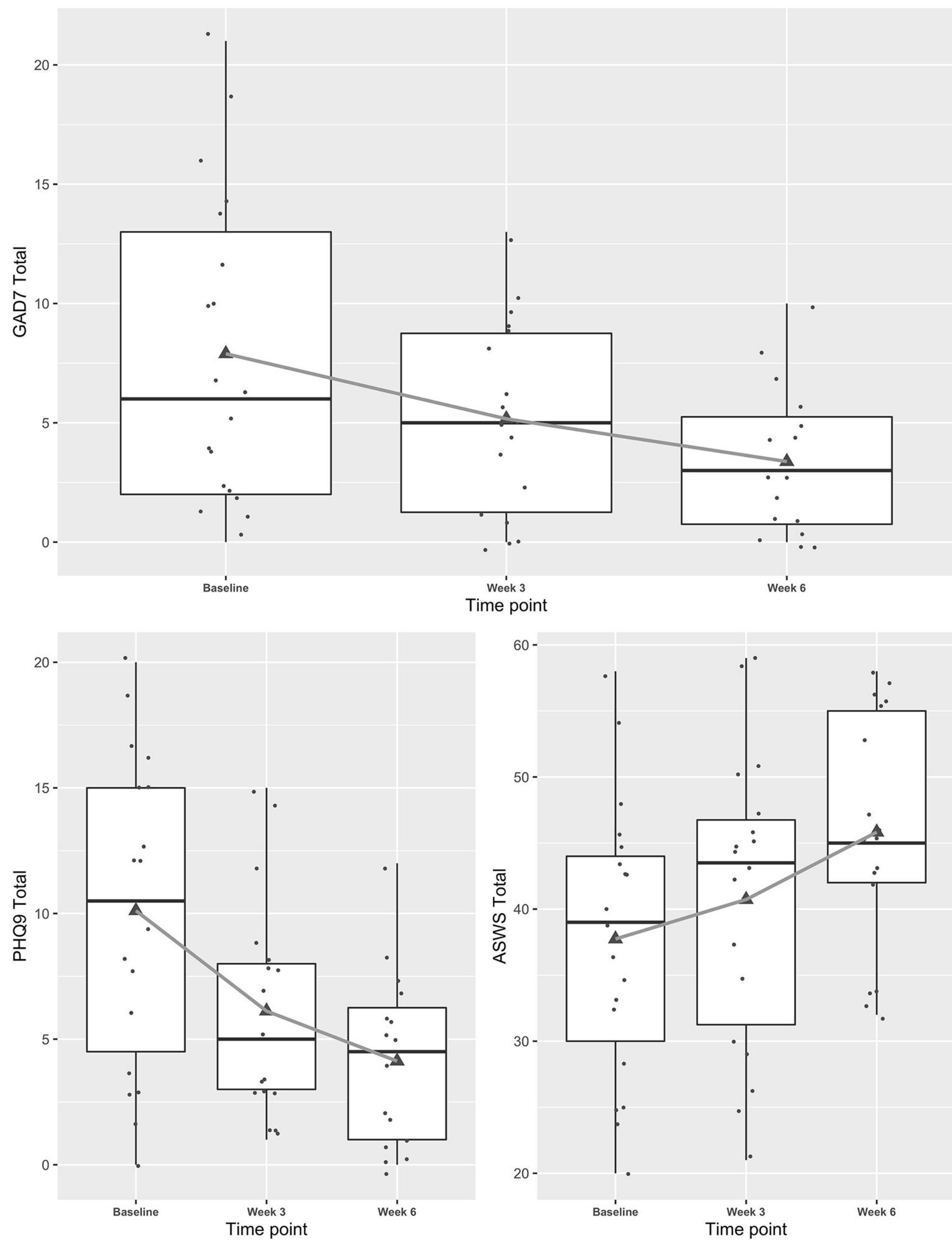

FIGURE 2 | Trajectories of mental health symptoms and sleep for youth participating in a Mobile Subthreshold Exercise Program (MSTEP) for concussion, Seattle, WA 2018–2019.

is needed to ensure improvement in symptoms is not due to the passage of time. The MSTEP intervention effect (i.e., decline in concussive symptoms) was similar to an in-person exercise program (STEP) at 3 weeks, but slightly less strong at 6 weeks (18). We also noted improvements in depression, anxiety, sleep, and health-related quality of life, all of which paralleled declines in concussive symptoms. Future research will be needed to determine whether such improvements are due to resolution of concussive symptoms, or represent secondary endpoints. Fear-avoidance of concussive symptoms declined as it did in our previous pilot work (18), again suggesting that rehabilitative exercise addresses not only physiologic symptoms, but psychologic issues (such as fear of concussive symptoms) that may be responsible for symptom perpetuation.

This was a pilot study, and as such the sample size was small limiting generalizability. We note that the rate of recruitment appears low, which could introduce bias. However, in truth only 20% of youth declined participation. The remaining individuals either never responded to outreach (passive decline) or stopped responding. We suspect that many of these individuals recovered and therefore were no longer eligible, but this is difficult to verify. In any case, our recruitment numbers were comparable to a study by another group using in-person exercise to treat youth with PPCS (13). We also note that we did not have a concurrent control group for comparison and thus we cannot assess efficacy. Our next step is to conduct a larger randomized controlled trial of the MSTEP approach using an active control comparator (a stretching intervention) to assess the effect of the intervention on concussive symptoms and health-related quality of life, and examine potential mediators of the intervention effect such as fear-avoidance of concussive symptoms. We also plan to measure MVPA objectively using hip-mounted accelerometry, to assess whether increases in MVPA mediate recovery.

CONCLUSIONS

A telehealth-delivered rehabilitative exercise program for youth with concussion (MSTEP) is both feasible and acceptable. A larger randomized controlled trial is needed to assess efficacy for this approach.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Seattle Children's Research Institute IRB. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

SC conceived and designed the study, obtained funding, coordinated data collection, oversaw analysis, drafted the manuscript, and submitted the final version. JM, TP, and FR contributed to the design of the study, supported data collection and analysis, provided critical revisions to the manuscript, and approved the final version. CZ completed the quantitative data analysis, provided critical revisions to the manuscript, and approved the final version. TG-G completed the data collection, cleaned and prepared data for final analysis provided critical revisions to the manuscript, and approved the final version. KJ provided insight into the design of the study (particularly the intervention methodology), supported data analysis, provided critical revisions to the manuscript, and approved the final version. All authors contributed to the article and approved the submitted version.

FUNDING

The support for this research was provided by the Satterberg Foundation in addition to internal funds from the Institute for Child Health, Behavior and Development, Seattle Children's Research Institute. Neither organization had any involvement in the study design, analysis, or reporting of results.

ACKNOWLEDGMENTS

We would like to thank the clinicians who partnered with us to ensure we could offer this treatment to youth with concussion, and the youth and parents who engaged with us in this work.

REFERENCES

1. Bryan MA, Rowhani-Rahbar A, Comstock RD, Rivara F, Seattle Sports Concussion Research Collaborative. Sports- and Recreation-Related Concussions in US Youth. *Pediatrics.* (2016) 138:e20154635. doi: 10.1542/peds.2015-4635
2. Barlow KM, Crawford S, Brooks BL, Turley B, Mikrogianakis A. The incidence of postconcussion syndrome remains stable following mild traumatic brain injury in children. *Pediatr Neurol.* (2015) 53:491–7. doi: 10.1016/j.pediatrneurol.2015.04.011
3. Zemek R, Barrowman N, Freedman SB, Gravel J, Gagnon I, McGahern C, et al. Clinical risk score for persistent postconcussion symptoms among children with acute concussion in the ED. *JAMA.* (2016) 315:1014. doi: 10.1001/jama.2016.1203
4. Russell K, Selci E, Chu S, Fineblit S, Ritchie L, Ellis MJ. Longitudinal assessment of health-related quality of life following adolescent sports-related concussion. *J Neurotrauma.* (2017) 34:2147–53. doi: 10.1089/neu.2016.4704
5. Fineblit S, Selci E, Loewen H, Ellis M, Russell K. Health-related quality of life after pediatric mild traumatic brain injury/concussion: a systematic review. *J Neurotrauma.* (2016) 33:1561–8. doi: 10.1089/neu.2015.4292
6. Russell K, Selci E, Black B, Ellis MJ. Health-related quality of life following adolescent sports-related concussion or fracture: a prospective cohort study. *J Neurosurg Pediatr.* (2019) 23:455–64. doi: 10.3171/2018.8.PEDS18356
7. Howell DR, Taylor JA, Tan CO, Orr R, Meehan WP. The role of aerobic exercise in reducing persistent sport-related concussion symptoms. *Med Sci Sports Exerc.* (2019) 51:647–52. doi: 10.1249/MSS.0000000000001829
8. Leddy JJ, Kozlowski K, Donnelly JP, Pendergast DR, Epstein LH, Willer B. A preliminary study of subsymptom threshold exercise training for refractory post-concussion syndrome. *Clin J Sport Med.* (2010) 20:21–7. doi: 10.1097/JSM.0b013e3181c6c22c
9. Leddy JJ, Haider MN, Hinds AL, Darling S, Willer BS. A preliminary study of the effect of early aerobic exercise treatment for sport-related concussion in males. *Clin J Sport Med.* (2018) 29:353–360. doi: 10.1097/JSM.0000000000000663
10. Leddy JJ, Haider MN, Ellis MJ, Mannix R, Darling SR, Freitas MS, et al. Early subthreshold aerobic exercise for sport-related concussion. *JAMA Pediatr.* (2019) 173:319–25. doi: 10.1001/jamapediatrics.2018.4397
11. Gagnon I, Galli C, Friedman D, Grilli L, Iverson GL. Active rehabilitation for children who are slow to recover following sport-related concussion. *Brain Injury.* (2009) 23:956–64. doi: 10.3109/02699050903373477
12. Gagnon I, Grilli L, Friedman D, Iverson GL. A pilot study of active rehabilitation for adolescents who are slow to recover from sport-related concussion. *Scand J Med Sci Sports.* (2015) 26:299–306. doi: 10.1111/sms.12441
13. Kurowski BG, Hugentobler J, Quatman-Yates C, Taylor J, Gubanich PJ, Altaye M, et al. Aerobic exercise for adolescents with prolonged symptoms after mild traumatic brain injury: an exploratory randomized clinical trial. *J Head Trauma Rehabil.* (2016) 32:79–89. doi: 10.1097/HTR.0000000000000238
14. Gauvin-Lepage J, Friedman D, Grilli L, Sufrategui M, De Matteo C, Iverson GL, et al. Effectiveness of an exercise-based active rehabilitation intervention for youth who are slow to recover after concussion. *Clin J Sport Med.* (2018) 30:423–432. doi: 10.1097/JSM.0000000000000634
15. Grabowski P, Wilson J, Walker A, Enz D, Wang S. Multimodal impairment-based physical therapy for the treatment of patients with post-concussion syndrome: a retrospective analysis on safety and feasibility. *Phys Ther Sport.* (2017) 23:22–30. doi: 10.1016/j.ptsp.2016.06.001

16. Dobney DM, Grilli L, Kocilowicz H, Beaulieu C, Straub M, Friedman D, et al. Evaluation of an active rehabilitation program for concussion management in children and adolescents. *Brain Injury.* (2017) 31:1753–9. doi: 10.1080/02699052.2017.1346294
17. Broshek DK, De Marco AP, Freeman JR. A review of post-concussion syndrome and psychological factors associated with concussion. *Brain Injury.* (2015) 29:228–37. doi: 10.3109/02699052.2014.974674
18. Chrisman S, Whitlock K, Mendoza J, Burton MS, Somers E, Hsu A, et al. Pilot randomized controlled trial of an exercise program requiring minimal in-person visits for youth with persistent sport-related concussion. *Front Neurol.* (2019) 10:623. doi: 10.3389/fneur.2019.00623
19. Hsing JC, Wang CJ, Wise PH. Child Health and Telehealth in Global, Underresourced settings. *Pediatr Clin North Am.* (2020) 67:773–81. doi: 10.1016/j.pcl.2020.04.014
20. Krist AH, DeVoe JE, Cheng A, Ehrlich T, Jones SM. Redesigning primary care to address the COVID-19 pandemic in the midst of the pandemic. *Ann Fam Med.* (2020) 18:349–54. doi: 10.1370/afm.2557
21. Shigekawa E, Fix M, Corbett G, Roby DH, Coffman J. The current state of telehealth evidence: a rapid review. *Health Affairs.* (2018) 37:1975–82. doi: 10.1377/hlthaff.2018.05132
22. Mendoza JA, Baker KS, Moreno MA, Whitlock K, Abbey-Lambertz M, Waite A, et al. A Fitbit and Facebook mHealth intervention for promoting physical activity among adolescent and young adult childhood cancer survivors: a pilot study. *Pediatr Blood Cancer.* (2017) 64:e26660. doi: 10.1002/pbc.26660
23. Schoenfelder E, Moreno M, Wilner M, Whitlock KB, Mendoza JA. Piloting a mobile health intervention to increase physical activity for adolescents with ADHD. *Prev Med Rep.* (2017) 6:210–3. doi: 10.1016/j.pmedr.2017.03.003
24. Palermo TM, Law EF, Fales J, Bromberg MH, Jessen-Fiddick T, Tai G. Internet-delivered cognitive-behavioral treatment for adolescents with chronic pain and their parents. *Pain.* (2016) 157:174–85. doi: 10.1097/j.pain.0000000000000348
25. Asmundson GJG, Noel M, Petter M, Parkerson HA. Pediatric fear-avoidance model of chronic pain: foundation, application and future directions. *Pain Res Manag.* (2009) 17:397–405. doi: 10.1155/2012/908061
26. Vlaeyen JW, Linton SJ. Fear-avoidance and its consequences in chronic musculoskeletal pain: a state of the art. *Pain.* (2000) 85:317–32. doi: 10.1016/S0304-3959(99)00242-0
27. Wilson AC, Lewandowski AS, Palermo TM. Fear-avoidance beliefs and parental responses to pain in adolescents with chronic pain. *Pain Res Manag.* (2011) 16:178–82. doi: 10.1155/2011/296298
28. Silverberg ND, Panenka WJ, Iverson GL. Fear avoidance and clinical outcomes from mild traumatic brain injury. *J Neurotrauma.* (2018) 35:1864–73. doi: 10.1089/neu.2018.5662
29. Wijenberg MLM, Stapert SZ, Verbunt JA, Ponsford JL, Van Heugten CM. Does the fear avoidance model explain persistent symptoms after traumatic brain injury? *Brain Injury.* (2017) 31:1597–604. doi: 10.1080/02699052.2017.1366551
30. Bailey KM, Carleton RN, Vlaeyen JWS, Asmundson GJG. Treatments addressing pain-related fear and anxiety in patients with chronic musculoskeletal pain: a preliminary review. *Cogn Behav Ther.* (2010) 39:46–63. doi: 10.1080/16506070902980711
31. Harris PA, Taylor R, Minor BL, Elliott V, Fernandez M, O'Neal L, et al. The REDCap consortium: building an international community of software platform partners. *J Biomed Inf.* (2019) 95:103208. doi: 10.1016/j.jbi.2019.103208
32. McCrory P, Meeuwisse W, Dvorak J, Aubry M, Bailes J, Broglio S, et al. Consensus statement on concussion in sport-the 5 th international conference on concussion in sport held in Berlin, October 2016. *Br J Sports Med.* (2017) 51:838–47. doi: 10.1136/bjsports-2017-097699
33. Moran LM, Taylor HG, Rusin J, Bangert B, Dietrich A, Nuss KE, et al. Do postconcussive symptoms discriminate injury severity in pediatric mild traumatic brain injury? *J Head Trauma Rehabil.* (2011) 26:348–54. doi: 10.1097/HTR.0b013e3181f8d32e
34. Allor KM, Pivarnik JM. Use of heart rate cutpoints to assess physical activity intensity in sixth-grade girls. *Pediatr Exerc Sci.* (2000) 12:284–92. doi: 10.1123/pes.12.3.284
35. Simons-Morton BG, Parcel GS, O'Hara NM, Blair SN, Pate RR. Health-related physical fitness in childhood: status and recommendations. *Annu Rev Public Health.* (1988) 9:403–25. doi: 10.1146/annurev.pu.09.050188.002155
36. Piercy KL, Troiano RP, Ballard RM, Carlson SA, Fulton JE, Galuska DA, et al. The physical activity guidelines for Americans. *JAMA.* (2018) 320:2020–8. doi: 10.1001/jama.2018.14854
37. *Common Data Elements for Traumatic Brain Injury*. National Institutes of Health. Available online at: https://www.commondataelements.ninds.nih.gov/Traumatic%20Brain%20Injury#pane-162 (accessed March 22, 2021).
38. Yeates KO, Luria J, Bartkowski H, Rusin J, Martin L, Bigler ED. Postconcussive symptoms in children with mild closed head injuries. *J Head Trauma Rehabil.* (1999) 14:337–50. doi: 10.1097/00001199-199908000-00003
39. Ayr LK, Yeates KO, Taylor HG, Browne M. Dimensions of postconcussive symptoms in children with mild traumatic brain injuries. *J Int Neuropsychol Soc.* (2009) 15:19–30. doi: 10.1017/S1355617708090188
40. Taylor HG, Dietrich A, Nuss K, Wright M, Rusin J, Bangert B, et al. Post-concussive symptoms in children with mild traumatic brain injury. *Neuropsychology.* (2010) 24:148–59. doi: 10.1037/a0018112
41. Fay TB, Yeates KO, Taylor HG, Bangert B, Dietrich A, Nuss KE, et al. Cognitive reserve as a moderator of postconcussive symptoms in children with complicated and uncomplicated mild traumatic brain injury. *J Int Neuropsychol Soc.* (2010) 16:94–105. doi: 10.1017/S1355617709991007
42. Hajek C a, Yeates KO, Taylor HG, Bangert B, Dietrich A, Nuss KE, et al. Agreement between parents and children on ratings of post-concussive symptoms following mild traumatic brain injury. *Child Neuropsychol.* (2011) 17:17–33. doi: 10.1080/09297049.2010.495058
43. Varni JW, Seid M, Kurtin PS. PedsQL 4.0: reliability and validity of the Pediatric Quality of Life Inventory version 4.0 generic core scales in healthy and patient populations. *Med Care.* (2001) 39:800–12. doi: 10.1097/00005650-200108000-00006
44. Simons LE, Sieberg CB, Carpino E, Logan D, Berde C. The Fear of Pain Questionnaire (FOPQ): assessment of pain-related fear among children and adolescents with chronic pain. *J Pain.* (2011) 12:677–86. doi: 10.1016/j.jpain.2010.12.008
45. Turk DC, Wilson HD. Fear of pain as a prognostic factor in chronic pain: conceptual models, assessment, and treatment implications. *Curr Pain Headache Rep.* (2010) 14:88–95. doi: 10.1007/s11916-010-0094-x
46. Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. *J Gen Intern Med.* (2001) 16:606–13. doi: 10.1046/j.1525-1497.2001.016009606.x
47. Richardson LP, McCauley E, Grossman DC, McCarty C a, Richards J, Russo JE, et al. Evaluation of the Patient Health Questionnaire-9 Item for detecting major depression among adolescents. *Pediatrics.* (2010) 126:1117–23. doi: 10.1542/peds.2010-0852
48. Fann JR, Bombardier CH, Dikmen S, Esselman P, Warms CA, Pelzer E, et al. Validity of the Patient Health Questionnaire-9 in assessing depression following traumatic brain injury. *J Head Trauma Rehabil.* (2005) 20:501–11. doi: 10.1097/00001199-200511000-00003
49. Löwe B, Unützer J, Callahan CM, Perkins AJ, Kroenke K. Monitoring depression treatment outcomes with the patient health questionnaire-9. *Med Care.* (2004) 42:1194–201. doi: 10.1097/00005650-200412000-00006
50. Maizels M, Smitherman TA, Penzien DB. A review of screening tools for psychiatric comorbidity in headache patients. *Headache.* (2006) 46:98–109. doi: 10.1111/j.1526-4610.2006.00561.x
51. Spitzer RL, Kroenke K, Williams JBW, Löwe B. A brief measure for assessing generalized anxiety disorder. *Arch Intern Med.* (2006) 166:1092. doi: 10.1001/archinte.166.10.1092
52. Löwe B, Decker O, Müller S, Brähler E, Schellberg D, Herzog W, et al. Validation and standardization of the Generalized Anxiety Disorder Screener (GAD-7) in the general population. *Med Care.* (2008) 46:266–74. doi: 10.1097/MLR.0b013e318160d093
53. Essner B, Noel M, Myrvik M, Palermo T. Examination of the factor structure of the Adolescent Sleep-Wake Scale (ASWS). *Behav Sleep Med.* (2015) 13:296–307. doi: 10.1080/15402002.2014.896253
54. Braun V, Clarke V. Thematic analysis. In Cooper H, Camic PM, Long DL, Panter AT, Rindskopf D, Sher KJ, editors. *APA Handbook of Research Methods in Psychology, Vol. 2: Research Designs: Quantitative, Qualitative,*

Neuropsychological, Biological (ORCID: 0000-0002-4444-6544). Washington, DC: American Psychological Association (2012). p. 57–71.

55. Kuznetsova A, Brockhoff PB, Christensen RH. lmerTest package: tests in linear mixed effects models. *J Stat Softw*. (2017) 82:1–26. doi: 10.18637/jss.v082.i13
56. R Core Team. *A Language and Environment for Statitistical Computing*. Vienna: R Foundation for Statistical Computing (2020). Available online at: https://www.R-project.org/ (accessed March 22, 2021).
57. Leddy JJ, Baker JG, Kozlowski K, Bisson L, Willer B. Reliability of a graded exercise test for assessing recovery from concussion. *Clin J Sport Med*. (2011) 21:89–94. doi: 10.1097/JSM.0b013e3181fdc721

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

APPENDIX

Table A1 | Output from mixed effects regression modeling examining trajectory of concussive symptoms, mental health symptoms, sleep, health-related quality of life, and fear-avoidance during the Mobile Subthreshold Exercise Program (MSTEP) for concussion, Seattle, WA 2018–2019.

Outcome	3 Weeks vs. Baseline[g]		6 Weeks vs. Baseline[g]	
	β (95% CI)	*P*-value	β (95% CI)	*P*-value
HBI[a]	−7.12 (−12.50, −1.77)	0.01	−10.60 (−16.00, −5.10)	0.0002
GAD-7[b]	−2.61 (−4.78, −0.45)	0.019	−4.28 (−6.54, −2.02)	0.0003
PHQ-9[c]	−3.97 (−6.05, −1.89)	0.0002	−5.97 (−8.10, −3.85)	<0.0001
ASWS[d]	3.06 (−0.15, 6.27)	0.06	7.67 (4.40, 11.00)	<0.0001
PedsQL[e]	9.33 (2.85, 15.80)	0.005	15.10 (8.56, 21.60)	<0.0001
FOPQ[f]	−12.40 (−20.40, −4.42)	0.003	−21.60 (−29.80, −13.50)	<0.0001

[a]HBI, Health and Behavior Inventory (concussive symptoms); [b]GAD-7, Generalized Anxiety Disorder-7 item; [c]PHQ9, Patient Health Questionnaire-9 item; [d]ASWS, Adolescent Sleep Wake Scale; [e]PedsQL, Pediatric Quality of Life Survey (youth self-report); [f]FOPQ, Fear of Pain Questionnaire (youth self-report, adapted for concussive symptoms); [g]All models controlled for child age, sex, duration of symptoms, and prior concussion history.

frontiers in Pediatrics

ORIGINAL RESEARCH
published: 10 June 2021
doi: 10.3389/fped.2021.642381

Telehealth for Children With Epilepsy Is Effective and Reduces Anxiety Independent of Healthcare Setting

Kerstin Alexandra Klotz[1,2,3]*, *Felippe Borlot*[4], *Morris H. Scantlebury*[4,5], *Eric T. Payne*[4,5], *Juan Pablo Appendino*[5], *Jan Schönberger*[1,2,3] and *Julia Jacobs*[1,4,5]

[1] Department of Neuropediatrics and Muscle Disorders, Faculty of Medicine, Medical Center-University of Freiburg, University of Freiburg, Freiburg, Germany, [2] Faculty of Medicine, Epilepsy Center, Medical Center-University of Freiburg, University of Freiburg, Freiburg, Germany, [3] Berta-Ottenstein-Programme, Faculty of Medicine, University of Freiburg, Freiburg, Germany, [4] Cumming School of Medicine, Alberta Children's Hospital Research Institute and Hotchkiss Brain Institute, University of Calgary, Calgary, AB, Canada, [5] Section of Neurology, Department of Pediatrics, Alberta Children's Hospital, Cumming School of Medicine, University of Calgary, Calgary, AB, Canada

OPEN ACCESS

Edited by:
*Mark Lo,
University of Washington,
United States*

Reviewed by:
*Edward Novotny,
University of Washington,
United States
Luca De Palma,
Bambino Gesù Children Hospital
(IRCCS), Italy
Brenda Elaine Porter,
Stanford University, United States
Friederike Moeller,
Great Ormond Street Hospital for
Children NHS Foundation Trust,
United Kingdom*

***Correspondence:**
*Kerstin Alexandra Klotz
kerstin.alexandra.klotz@uniklinik-freiburg.de*

Specialty section:
*This article was submitted to
Pediatric Neurology,
a section of the journal
Frontiers in Pediatrics*

Received: *15 December 2020*
Accepted: *19 April 2021*
Published: *10 June 2021*

Citation:
Klotz KA, Borlot F, Scantlebury MH, Payne ET, Appendino JP, Schönberger J and Jacobs J (2021) Telehealth for Children With Epilepsy Is Effective and Reduces Anxiety Independent of Healthcare Setting. Front. Pediatr. 9:642381. doi: 10.3389/fped.2021.642381

Objectives: The use of telemedicine has grown exponentially as an alternative to providing care to patients with epilepsy during the pandemic. We investigated the impact of the current pandemic among children with epilepsy from two distinct pediatric epilepsy centers. We also compared perceptions among those who received telemedicine against those who did not.

Methods: We developed a questionnaire and invited families followed in Freiburg, Germany, and Calgary, Alberta, Canada, to participate during the initial 9 months of the pandemic. The survey contained 32 questions, 10 of which were stratified according to telemedicine exposure.

Results: One hundred twenty-six families (80 in Freiburg, 46 in Calgary) participated, and 40.3% received telemedicine care. Most children (mean age 10.4 years, *SD* 5.1) had chronic epilepsy but poorly controlled seizures. Negative impacts were reported by 36 and 65% of families who had to reschedule appointments for visits and diagnostics, respectively. Nearly two-thirds of families reported no change in seizure frequency, while 18.2% reported either worsening or improvement of seizures. Although most families did not note behavioral changes, 28.2% reported behavior worsening. Families who received telemedicine care had a statistically significant reduction of parental self-reported anxiety level after virtual visits compared to those who did not experience telemedicine. Families with telemedicine consultations were more likely to consider future virtual care (84 vs. 65.2% of those without), even after the pandemic. Patient data safety, easy access to specialized services, and consistency with the same healthcare provider were graded as important in both centers, while a shorter waiting time was most relevant in Calgary.

Conclusion: In our cohort, some children with epilepsy experienced increased seizures and worsening behavior during the first 9 months of the current pandemic. In addition, our data suggest that telemedicine might reduce parental anxiety symptoms, and families who experienced telehealth were more positive and open to similar appointments in the future.

Keywords: epilepsy, telehealth, anxiety, COVID pandemic, seizures, health system

INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic has had a substantial impact on the way healthcare providers and institutions deliver care worldwide. Face-to-face outpatient services were abruptly closed, and many families of chronically ill children were left without the expected support. Indeed, among children with epilepsy, regular medical support is of paramount importance given the unpredictability of seizures and the complex care many of these patients require, including developmental and behavioral challenges (1).

Telemedicine use has grown exponentially as an option for epilepsy care and decreases the risk of COVID-19 exposure for families and healthcare providers. Even though telemedicine has been successfully used to provide epilepsy care for over a decade in some centers (2, 3), it was underutilized in epilepsy care before the pandemic (4). Initially designed to provide care in rural and remote areas, telemedicine effectiveness and patients' and providers' high satisfaction rates have encouraged its implementation in several centers (3, 5–7). In addition, virtual visits may also save costs for patients (3). Furthermore, with communication tools becoming easily accessible throughout the world, many patients and providers have expressed their willingness to incorporate both in-person and virtual appointments (7, 8).

Although recent studies have shown that telemedicine is feasible and effective in child neurology and epilepsy care (3, 5, 9), scattered data are available for the current pandemic, including how parents of children with epilepsy perceive the pandemic is impacting their child's overall health, seizures, and behavior and parental anxiety levels and whether direct exposure to telemedicine impacts these perceptions.

The objectives of this study were (i) to investigate the consequences of the pandemic as reported by families followed in two pediatric epilepsy centers, one in Canada and one in Germany; (ii) to compare families with and without telemedicine experience during the first 9 months of the pandemic; and, finally; (iii) to learn what families consider important when it comes to telemedicine.

MATERIALS AND METHODS

We developed a structured and stratified questionnaire using an online survey tool and invited families with outpatient appointments scheduled between February and October 2020 to participate. Our questionnaire was developed to obtain an overview of parents' perception in the way we had to adapt delivery of care during the pandemic and their feelings about the pandemic-related acute measures, rather than assessing specific intervention effects of telemedicine. For participating, patients must have been diagnosed with epilepsy by a pediatric neurologist, according to the International League Against Epilepsy (ILAE) criteria (10). A short introduction explained the term "telehealth" to all participants. The survey contained 32 questions with the last 10 modified depending on whether the patient had or had not participated in a telemedicine consultation. The survey started with questions about the patient's age and epilepsy history, including age at first seizure, current treatment, seizure frequency, and routine epilepsy-care schedule. The second part included questions about scheduled appointments and diagnostics during the pandemic, the impact of changed or canceled appointments on the child's health, and the impact of pandemic-related restrictions on the child's health. The third part focused on telemedicine, including what technical equipment was available in their household. Depending on whether the patients had telemedicine care during the pandemic, the questions were stratified. From those participants reporting previous telemedicine appointments, information about the following topics were asked: provider specialty using telemedicine, type of medium used, and whether the appointment was considered helpful regarding several aspects of the child's epilepsy. For families without previous telemedicine appointments during the pandemic, the survey included questions about their media preferences, expectations, and whom they would prefer to conduct a virtual health consultation. Finally, all participants were asked about the importance of data protection, accessibility, other aspects of telehealth consultations, preferred media, and reasons to consider telehealth in the future even after the pandemic. This survey was approved by the ethics committees from both Albert-Ludwigs-Universität Freiburg (No. 68/18) in Germany and Alberta Children's Hospital Research Institute (REB20-0670) in Canada. The English and German versions of the survey are available in the **Supplementary Material** (Survey Telehealth English version and Survey Telehealth German version).

Descriptive statistical analysis was performed with GraphPad Prism (V. 9.0, GraphPad Software, San Diego, CA, USA). Categorical variables are presented in absolute numbers and percentages and quantitative data as means and standard deviations. Percentages apply to the number of answers for any given question. A Fisher exact test was used for group comparisons of categorical and ordinal values and a Mann–Whitney U test for comparison of numerical values. *P*-values $\leq$0.05 were regarded as statistically significant.

RESULTS

Demographics, Cancelations, and Impact of the Pandemic in the Study Population

Overall, 80 families in Freiburg and 46 families in Calgary answered the questionnaire. The response rate was 41.5% (126/303). Of those, 119 questionnaires were complete and could be included for analysis. For details about patients' epilepsy and routine epilepsy care, see **Table 1**. Most participants reported more than one available technical equipment for telemedicine in their household, and the following devices were available: phone 94.6% (n = 106), Wi-Fi 93.8% (n = 105), tablet with camera 86.8% (n = 97), personal computer with camera 83.0% (n = 93), and chat programs 80.4% ($n = 90$).

At the onset of the pandemic, 63.8% (n = 76/119) had an outpatient appointment scheduled or were waiting for an appointment. In 32.9% (n = 25/76) of those, the appointment

TABLE 1 | Patient characteristics.

	All (n = 126)	Freiburg (n = 80)	Calgary (n = 46)	P-value
Age in years mean (SD)	10.4 (5.1)	10.0 (5.2)	11.2 (4.8)	0.08
First seizure n (%)				
Within 1 month	14 (11.3)	10 (12.8)	4 (8.7)	0.57
Within 1 year	9 (7.3)	2 (2.6)	7 (15.2)	0.01
Within 1–5 years	40 (32.3)	31 (39.7)	9 (19.6)	0.03
>5 Years ago	61 (49.1)	35 (44.9)	26 (56.5)	0.27
Seizures within 12 months	93 (74.4)	57 (73.1)	36 (76.6)	0.53
Currently on any ASM	118 (95.2)	75 (96.2)	43 (93.5)	1.0
Change of therapy within the last 12 months	67 (54.0)	41 (52.6)	26 (56.2)	0.58
Seizure frequency				
Daily	33 (37.1)	20 (37.0)	13 (37.2)	0.26
Weekly	14 (15.7)	8 (14.8)	6 (17.1)	0.36
Monthly	22 (24.7)	15 (27.8)	7 (20.0)	1.0
Less than monthly	20 (22.5)	11 (20.4)	9 (25.7)	0.18
Tonic–clonic seizures n (%)				
Never	39 (32.2)	25 (32.9)	14 (31.1)	1.0
Past only	47 (38.8)	29 (38.2)	18 (40.0)	0.57
Recently	35 (28.9)	22 (28.9)	13 (28.9)	1.0
History of prolonged seizures n (%)	49 (40.2)	36 (47.4)	13 (28.3)	0.09
Epilepsy care				
By pediatric neurologist	114 (94.2)	71 (93.4)	43 (95.6)	1.0
By pediatrician	6 (5.0)	4 (5.3)	2 (4.4)	1.0
By family physician	1 (0.8)	1 (1.3)	0	1.0
Scheduled outpatient appointments				
Monthly	6 (5.0)	6 (8.0)	0	0.08
3–4 Times per year	48 (39.7)	30 (40.0)	18 (39.1)	1.0
Twice per year	49 (40.4)	33 (44.0)	16 (34.8)	0.35
Annually or less	18 (14.9)	6 (8.0)	12 (26.1)	0.009

Percentages calculated by number of responses for each question. ASM, anti-seizure medication.

could take place as scheduled, in 40.8%, it was canceled and replaced by a virtual consultation; in 14.5%, it was canceled and replaced by a later appointment; and in 11.8%, it was canceled without an alternative appointment. For those 51 cases that a scheduled appointment had to be changed, the majority (62%) felt that it did not impact their child's health, but 36% felt a negative impact either because treatment or planning of further diagnostics was delayed (28%) or because important questions were not addressed (8%). Diagnostic tests were scheduled in 26.9% of patients ($n = 32/119$) at the beginning of the pandemic, including electroencephalogram (EEG; n = 11), video-EEG monitoring (n = 8), MRI (n = 3), PET (n = 1), and others (renal ultrasound, n = 1; sleep study, n = 1; ophthalmologist appointment, n = 1). Of those, diagnostic tests took place as scheduled in 37.5%, but in 43.8%, these investigations were canceled with a postponed appointment; in 18.8%, canceled tests were left without an alternative. In most cases (65%), parents were concerned about a negative impact on their child's health if diagnostic appointments were canceled or postponed mainly because diagnostics were necessary to change or initiate a certain treatment (69%). During the pandemic-related restrictions, the majority of parents observed no change in overall health (59.5%, $n = 47/79$), seizure frequency (63.6%, $n = 49/77$), or behavior (52.6%, $n = 41/78$); whereas 25.3% ($n = 20/79$) observed an improvement in overall health, 18.2% ($n = 14/77$) in seizure frequency, and 19.2% ($n = 15/78$) in behavior. Worsening of overall health was reported in 15.2% ($n = 12/79$), of seizure frequency in 18.2% ($n = 14/77$), and of behavior in 28.2% ($n = 22/79$). Nearly one-third of parents reported anxiety that their child's epilepsy would worsen during the pandemic (30.7%, 35/114).

Telemedicine Experience Vs. No Telemedicine Experience

Overall, 40.3% ($n = 48/119$) of participants received telemedicine care, and some of these patients were seen more than once and used different media. Appointments regarding the epilepsy were mainly with pediatric neurologists (76.6%, n = 36), and in some cases, with their pediatrician (23.4%), family physician (12.8%), a registered nurse (12.8%), or other subspecialties including neurosurgeons or metabolic clinics (19.1%). Phone was the medium used in most telehealth appointments (83%, n = 39), whereas Internet services (specialized telemedicine platform, email, etc.) were used by 57.4%. Almost all families perceived the virtual consultation as helpful (95.5%, n = 42/44). Within the comments, parents stated that it was helpful because "*many aspects, e.g., adapting the medication or counseling can be easily done over the phone*." Others stated that it was not helpful because "*telehealth is less personal and it is hard to build a relationship, especially for autistic or severely impaired children*." Compared to in-person appointments, 47.7% (n = 21/44) found telemedicine efficient, 38.6% (n = 17) nearly as efficient, and 13.6% (n = 6) found it only partially helpful. Thirty-two percent (n = 14/44) had to come to the hospital despite virtual visits because (i) it was recommended during the telemedicine consultation (42.8%), (ii) acute deterioration (28.6%), or (iii) unrelated to epilepsy (28.6%). For further telemedicine consultations, most families would prefer phone calls (46.5%, n = 20) or online video chats (41.9%); only 7.0% would prefer a telehealth platform, and none would prefer the consultation to be *via* email.

At the time of the survey, 59.6% (n = 71/119) of all families had not experienced telemedicine. If this modality was needed and available in the near future, most families expected it to be with a pediatric neurologist (89.8%, n = 62) and *via* Internet services (58.5%) or *via* phone (48.6%). Sixty-seven percent expected it to be helpful, and reasons stated were that "*telehealth is an option during quarantine and lockdown to get in contact with a medical professional*." Of those expecting telehealth not to be helpful, comments included "*no diagnostics possible*" and the fact that "*contact would be mainly between parents and physician, not so much with the child*." Virtual appointments were expected to be as efficient in 17.1% (n = 12/70), nearly as efficient in 38.6%, partially helpful in 35.7%, and not helpful in 8.6%.

Parental Self-Reported Anxiety Levels, Differences Between the Two Centers, and Other Relevant Aspects of Telemedicine

Related to parental anxiety levels, relevant differences were seen between families with and without previous telemedicine experience. In both groups, roughly 30% expected that anxiety symptoms could worsen during the pandemic. However, parents with telemedicine experience reported a reduction of anxiety after a telemedicine consultation, while the great majority of parents with no experience would not believe that their anxiety levels would reduce very much after a virtual consultation (**Figure 1**). Also, 84% of families with previous telemedicine consultations (vs. 65.2% of those with no telemedicine experience) would be more likely to consider changing all or some of their appointments to telemedicine in the future, even after the pandemic. Conversely, 34.8% of families who did not experience virtual appointments (vs. only 15.9% of those who did, $P = 0.03$) would not consider changing all or most of their future appointments (**Table 2**).

There were a few differences between families from Freiburg and families from Calgary. From the patient characteristics (**Table 1**), there were statistically significant differences in regard to scheduled outpatient appointments with neurology. Monthly outpatient visits were reported only in Freiburg (8 vs. 0%, $P = 0.08$), while 26% of Calgary families reported annual or less frequent visits (vs. 8% in Freiburg, $P = 0.009$). When asked how long they felt they could handle their child's disease with virtual appointments only before presenting to an emergency department, 8.7% of families from Freiburg reported a time frame of <1 month, 44.9% between 2 and 6 months, 34.8% between 6 and 12 months, and 11.6% more than 12 months. In Calgary, 2.4% of families reported a time frame of <1 month, 9.5% between 2 and 6 months, 45.2% between 6 and 12 months, and 42.9% more than 12 months. There were also differences between the two centers regarding the importance of health consultations and reasons to consider telemedicine even after the pandemic (**Figures 2A,B**).

DISCUSSION

Our study gathered 126 responses from two distinct pediatric epilepsy centers during the first 9 months of the COVID-19 pandemic. Although geographically apart, the patient populations studied were similar in the two centers consisting of children (mean age 10.4 years, *SD* 5.1) with chronic epilepsy but poorly controlled seizures in the past 12 months, many of whom required recent medication changes. In keeping with another survey carried out in North America, technology access telemedicine was not a limitation to our patients (7). However, one should consider limited access to Internet as a relevant barrier for virtual clinics in underdeveloped countries, and telephone contact should be prioritized (11).

One small difference we noted between the two centers was the frequency patients are seen by their neurologists (**Table 1**). In Calgary, 26.1% of children are seen yearly or less frequently compared to 8% of children in Freiburg. This finding purely reflects the wait-list aspects from both centers, showing that follow-up visits are usually more frequent in Germany. One explanation for this could be that registered nurses and family practitioners are often involved in epilepsy patient care in Calgary. Also, this slight difference reflects families' perception about their ability to manage their child's disease only virtually before having to come to the emergency department. In Freiburg, most responders felt that they could handle it for 2–6 months, and only 11.6% responded more than 12 months. On the other hand, the majority of families from Calgary responded 6–12 months, closely followed by a time frame of 12 months reported by more than 40%. Considering similar patient populations, this difference might suggest that because of longer wait times to see a neurologist regularly, families may develop more autonomy and confidence over time, as well as less need to visit emergency services.

For families that had to cancel or reschedule outpatient visits, more than a third were concerned about negative impacts on their child's health. Furthermore, for those who had diagnostic tests rescheduled or canceled, nearly two-thirds felt the same way. Another study from Germany (12) has also pointed to epilepsy patient frustrations and concerns after the latest changes

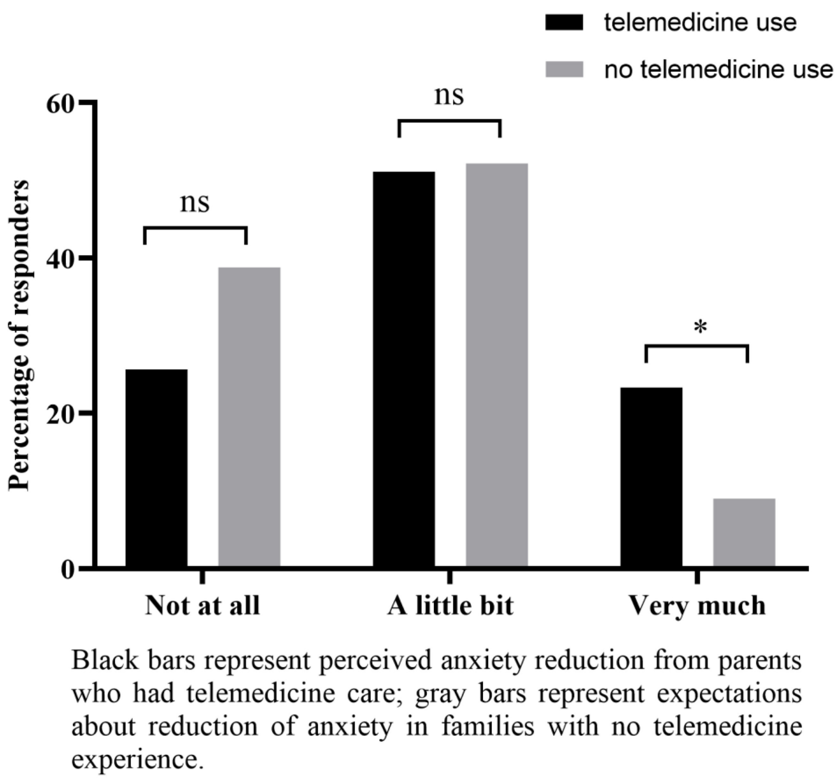

FIGURE 1 | Perceived reduction of anxiety because of telehealth consultation (parents who received telemedicine care) and expected reduction of anxiety in case of a future telehealth consultation (parents with no telemedicine experience). **P*-value ≤ 0.05; ns, not significant.

TABLE 2 | Consideration of future telemedicine consultations.

Would you consider changing all or most of your appointments to this form if possible, even after the pandemic?			
	Previous use of telemedicine ($n = 44$)	**No previous use of telemedicine ($n = 69$)**	***P*-value**
Yes, all	4 (9.1)	8 (11.6)	0.76
Yes, some	33 (75.0)	37 (53.6)	0.03
No, I prefer personal appointments	7 (15.9)	24 (34.8)	0.03

in the way care is currently delivered. Only a minority of patients (12.5%) followed in a tertiary epilepsy center in Frankfurt showed lack of understanding or reacted with anger after having their in-person visits canceled. As our patients stated, some of their concerns were also related to diagnostic and potential treatment delays. We believe that under normal circumstances, perhaps these abrupt visit cancelations would not impact the majority of people; however, given all the psychological distress caused by the current outbreak (13), services might consider offering coping mechanism strategies for families should future abrupt cancelations be required.

Even though one-third of parents revealed anxiety with the possibility of increased seizures during the pandemic, overall, this was not commonly noted. While worsening of behavior was reported by 28.2% of families, increased seizures and worsening of overall health were, respectively, noted in 18.2 and 15.2%. Similarly, from 109 telemedicine appointments in Frankfurt, 14.7% also reported increased seizure frequency (12). At this point, it is unclear whether these reported symptoms can be truly related to stress or any other pandemic-related cause, given the fluctuations usually seen in patients with chronic and uncontrolled epilepsies. Ideally, a baseline standardized assessment (including seizure frequency, emergency department visits, and rescue medication utilization) prior and during the pandemic would be necessary to evaluate whether an association exists between restrictive measures and seizure burden. However, consistent with our study, among 255 adult epilepsy patients studied during the first month of confinement in Spain, only 10% reported an increase in seizure frequency (14). These authors noted a higher risk of increased seizures due to tumor-related

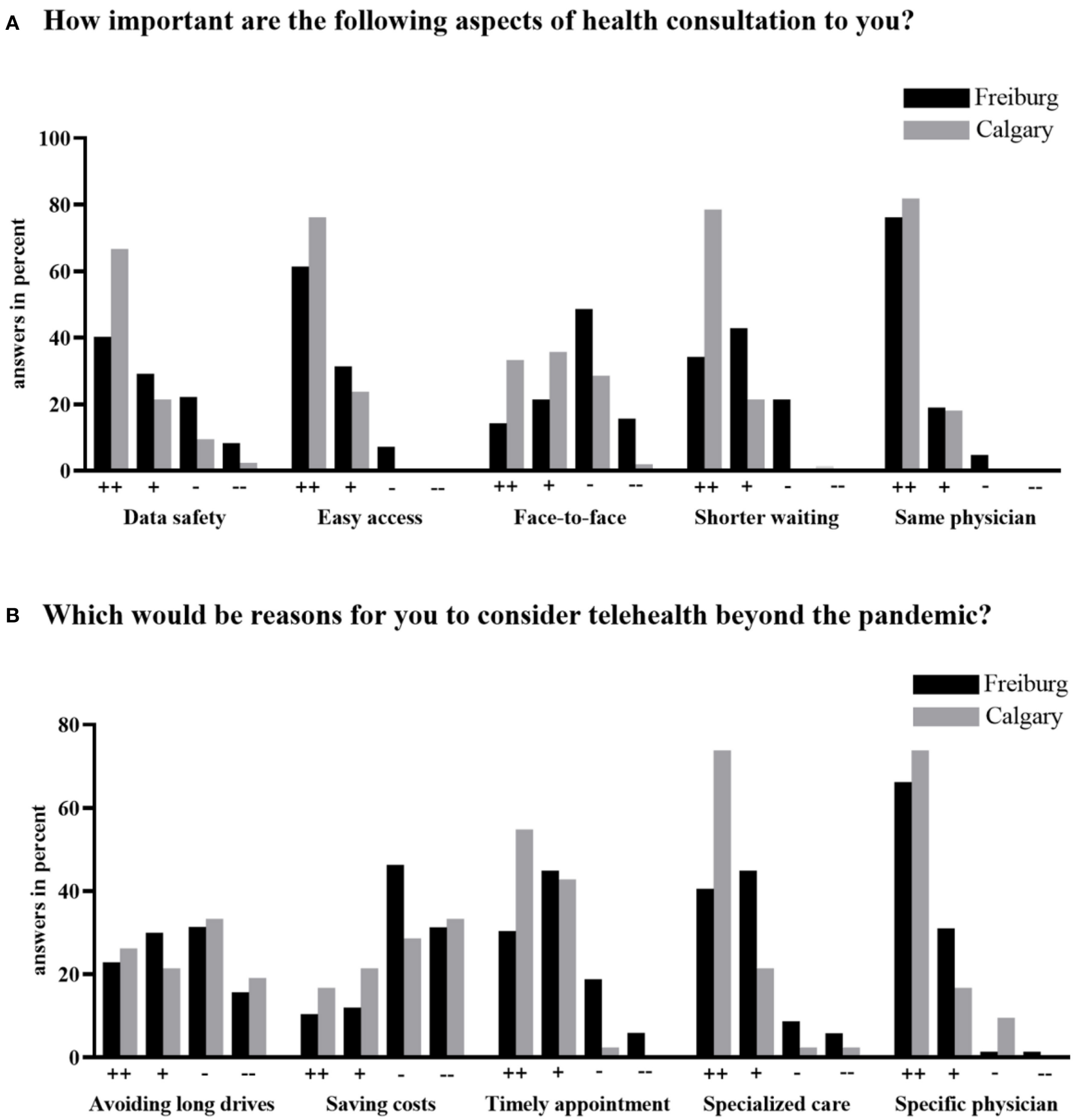

FIGURE 2 | Importance of health consultations in general **(A)** and reasons to consider telehealth beyond the time of the pandemic **(B)** reported by families in Freiburg, Germany ($n = 72$) and Calgary, Alberta, Canada ($n = 42$).

seizures, medically refractory epilepsy, insomnia, fear of epilepsy, and income reduction.

After comparing families with and without telemedicine experience, we have found statistically significant differences related to self-reported parental anxiety after experiencing virtual visits, albeit no objective scales were used. While only 9% of parents who have not tried telemedicine expected anxiety to decrease "very much," 20% of those who had tried telemedicine declared that their anxiety levels were reduced "very much." These data reinforce the efficacy of telemedicine in epilepsy care compared to face-to-face visits not only by epilepsy parameters such as seizure frequency, emergency room visits, and hospital admissions (2) but also addressing parental concerns.

Further analyses of data comparison from families with and without telemedicine experience have shown that while the former group would be willing to switch all or most of their future appointments to virtual visits, the latter group was opposed to this change. This reluctance observed in families without prior telemedicine experience also reflects their impression that virtual visits are only partially (35.7%) or not (8.6%) helpful, as opposed to nearly 90% of families who have experienced telemedicine and reported this modality as nearly or as efficient as face-to-face visits. The impression from our families who have been exposed to telemedicine supports several other research data. Twelve years before the current outbreak, a pilot study investigated the satisfaction with telemedicine among epilepsy patients from rural areas of Alberta (3). Aside from being very satisfied with telemedicine, more than 90% of these patients were willing to have their follow-up appointments through the same method. Moreover, all patients in the telemedicine group agreed that telemedicine saved money compared to in-person visits.

Over the past year, many epilepsy centers worldwide have shared their experience in regard to patients' or families' perception of telemedicine usefulness either in adults and pediatrics. High levels of satisfaction over 85% have been consistently noted in all studies (6, 8, 14, 15). Given the elevated satisfaction level noted among healthcare providers as well (9, 16), we believe that even after the pandemic, most epilepsy centers will implement telemedicine as part of their routine care. However, some limitations related to telemedicine should be recognized, including unexpected technical issues, lack of an appropriate reimbursement policy, impossibility to perform a full neurological exam, and lack of privacy for teenagers when attending visits from their parents' house (17).

Finally, when it comes to what families consider relevant in telemedicine, families from both centers agreed upon data safety, easy access to services, and consistency of services offered by the same familiar healthcare provider. A shorter waiting time was most relevant in Calgary, where longer waiting times exist. Likewise, timely appointments were nearly 100% rated as important or very important in Calgary for families to consider telehealth beyond the pandemic. Another relevant aspect consistently graded as important in both centers was their access to specialized care, while economic aspects were not seen as important for most families. Given the complexity of patients seen in both centers, these data suggest that families would prioritize telemedicine in order to keep their children's follow-up linked to epilepsy specialists and specialized centers.

Our study has some limitations. The patient samples from both centers may not represent newly diagnosed children with epilepsy, given that more than 80% of our families reported seizures for more than 12 months. Therefore, it is uncertain whether the level of parental anxiety in newly diagnosed cases changed with telemedicine, as our sample size did not allow us to explore this further. Furthermore, patient symptom evaluation consisted of a pure description of parental perception rather than objective measures or scales. In order to confirm our findings, future studies should use standardized methods to measure anxiety levels in parents and patients before and after telemedicine experience. Among several tools, the State–Trait Anxiety Inventory (STAI) has been translated and adapted in 48 languages (18). In addition, the Epilepsy Anxiety Survey Instrument (EASI) can be used specifically for people with epilepsy (19). One intrinsic issue from survey studies is the non-response bias. Our study might have a nearly 60% non-response bias if the opinions of non-responders differ substantially from those of responders. In addition, there is also a potential selection bias, given that the families who agreed to participate in an online survey are likely to have better knowledge and acceptance of telemedicine overall.

CONCLUSIONS

Some children with epilepsy and their families have been negatively impacted by the pandemic, including worsening of overall health and behavior, and increased seizures. Independent of healthcare system and cultural surroundings, our data suggest that telemedicine can be helpful in managing epilepsy, and it might reduce parental anxiety levels. In our experience, families who used telemedicine were more positive toward similar future appointments. Despite potential barriers, telemedicine use in pediatric epilepsy is a valuable care alternative for patients and healthcare providers, and it is likely to continue post pandemic.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of Freiburg Ethic Review Board, University of Calgary Ethic Review Board. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

All authors met the International Committee of Medical Journal Editors authorship criteria and had full access to relevant data. Neither honoraria nor payments were made for authorship. All authors contributed to the study concept and design and interpretation of the data. KK performed the statistical analysis. All authors contributed to manuscript revision and read and approved the submitted version.

FUNDING

The Epilepsy Program in Calgary was supported by the Alberta Children's Hospital Foundation.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fped.2021.642381/full#supplementary-material

REFERENCES

1. Adan GH, Mitchell JW, Marson T. Epilepsy care in the COVID-19 era 0207. *Clin Med.* (2020) 20:e104–6. doi: 10.7861/clinmed.2020-
2. Rasmusson KA, Hartshorn JC. A comparison of epilepsy patients in a traditional ambulatory clinic and a telemedicine clinic. *Epilepsia.* (2005) 46:767–70. doi: 10.1111/j.1528-1167.2005.44804.x
3. Ahmed SN, Mann C, Sinclair DB, Heino A, Iskiw B, Quigley D, et al. Feasibility of epilepsy follow-up care through telemedicine: a pilot study on the patient's perspective. *Epilepsia.* (2008) 49:573–85. doi: 10.1111/j.1528-1167.2007.01464.x
4. Ahmed SN, Wiebe S, Mann C, Ohinmaa A. Telemedicine and epilepsy care - a Canada Wide Survey. *Can J Neurol Sci J Can Sci Neurol.* (2010) 37:814–8. doi: 10.1017/S0317167100051490
5. Bahrani K, Singh MB, Bhatia R, Prasad K, Vibha D, Shukla G, et al. Telephonic review for outpatients with epilepsy—a prospective randomized, parallel group study. *Seizure.* (2017) 53:55–61. doi: 10.1016/j.seizure.2017.11.003
6. Fortini S, Espeche A, Caraballo R. Telemedicine and epilepsy: a patient satisfaction survey of a pediatric remote care program. *Epilepsy Res.* (2020) 165:106370. doi: 10.1016/j.eplepsyres.2020.106370
7. Casares M, Wombles C, Skinner HJ, Westerveld M, Gireesh ED. Telehealth perceptions in patients with epilepsy and providers during the COVID-19 pandemic. *Epilepsy Behav.* (2020) 112:107394. doi: 10.1016/j.yebeh.2020.107394
8. von Wrede R, Moskau-Hartmann S, Baumgartner T, Helmstaedter C, Surges R. Counseling of people with epilepsy via telemedicine: experiences at a German tertiary epilepsy center during the COVID-19 pandemic. *Epilepsy Behav.* (2020) 112:107298. doi: 10.1016/j.yebeh.2020.107298
9. Rametta SC, Fridinger SE, Gonzalez AK, Xian J, Galer PD, Kaufman M, et al. Analyzing 2,589 child neurology telehealth encounters necessitated by the COVID-19 pandemic. *Neurology.* (2020) 95:e1257–66. doi: 10.1212/WNL.0000000000010010
10. Scheffer IE, Berkovic S, Capovilla G, Connolly MB, French J, Guilhoto L, et al. ILAE classification of the epilepsies: position paper of the ILAE Commission for Classification and Terminology. *Epilepsia.* (2017) 58:512–21. doi: 10.1111/epi.13709
11. Lima MC, Sander M, dos Santos Lunardi M, Ribeiro LC, Rieger DK, Lin K, et al. Challenges in telemedicine for adult patients with drug-resistant epilepsy undergoing ketogenic diet treatment during the COVID-19 pandemic in the public healthcare system in Brazil. *Epilepsy Behav.* (2020) 113:107529. doi: 10.1016/j.yebeh.2020.107529
12. Willems LM, Balcik Y, Noda AH, Siebenbrodt K, Leimeister S, McCoy J, et al. SARS-CoV-2-related rapid reorganization of an epilepsy outpatient clinic from personal appointments to telemedicine services: a German single-center experience. *Epilepsy Behav.* (2020) 112:107483. doi: 10.1016/j.yebeh.2020.107483
13. French MT, Mortensen K, Timming AR. Psychological distress and coronavirus fears during the initial phase of the COVID-19 pandemic in the United States. *J Ment Health Policy Econ.* (2020) 23:93–100.
14. Fonseca E, Quintana M, Lallana S, Luis Restrepo J, Abraira L, Santamarina E, et al. Epilepsy in time of COVID-19: a survey-based study. *Acta Neurol Scand.* (2020) 142:545–54. doi: 10.1111/ane.13335
15. Fesler JR, Stanton S, Merner K, Ross L, McGinley MP, Bena J, et al. Bridging the gap in epilepsy care: a single-center experience of 3700 outpatient tele-epilepsy visits. *Epilepsia.* (2020) 61: e95–100. doi: 10.1111/epi.16619
16. Kuchenbuch M, D'Onofrio G, Wirrell E, Jiang Y, Dupont S, Grinspan ZM, et al. An accelerated shift in the use of remote systems in epilepsy due to the COVID-19 pandemic. *Epilepsy Behav.* (2020) 112:107376. doi: 10.1016/j.yebeh.2020.107376
17. Sattar S, Kuperman R. Telehealth in pediatric epilepsy care: a rapid transition during the COVID-19 pandemic. *Epilepsy Behav.* (2020) 111:107282. doi: 10.1016/j.yebeh.2020.107282
18. Julian LJ. Measures of anxiety. *Arthritis Care Res (Hoboken).* (2011) 63:S467–72. doi: 10.1002/acr.20561
19. Scott AJ, Sharpe L, Thayer Z, Miller LA, Hunt C, MacCann C, et al. Design and validation of two measures to detect anxiety disorders in epilepsy: the Epilepsy Anxiety Survey Instrument and its brief counterpart. *Epilepsia.* (2019) 60:2068–77. doi: 10.1111/epi.16348

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Pediatrics

ORIGINAL RESEARCH
published: 12 July 2021
doi: 10.3389/fped.2021.645236

Differential Use of Pediatric Video Visits by a Diverse Population During the COVID-19 Pandemic: A Mixed-Methods Study

Jennifer L. Rosenthal, Christina O'Neal, April Sanders and Erik Fernandez y Garcia*

Department of Pediatrics, University of California, Davis, Sacramento, CA, United States

Objective: To describe and explore pediatric ambulatory video visit use by patient characteristics during the coronavirus disease 2019 (COVID-19) pandemic.

Methods: We conducted an explanatory sequential mixed methods study with integration at the design and methods level. Phase 1 was a cross-sectional analysis of general and specialty pediatric ambulatory encounters to profile the use of video visits by patient characteristics. We performed descriptive analyses for each variable of interest and estimated a multivariable logistic regression model to analyze factors associated with the odds of having a video visit. Phase 2 was a qualitative exploration using semi-structured interviews with healthcare team members to understand the contextual factors influencing video visit usage. We used an interview guide to solicit information related to general perceptions about ambulatory video visits, reactions to the quantitative phase data, and strategies for optimizing equitable reach of video visits. Data were analyzed using a combination of deductive and inductive analysis.

Results: Among the 5,464 pediatric ambulatory encounters completed between March 11 and June 30, 2020, 2,127 were video visits. Patient factors associated with lower odds of having a video visit rather than an in-person visit included being Spanish-speaking (aOR 0.27, 95% CI 0.20–0.37) and other non-English-speaking (aOR 0.50, 95% CI 0.34–0.75) in comparison to English-speaking. Patients with public insurance also had a lower odds of having a video visit in comparison to privately insured patients (aOR 0.77, 95% CI 0.67–0.88). Qualitative interviews identified five solution-based themes: (1) Promoting video visits in a way that reaches all patient families; (2) Offering video visits to all patient families; (3) Mitigating digital literacy barriers; (4) Expanding health system resources to support families' specific needs; and (5) Engaging and empowering health system personnel to expand video visit access.

Conclusion: We identified differences in pediatric ambulatory video visit use by patient characteristics, with lower odds of video visit use among non-English-speaking and publicly insured patients. The mixed-methods approach allowed for the perspectives of our interview participants to contextualize the finding and lead to suggestions for improvement. Both our findings and the approach can be used by other health systems to ensure that all patients and families receive equal video visit access.

Keywords: telemedicine, COVID-19, pediatrics, ambulatory care, health equity

OPEN ACCESS

Edited by:
Mark Lo,
University of Washington,
United States

Reviewed by:
Lyndsay Harshman,
The University of Iowa, United States
Aviva Michelle Goldberg,
University of Manitoba, Canada

****Correspondence:***
Jennifer L. Rosenthal
rosenthal@ucdavis.edu

Specialty section:
This article was submitted to Pediatric Nephrology, a section of the journal Frontiers in Pediatrics

Received: *22 December 2020*
Accepted: *07 May 2021*
Published: *12 July 2021*

Citation:
Rosenthal JL, O'Neal C, Sanders A and Fernandez y Garcia E (2021) Differential Use of Pediatric Video Visits by a Diverse Population During the COVID-19 Pandemic: A Mixed-Methods Study. Front. Pediatr. 9:645236. doi: 10.3389/fped.2021.645236

INTRODUCTION

Telehealth is defined as the use of medical information exchanged via electronic communications to support and provide health care (1). Live encounters that involve real-time, synchronous, bi-directional audio and videoconferencing between patients and their health care providers (hereafter known as "video visits") are a form of telehealth. Recognized benefits of video visits include mitigating healthcare access barriers related to geography, time, finances, and unique circumstances such as travel burdens for technology-dependent children (2–4). The American Academy of Pediatrics promotes telehealth as a strategy to increase continuity, efficiency, and quality in pediatric healthcare (5).

The coronavirus disease 2019 (COVID-19) pandemic has accelerated the adoption of video visit use for ambulatory patient care encounters (6–10), in great part to preserve personal protective equipment and minimize the transmission risk of infection to healthcare providers, patients, and families. In order to facilitate the adoption of video visits during this unprecedented time, changes in reimbursement, HIPAA (Health Insurance Portability and Accountability Act), and licensure regulations have been implemented (11–13).

Experts have raised concerns that the expanded use of healthcare-related technology during COVID-19 can exacerbate healthcare disparities for vulnerable populations despite the promise for improving healthcare outcomes overall (14–16). There has been limited but important work describing the aspects of video visits that may limit their use in specific populations including low digital health literacy, cultural preference for in-person visits, and limited access to reliable internet or technological devices (e.g., smartphones, tablets, computers) that are required to conduct a video visit (17). However, research is necessary to better understand the patterns of video visit use by patient characteristics during this important time in history. Our objective was therefore to describe and explore pediatric ambulatory video visit use by patient characteristics during COVID-19. The overarching question that guided this mixed methods study was: How does video visit use during COVID-19 for pediatric ambulatory encounters differ depending on patient characteristics, and what are the contextual factors that influence video visit usage?

MATERIALS AND METHODS

Mixed Methods Integration

We conducted an explanatory sequential mixed methods study. This two-phase design began with a cross-sectional analysis of pediatric ambulatory encounters using electronic health records to profile the use of video visits (i.e., quantitative phase). The second phase was a qualitative exploration using semi-structured interviews and a combination of inductive and deductive methods to generate contextualized understanding of video visit usage (i.e., qualitative phase).

In addition to implementing integration at the design level, we integrated at the methods level through connecting (18), whereby the results from the quantitative phase informed the sampling criteria regarding the types of providers recruited for the qualitative phase. Furthermore, we implemented integration through building; (18) we used the quantitative data to refine our interview guide and develop our deductive codes. **Figure 1** shows an overview of the study methodology.

Setting

This study took place at a quaternary care academic health system with an integrated primary and specialty ambulatory clinic network in Northern California. This medical center is the referral center for children across a 33-county region covering 65,000 square miles and serving over 1 million children. More than 120 physicians provide ambulatory care to our pediatric patients and families.

Our health system began offering pediatric ambulatory video visits in March 2019. Prior to COVID-19, the use of pediatric ambulatory video visits represented 1% of all pediatric ambulatory visits. We used the telehealth platform Epic MyChart (Epic Systems, Verona, WI) to conduct video visits. Parent or guardian (referred to as "parents" hereafter) requirements to conduct a video visit included establishing a MyChart account for the child and having a video-enabled smart device with WiFi or cellular access. The clinician requirements to conduct a video visit included having an iOS smart device with WiFi or cellular access. Clinicians could not use a desktop computer nor Android device, as these equipment types were not supported by our telehealth platform.

The quantitative phase of this study began during the initiation of a statewide COVID-19 shelter-in-place order. Initially, the general pediatric clinic tried to restrict in-person visits to children 2 years and younger. This policy was lifted after 2 months and did not occur in specialty clinics. General and specialty clinic physicians reviewed their scheduled patients to determine which appointments could convert to video; this decision was at the discretion of the physician. Two months into the study, safety protocols were implemented (e.g., universal masking with face shields, isolation rooms), and the pediatric clinics began scheduling new appointments as in-person visits again. Visitation restrictions permitted one parent to attend the in-person visits with the child.

Quantitative Phase

Patient Population

For this cross-sectional analysis, we included all patients age 0–25 years who completed an ambulatory encounter with a Department of Pediatrics physician between March 11 and June 30, 2020. We included both in-person and video visits. All general and specialty ambulatory pediatric clinics located on the medical center campus were included; we excluded satellite and outreach clinics. Ambulatory encounters for procedures were excluded. We included patients up to age 25 years in order to include the young adults seen by pediatric physicians.

Data Source and Variables

We obtained patient-level data from the electronic health record. Patient characteristics included age, gender, race/ethnicity, language, insurance status, clinic type (surgical specialty, non-surgical specialty, general), and driving distance from residence

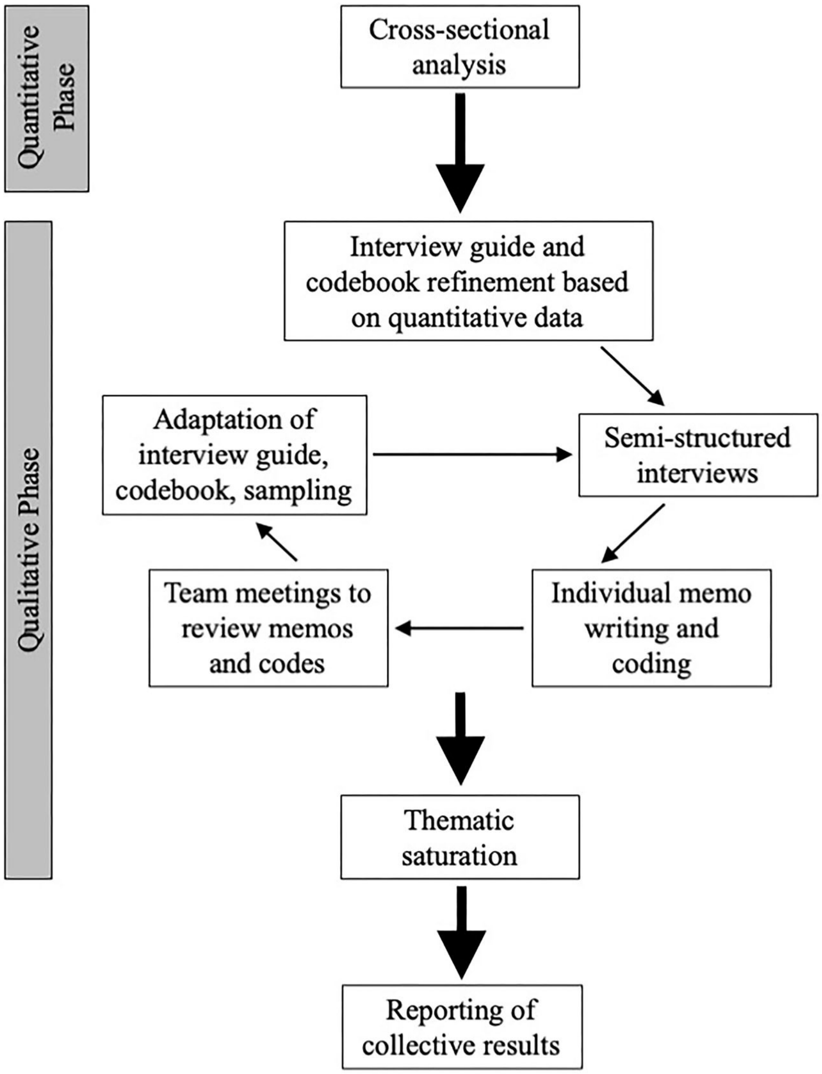

FIGURE 1 | Study methodology.

to clinic (determined using the Google Cloud Platform's Distance Matrix API).

Analysis

We performed descriptive analyses for each variable of interest. For each categorical characteristic, we compared data between in-person visits vs. video visits using Pearson's chi-square tests. For each category, we calculated the proportion of video visits as a ratio of the number of video visit encounters (numerator) to the number of video visit plus in-person visit encounters (denominator). We estimated a multivariable logistic regression model to analyze factors associated with the odds of having a video visit, including covariates from the univariate analyses.

Qualitative Phase

Interview Participants and Data Collection

We initially used purposive sampling (19) to identify clinicians and staff working in roles that would provide unique insights into the contextual factors influencing the video visit usage patterns observed from our quantitative data. Initial recruitment targeted telehealth program staff, information technology (IT) staff, professional medical interpreters, and physicians. We subsequently purposively sampled marketing staff to further explore marketing-related topics that arose in the initial interviews. We additionally used snowball sampling (20) to identify other potential contributory roles including triage nurses, clinic nurses, clinic managers, and medical office service coordinators.

One-on-one interviews were conducted from August through November 2020. Participants were recruited via e-mail. Eligible participants were aged 18 years and older and English-speaking. We collected demographic information during the interviews, including age, gender, race, ethnicity, clinical role, and years' experience. All interviews were conducted via videoconference and audio recorded and transcribed. Interviewers used an

TABLE 1 | Profile of patient-level characteristics for ambulatory video visits and in-person visits.

Patient characteristics	Video visit (*N* = 2,127)		In-Person visit (*N* = 3,337)		Proportion as video visits, %	*P*
Age, years, *n (%)*						<0.001
0–1	348	(16.4)	775	(23.2)	31.0	
2–5	418	(19.7)	705	(21.1)	37.2	
6–11	539	(25.3)	832	(24.9)	39.3	
12–18	752	(35.4)	952	(28.5)	44.1	
19+	70	(3.3)	73	(2.2)	49.0	
Gender, *n (%)*						0.015
Male	1,121	(52.7)	1,871	(56.1)	37.5	
Female	1,006	(47.3)	1,466	(43.9)	40.7	
Race & Ethnicity, *n (%)*						<0.001
Non-Hispanic White	1,030	(48.4)	1,283	(38.5)	44.5	
Latinx or Hispanic	466	(21.9)	976	(29.3)	32.3	
African American or Black	159	(7.5)	233	(7.0)	40.6	
Asian	212	(10.0)	280	(8.4)	43.1	
Pacific Islander	18	(0.9)	26	(0.8)	40.9	
American Indian or Alaska Native	13	(0.6)	8	(0.2)	61.9	
Other	41	(1.9)	178	(5.3)	18.7	
Missing	188	(8.8)	353	(10.6)	34.8	
Language, *n (%)*						<0.001
English	2,023	(95.1)	2,843	(85.2)	41.6	
Spanish	61	(2.9)	346	(10.4)	15.0	
Other	40	(1.9)	146	(4.4)	21.5	
Missing	3	(0.1)	2	(0.1)	60.0	
Insurance, *n (%)*						<0.001
Private	1,155	(54.3)	1,531	(45.9)	43.0	
Public	971	(45.6)	1,803	(54.0)	35.0	
Other	1	(0.1)	3	(0.1)	25.0	
Clinic Type, *n (%)*						<0.001
Non-Surgical Specialty	1,161	(54.6)	1,414	(42.4)	45.1	
Surgical Specialty	118	(5.6)	325	(9.7)	26.6	
General Pediatrics	848	(39.9)	1,598	(47.9)	34.7	
Distance, miles, *median (25–75% IQR)*	55.4	(27.2–155.7)	44.9	(21.4–112.6)		

P-value determined using Pearson's chi-square test to compare data between in-person vs. video visits. IQR, inter-quartile range.

interview guide to structure the interview. The guide included questions to solicit information related to the following three topics: (1) general experiences with and perceptions about ambulatory video visits, (2) reactions to the video visits usage data from the quantitative phase, and (3) strategies for optimizing equitable reach of video visits. Interviewers maintained field notes with contextual observations. Each participant provided verbal informed consent and received a $50 gift card. Interviews were conducted until thematic saturation was reached.

Analysis

We used a combination of deductive and inductive analysis (21). Data were analyzed in an iterative process using a constant comparative approach (22, 23). We applied the quantitative phase results to develop an initial codebook of a priori codes related to the patterns identified in the data. Three team members (JR, AS, and EFG) independently conducted memo writing and coding of the initial five transcripts using the a priori codes while simultaneously identifying emergent codes. The team met virtually to discuss the relevance and definitions of the coding structure and new topics from inductive coding. Any team member who could not attend the meetings shared their memos and codes electronically; those memos and codes were reviewed at the team meetings and included in the discussions. We adapted the interview guide based on the initial codes. We then resumed independent memo writing and coding followed by team meetings to ensure consensus on application of codes, refine dimensions of existing codes, add new codes, develop categories, and identify theoretical direction. This iterative process was repeated with every 2–3 transcripts. We revisited prior transcripts as new codes were identified. We identified linkages and patterns between the codes, which became our analytic themes. Once data coalesced around similar themes across the participants' roles, we concluded that saturation of themes was met.

Data validation occurred through investigator triangulation (24). The qualitative analysis team consisted of a general pediatric attending (EFG), a telehealth medical director (JR), and a patient-centered care research coordinator with ambulatory clinical experience (AS). Two of the investigators (JR and EFG) had extensive qualitative research experience. An additional measure taken to enhance validity was the purposeful selection of the qualitative sample using the quantitative results to identify participants who could provide the best explanations (25). We used ATLAS.ti to organize and store coding and data analysis (26). This study was approved as exempt by the University of California Davis Institutional Review Board.

RESULTS

Quantitative Phase

During the 16-week study period, there were 5,464 pediatric ambulatory encounters, of which 3,337 were in person and 2,127 were video visits. As shown in **Table 1**, Latinx/Hispanic patients were less likely to complete their ambulatory encounter by video (32.3%) than patients in other race/ethnicity categories (40.6–44.5%). For Spanish-speaking families, a greater percentage of them completed in-person visits (10.4%) than video visits (2.9%). Patients with private insurance were more likely to complete video visits (43.0%) than patients with public insurance (35.0%).

Characteristics Associated With Having a Video Visit

In multivariable analysis, patient factors associated with higher odds of having a video visit rather than an in-person visit included age > 18 years, English-speaking, private insurance, and non-surgical specialty clinic (**Table 2**). Latinx/Hispanic patients had lower odds (based on the point estimate) of having a video visit in comparison to non-Latinx/Hispanic White patients (adjusted odds ratio [aOR] 0.86, 95% confidence interval [CI] 0.73–1.00). In comparison to English-speaking patients, Spanish-speaking patients (aOR 0.27, 95% CI 0.20–0.37) and other non-English-speaking patients (aOR 0.50, 95% CI 0.34–0.75) had lower odds of having a video visit. Patients with public insurance had lower odds of having a video visit in comparison to patients with private insurance (aOR 0.77, 95% CI 0.67–0.88). Regarding distance from the patient's home to the clinic, for every 100-mile increase in distance, the adjusted odds of having a video visit increased 1.25-fold (95% CI 1.19–1.32).

TABLE 2 | Patient characteristics associated with having a video visit rather than an in-person visit.

	Unadjusted OR, 95% CI	Adjusted OR, 95% CI
Age, years		
0–1	0.47, 0.33–0.67	0.56, 0.38–0.83
2–5	0.62, 0.44–0.88	0.78, 0.53–1.14
6–11	0.68, 0.48–0.95	0.77, 0.53–1.13
12–18	0.82, 0.59–1.16	0.89, 0.61–1.30
19+	Ref	Ref
Gender		
Male	Ref	Ref
Female	1.15, 1.03–1.28	1.08, 0.96–1.22
Race & Ethnicity		
Non-Hispanic White	Ref	Ref
Latinx or Hispanic	0.59, 0.52–0.68	0.86, 0.73–1.00
African American or Black	0.85, 0.68–1.06	1.02, 0.81–1.29
Asian	0.94, 0.77–1.15	1.21, 0.98–1.49
Pacific Islander	0.86, 0.47–1.58	0.94, 0.50–1.74
American Indian or Alaska Native	2.02, 0.84–4.90	2.11, 0.84–5.30
Other	0.29, 0.20–0.41	0.41, 0.29–0.59
Language		
English	Ref	Ref
Spanish	0.25, 0.19–0.33	0.27, 0.20–0.37
Other	0.39, 0.27–0.55	0.50, 0.34–0.75
Insurance		
Private	Ref	Ref
Public	0.71, 0.64–0.80	0.77, 0.67–0.88
Other	0.44, 0.05–4.25	[–]
Clinic Type		
Non-Surgical Specialty	Ref	Ref
Surgical Specialty	0.44, 0.35–0.55	0.40, 0.32–0.52
General Pediatrics	0.65, 0.58–0.72	0.67, 0.59–0.76
Distance, 100 miles	1.22, 1.16–1.28	1.25, 1.19–1.32

Associations with pediatric ambulatory encounters conducted as a video visit were compared with in-person visits. The multivariable logistic regression model included the covariates that are listed in this table. OR, odds ratio; Ref, reference.

Qualitative Phase

We conducted sixteen ∼30–45-min interviews with individuals representing the telehealth program ($n = 3$), IT ($n = 2$), professional medical interpreting ($n = 1$), physicians ($n = 2$), marketing ($n = 1$), triage nurses ($n = 1$), clinic nurses or managers ($n = 2$), and medical office service coordinators ($n = 4$). Characteristics of participants are provided in **Table 3**.

We identified five overarching analytic themes across the transcripts that pertained to the contextual factors that influence video visit usage. Major themes were developed to be solution-based and included: (1) Promoting video visits in a way that reaches all patient families; (2) Offering video visits to all patient families; (3) Mitigating digital literacy barriers; (4) Expanding health system resources to support families' specific needs; (5) Engaging and empowering health system personnel to expand video visit access. These themes are explored in more detail below with representative quotes in **Table 4**.

Theme 1—Promoting Video Visits in a Way That Reaches All Patient Families

Multiple participants across different roles reported that the awareness of video visits was not necessarily known by all of

TABLE 3 | Interview participant characteristics.

	n (%)
Age, years	
25–34	5 (31.2%)
35–44	6 (37.5%)
45–54	4 (25.0%)
55+	1 (6.2%)
Gender	
Male	2 (12.5%)
Female	14 (87.5%)
Race & Ethnicity	
Non-Hispanic White	9 (56.2%)
Latinx or Hispanic	1 (6.2%)
African American or Black	1 (6.2%)
Asian	2 (12.5%)
Pacific Islander	1 (6.2%)
American Indian or Alaska Native	2 (12.5%)
Role	
Telehealth program staff	3 (18.8%)
Information technology staff	2 (12.5%)
Professional medical interpreter	1 (6.2%)
Marketing staff	1 (6.2%)
Physician	2 (12.5%)
Triage nurse	1 (6.2%)
Clinic nurse or manager	2 (12.5%)
Medical office service coordinator	4 (25.0%)
Years in profession	
<5	3 (18.8%)
6–10	5 (31.2%)
11–20	7 (43.8%)
21+	1 (6.2%)

our diverse groups of patient families. Specifically, participants shared that lower-income, publicly-insured, and non-English-speaking patients were frequently less aware of the video visits option. This lack of awareness was thought to be a contributing factor for the quantitative results regarding lower odds of video visit usage among non-English-speaking and publicly-insured patients. Participants stated that limited awareness existed in part due to marketing mostly being in English and via the medical center's website or social media platforms, which thus may not reach those populations noted in the quantitative data of having lower use.

Another aspect highlighted by participants was the need to address parents' skepticism about video visits. They perceived that parents of publicly-insured children sometimes misunderstood their insurance coverage and feared that a video visit was more costly than the in-person charges (or lack thereof) to which they were accustomed. Participants also mentioned that non-English-speaking parents did not always know that a professional medical interpreter was available for video visits. These factors were thought to drive certain parents to preferentially use in-person visits.

Theme 2—Offering Video Visits to All Patient Families

Many of the participants shared that clinical providers and staff offered video visits less frequently to certain groups of patient families. Participants explained that inconsistent workflows and training on to whom to offer video visits resulted in this practice. In addition, almost every participant commented that navigating the video visit process was challenging. Therefore, any additional element that could make the process even more difficult—whether it be a real or perceived element—exacerbated the selective offering of video visits. Participants said that biases about a family influenced the perceptions on who was more or less likely to navigate the process. In particular, English-speaking parents and those profiled as "tech savvy" were often categorized as people who would be successful in navigating video visits. Additionally, video visits for patients in foster care required the foster parent to complete additional paperwork and this may lead to video visit failure. Thus, video visits were almost never offered to children in foster care. Some participants emphasized the need to standardize the video visit scheduling process in order to overcome the practice of selectively offering video visits to the patient families deemed most likely to successfully navigate the video visit process.

Theme 3—Mitigating Digital Literacy Barriers

The most recurring topic discussed by all participants was that the video visit platform, MyChart, was very "difficult" and "cumbersome" to navigate. The most challenging aspect of using MyChart in the context of setting up video visits was parents' creating the account. As a result, patients whose parents could not set-up MyChart were unable to conduct their ambulatory encounter as a video visit and defaulted to in-person visits. Furthermore, the MyChart platform was only available to our patient families in English, and assistance in navigating the process for non-English-speaking parents was variable. This language limitation was thought to be a primary driver of the language gap identified in the quantitative data. Numerous participants stated that a multi-language platform is a necessary investment that should be prioritized.

Theme 4—Expanding Health System Resources to Support Families' Specific Needs

The need to expand video visit resources to better support our patients and families was consistently expressed among all participants. First, the video visit written instructions were perceived to be overly complicated and not useful for those with low health and digital literacy. Additionally, the instructions were almost exclusively in English. Participants reported that some fliers were translated into Spanish but not into other languages. However, again, they emphasized that language appropriate instructions have limited effect when the MyChart platform was only in English.

Second, participants across various roles shared that they needed more clinical staff and IT personnel than was provided to assist patients and their families with the video visit process. In the setting of COVID, the exponential growth of video visits has surpassed their ability to address every patient family's needs. Participants stated that, for certain patients such as those who did

TABLE 4 | Exemplary quotes organized by theme.

Theme	Exemplary Quote
Promoting video visits in a way that reaches all patient families	"Low income like Medi-Cal families who maybe just aren't aware of the services are not potentially health literate in a way that they would advocate on behalf of themselves… I would assume that those types of families were under-served by the [video visit] service line… If you don't even know that there's services available to you, then you're in a position where you're not even making that decision on your own behalf."—Telehealth Program Staff "Privately insured patients, usually that means [their parents] have a job. So, that's where their insurance is coming from. So, they are probably a little more assimilated or acculturated to the environment… Our low-income populations and populations with little information, they may not know that any of this is available and that this is easy and that this is just as good as your normal visit in the clinic. So, more education through Medi-Cal? That would be good too."—Professional Medical Interpreter "I will just say that I do not think I've had a video visit with a non-English-speaking family. And I know that we have families who are signed up for MyChart whose parents are primarily Spanish-speaking or non-English-speaking, and even those families that have a MyChart account for their child, I have not had video visits with them. And my guess would be that the information that we provide, as an institution, all the way from the website level down to the information we provide in clinic, in person, that would help a family learn about video visits and about MyChart and accessing all of the capabilities it has, that we do not convey that as effectively to our non-English-speaking families."—Physician "We have a lot of opportunity within our public affairs and marketing team to partner much more closely with our equity and inclusion department… We have really, really gorgeous, beautiful marketing, but how far is it reaching? And is it targeted enough?"—Telehealth Program Staff "There was some media push, I think, and this is all with COVID… 'Hey, everyone should still get care, and you can get care in these different ways.' But I don't know if that extended beyond things like local news or local radio. I don't know if they went on Spanish language programming to try to help get that word out. So, it's always one of those things where you wonder, are we only talking to one subset of the population? Are we just skipping over a whole group of folks who would probably benefit from this?"—Physician "There is also a cultural reason for that, that the relationship with the provider is so important, because to them video visit doesn't feel like a full in-person—it's not the same. It's not the same experience, not the same feeling that you have established a relationship with the provider and that you're getting everything out of the visit that you would normally get when you showed up in the clinic… I don't see a wider outreach effort in order to normalize this and make this an option that is equal in quality to an in-person visit."—Professional Medical Interpreter "…It scares them. It's a technology issue, language issue, the app is in English. Then when they are in the clinic, they know that an interpreter will show up in one way or another, whether phone, video or in person they will be there. With video visits they don't know. Will there be language support? What is going to happen? Yeah. It's a little unsettling to them. A cultural issue comes into play also, that this is not a real doctor visit, it's just all on TV, right?"—Professional Medical Interpreter "It seems like [video visits are] something that could cost more money, and there should probably be some kind of thought and research as to how we promote that cost point, and how we communicate that cost point."—Marketing
Offering video visits to all patient families	"We should have a systematic approach across the board… it's not selectively sharing information. It's sharing information by default. So every person that walks into a clinic or every person that calls our nurse line is asked the same exact questions… 'Do you have access to the portal?' Right? It removes all possible bias… Certain biases are just going to play out. So the more you can automate it and the more than you can put it actually in the—in the hands of the patient, the better your uptake."—Telehealth Program Staff "First, unfortunately, people were actually told that only English-speaking patients could do video visits because there was not a great way to get interpreters involved. They did change that, and then there were multiple iterations of having interpreters involved… And now they can be ideally, easily in part of the visit."—Telehealth Program Staff "I've heard anecdotally from providers, which makes total sense… they want a successful encounter. They want to feel comfortable. They are so busy, so trying something new is stressful… They think, 'Oh, gosh, if the interpreter's not there, or they don't understand me, of if the connection drops,' then I mean there are just so many things that can go wrong… Connection is dropping, or the provider or clinician not knowing what to do or how to unmute themselves, or all these sort of like technology stressful things that they have to think about… So just wanting it to be in their control—that makes total sense to me that it wouldn't be the most comfortable thing to try something new or add onto their plate with the non-English-speaking family."—Telehealth Program Staff "Also, 'Are you biological mom?' Because if you're foster, or a guardian, then that's another hurdle to for Video Visit. So, as we're talking, even before I say, 'Video Visit,' because I don't want to offer it to a foster mom who doesn't have all the paperwork."—MOSC "There were people—potentially significant number of people that were hesitant at failure of a video visit, and that just creates some bias, whether subconscious or not of saying, 'I'm not even going to offer it to you because I don't think you're going to be able to handle it."'—Telehealth Program Staff "People of course have biases in their mind of who's going to follow through with the video visit. So Dr. X doesn't get mad at the person that scheduled it. You know? There are just so many ways on both sides that people want it to go well. So, they're going to lean toward the family that's probably there early. And maybe looks a certain way. And maybe has a certain type of insurance."—Telehealth Program Staff "It seems like commercial patients are just, they're more responsible with MyChart. And following up with stuff like that, than Medi-Cal… And sometimes I'll skip that step [of enrolling them in MyChart], and that tends to be more Medi-Cal patients than commercial patients."—MOSC "Clinic staff and people who know these patients probably have a good idea or sense, or even maybe a little bit of bias, in their mind in terms of do they no-show a lot? Do they maybe not follow through with things?… I heard doctors saying they wanted their patients and themselves to be set up for success. So if there's a family that maybe doesn't have great technology, they've said that before. Maybe they don't have phones or emails. They've said that before. I don't think they're going to try something new out, or something stressful with that particular family."—Telehealth Program Staff
Mitigating digital literacy barriers	"The majority of the patients I think that I've seen who have done video visits have been those with private insurance. Again, those with higher SES, more medically sophisticated, so not necessarily patients whose parents have graduate degrees or other things, but people who have navigated the system well."—Physician

(Continued)

TABLE 4 | Continued

Theme	Exemplary Quote
	"Our experience is that with populations who are limited English proficient, or deaf populations it was a learning curve when the pandemic started and the video visits became the new normal. The instructions on how to log on, how to set it up were difficult, cumbersome."—Professional Medical Interpreter "If you have a parent who's really technical and they can get on and they know how to do that, it's a walk in the park for them. But then, we might have our older folks—we have a lot of grandparents raising their grandkids nowadays, you know? So, that's a big one for them. I've had a couple of families that just, no matter how many times we've walked through it or we've showed them, or we've talked to them, they just still sometimes struggle, and I think that just is age and their savviness of technology."—Clinic Nurse/Manager "Either they don't have the right technology, meaning their phone isn't up to date, or they don't have the right thing, or they just get so frustrated because they don't understand that they just want to give up, which is totally fine. So, then we usually just call the clinics, let them know what's going on, and then they'll change it to a telephone appointment."—IT "Everything is in English. To sign up all of the terms and conditions that you're accepting are in English. So unless they have someone with them, or on the phone translating, that's tough. Of course, I mean we have now video visit instructions translated into Spanish, and working on other languages. But you still need—the whole system isn't translated. So, buttons are in English when you press 'Begin Visit,' so that's tough."—Telehealth Program Staff "Because the app is only offered in English, that's probably the biggest driving factor. I mean, I can promote it in Russian, but frankly, that's a little misleading if we're not actually offering it in Russian. So, I wouldn't suggest that we publish materials in other languages unless the end result is going to also be offered in other languages… I wouldn't want someone to be encouraged to sign up and download something, and then get in there and realize, 'Oh, this isn't what I thought."'—Marketing "I know some of our families that I think definitely would benefit, but… I think it's unfair because of the language barrier. So, we're asking them to sign up for this things that's completely in English and it's like, that would be like them telling us to sign something, for me, I don't speak Chinese. So, it would be like, 'Okay, all this is in Chinese, but sign up for it.' And you're looking at it like it's completely foreign, so I wish and hope that it would be in other languages, just to make it more user friendly for our people, our patients, our families."—Clinic Nurse/Manager
Expanding health system resources to support families' specific needs	"We'll have to do a better way of identifying why those gaps are there, and trying to meet them. But I think updating your website to be more clear, and maybe use bullets instead of paragraphs to communicate. And making sure we're translating."—Telehealth Program Staff "Having more extensive social work and care coordination that's culturally competent around specialty and primary care and really understanding who our populations are and targeting—targeting interventions that meet those people where they need to be met."—Telehealth Program Staff "I'd still say that video visits where I use an interpreter are still in the minority of what I do, and I think a lot of it is just like, I think a lot of it goes to the amount of time our nurses will spend…. They will look at the clinic schedule and they will make it a point to contact the family… But it's very time consuming, and in the past few months, they haven't been able to do that as much, because now it's just super overwhelming."—Physician "Parents usually would spend a good amount of time with the interpreter on the phone just trying to get them through the steps of getting into the video visit. So, very frustrating on all sides… It was so frustrating and they would just rather come into the clinic… So, some gave up and started coming in when the clinic's opened again."—Professional Medical Interpreter "[With COVID] our workload has just gone through the roof. So, it's like we can't spend as much time with these patients to get them 100 percent comfortable if they're not already tech savvy or they're not comfortable resolving issues on the fly as they go… It's that balancing act of how do I make sure the patient's good and how do I make sure my team's good so we're meeting our daily numbers."—IT "We need more [IT Help Desk] people. We are hiring more people, so I'm optimistic. Here's the thing. With hiring more people, even still, I mean, what we've been told to do, the quality is suffering… Yes, [the patients' families are] getting a call, but it's in one ear and out the other. I hope that maybe having more people will help that, but still it's so much volume. There's so many people that I don't know if they're going to be getting the experience that I would personally want them to have."—IT "They'll say, 'Well, the kid doesn't have a cell phone… Can we use mine?' It says no; it's gotta be the child's… [The teens] have to have their own email or cell phone, because it's the kid's medical record. Because they have to have full access to have a Video Visit to MyChart."—MOSC "I have a patient yesterday who specifically said that they live in a rural setting and they do not have a very reliable high-speed internet connection."—Physician "Big hurdles that I've heard from families are like, 'I'd love to do a video visit, but the thing is, we only have one computer for the whole household. If the other sibling is using the computer for school, then I can't use it for this.' In some of our families that live in really rural areas, I have to admit, it was very educational for me. Internet access is not as ubiquitous as I would have imagined, and so that was a huge challenge."—Physician
Engaging and empowering health system personnel to expand video visit access	"And then I think sort of calling out the data, too, so people know that this is happening. Like, 'Did you know that we as a department only saw X percent of non-English-speaking patients through video visit?' I think without people sort of showing this disparity and this gap in care to people, then having that awareness will hopefully help people to change."—Telehealth Program Staff "How do you turn this situation around? It takes the individualized approach, it takes patience, it takes working, putting resources into it. So, if we are looking for volume, then yes, they'll come back. They're back in clinics in high numbers. But that's not what we are looking at, right? That's not the goal. The goal is maybe triage and handle appointments that can be done through video, do them that way. But, for LEP [limited English proficiency] populations they were just sitting tight and waiting for once the clinics would open back up."—Professional Medical Interpreter "I would love to have more metrics and data around who's using it, and then within that, what demographics are using it, so that we can better identify who isn't using it, and hopefully find ways to advance this program amongst that population group… I would want to see age, race, language spoken, household income, things like that."—Marketing

(Continued)

TABLE 4 | Continued

Theme	Exemplary Quote
	"We made the impossible happen. Going from 100 video visits a week to 5,000 a week for COVID. So we can do even better now. I think smaller groups, showing the data, showing research to people, and then like what you're doing. Asking them, the people who are on the ground and part of it every day, of what would make it easier for everyone, to open up the access."—Telehealth Program Staff "As far as the staff, I don't think that they feel that they have a big, powerful voice… For instance, my phone bank, my MOSC who's answering the phone, she might not feel like, 'Hey, who do I even go to let them know this issue?'… So, you know, having somebody at the higher level who can make that decision understand that this is a real issue at the patient level."—Clinic Nurse/Manager "I think that we need more dedicated effort to specifically reaching out to those groups that are underrepresented when it comes to MyChart enrollment, and in addition, those groups that are underrepresented for having a video visit done… It would be great to hear from the families themselves about what the barriers are so that whatever outreach we provide can be most effective. So, rather than offering a solution that we think will work, finding what solutions will work for those families, probably not going to be one size fits all."—Physician "I think that it would be in our best interest to partner with the Office for Health Equity very frequently… That overall plan [to address video visit equity issues] needs to be built… The health equity group and communications would all be good to have at the table when that plan is being put together."—Marketing

MOSC, medical office service coordinator; IT, information technology.

TABLE 5 | Local actions taken to address identified factors contributing to differential use of video visits and the theme(s) each action targets.

Action	Description	Theme alignment
Quality improvement team	Multidisciplinary quality improvement team organized to decrease the difference between English vs. non-English-speaking patients for the percentage of video visits among all ambulatory visits.	(1) (2) (3) (4) (5)
IT help desk outreach	IT help desk has a targeted patient outreach workqueue (which includes non-English-speaking patient families); they proactively call these patient families when a video visit is scheduled to offer their assistance.	(2) (3) (4)
Language-appropriate materials for low-literacy audiences	IT Education and interpreting services are creating language-appropriate video visit materials designed for low health literacy patient families.	(1) (2) (3) (4)
Integration with video interpreting services	Video interpreting services platform now integrates into the video visit encounters; interpreters can be scheduled or invited to join the video visit on demand.	(4)
Patient navigators	The health system is hiring patient navigators to assist patient families with their additional needs in navigating the video visit process.	(2) (3) (4)

IT, information technology.
(1) Promoting video visits in a way that reaches all patient families; (2) Offering video visits to all patient families; (3) Mitigating digital literacy barriers; (4) Expanding health system resources to support families' specific needs; (5) Engaging and empowering health system personnel to expand video visit access.

not speak English, video visits required more time and effort from the health system in comparison to in-person visits. As a result, participants stated that "it's too much work" to do a video visit for certain patients. Additionally, video visits required extra steps on the family's end. Some parents who wanted to have a video visit for their child were left feeling frustrated and ultimately gave up despite assistance from the health system. Others could not have a video visit due to lack of equipment or insufficient internet access.

Theme 5—Engaging and Empowering Health System Personnel to Expand Video Visit Access

Some participants articulated the need to raise awareness about the differential uptake of video visits by certain groups of patient families. They explained that frontline providers and administrators were likely not aware of the differences in video visit access in certain populations. Very few of our participants responded that there were differences in uptake of video visits by groups of patients defined by insurance or language status when asked the open-ended question about their observations of any differences in video visit use depending on patient or family characteristics. However, upon being presented with the quantitative analyses of this current study, almost every participant said, "I'm not surprised." They requested that these analyses be disseminated so that data transparency could influence individual- and systems-level changes. In addition to increasing awareness, participants recommended empowering all providers to advocate for their patients' needs and to provide providers with the necessary resources to best support their patient families.

DISCUSSION

This mixed methods study profiled pediatric ambulatory encounters during COVID-19 and identified that being non-English-speaking and having public insurance were independent risk factors for lower odds of having a video visit rather than an in-person visit. The subsequent qualitative exploration provided a contextualized understanding of video visit usage and identified various factors perceived to contribute to the video visit access inequities. Our solution-based themes identified that strategies to improve equitable access include expanding the reach of video visit promotions, standardizing the process of offering video visits, enhancing resources to support all patient families, and engaging all health system personnel to address inequities.

The data from our present study adds to the growing body of evidence suggesting that the expanded adoption of telehealth during COVID-19 may be taken up by some groups of patients more than others. Our findings, that insurance and language are predictors of video visit use, are consistent with previous non-pediatric research highlighting this differential use. Data from one study examining internal medicine primary care visits suggested decreased video visit access among patients who were publicly-insured, non-English-speaking, and non-Hispanic White (14). Furthermore, Spanish-speaking patients and those enrolled in Medicaid have been found to be less likely to have access to technology that enables video visits (27). Qualitative research highlights that medical providers report seeing fewer patients with limited English proficiency than usual in the setting of increased video visits during COVID-19; low digital literacy and English-only telehealth platform instructions are described as factors contributing to low video visit usage among this population (28). Regarding our finding that the 0–1-year-old age group had the lowest odds of video visit use, this differential use is likely explained by the relatively high proportion of visits in this age group that involve immunizations and thus require an in person visit.

The limited pediatric-specific research on video visits during COVID-19 has examined video visit utilization among single specialties and has mixed results. One study of pediatric neurology encounters found video visits to be less frequent among patients in racial or ethnic minority groups (29). Another study of pediatric otolaryngology encounters demonstrated no change in the proportion of Spanish-speaking and Medi-Cal patients seen by the clinic when they transitioned from in-person visits to exclusively video visits; however, Spanish-speaking families were more likely to require rescheduling of their video visits, which the authors used as a proxy measure for barriers to access (30). This context of exclusively offering video visits is one potential explanation for why this pediatric otolaryngology study had different results than our present study. Nevertheless, the authors similarly concluded that increased staff support is a necessary investment to provide a sustainable level of video visits to patient families with language barriers.

Findings from our current mixed-methods study were presented internally and activated immediate actions to begin addressing the identified differential uptake of video visits by certain groups (**Table 5**). First, a multidisciplinary quality improvement team convened to decrease the difference between English vs. non-English-speaking patients for the percentage of video visits among all ambulatory visits. The improvement project used the study analyses to inform their key driver diagram and initial tests of change. As part of this improvement project, real-time data on video visit usage by language will be disseminated to telehealth program leadership and clinics. Second, the IT help desk received training on how to use interpreter services when assisting non-English-speaking patients and families. The help desk also has a targeted patient outreach workqueue. They proactively call patient families when a video visit is scheduled to offer their assistance; non-English-speaking patient families are on that list. Third, the telehealth program leadership began investigating the potential use of the multi-lingual MyChart platform. Simultaneously, IT Education and interpreting services are working to simplify patient family-facing video visit materials in order to ensure that resources are not only language-appropriate but also effective for those with low health literacy. Fourth, we implemented a streamlined workflow whereby our video interpreting services platform, Martti (Cloudbreak Health, Columbus, OH), integrates into the video visit encounters. Providers can either schedule an interpreter ahead of time, or providers can invite the interpreter to join the video visit on demand. Fifth, the health system is hiring patient navigators to assist patient families with their additional needs in navigating the video visit process. We will apply continuous improvement processes to identify how to optimize this new resource. Finally, recognizing that similar or additional differences in video visit use may exist in the adult population, a team began applying our approach with pediatric data to the adult ambulatory video visit data. We believe that a similar approach to internal analysis of video visit use by patient characteristics, reporting, and action would be valuable to other health systems and is reflective of quality improvement best practices.

As our process of disseminating our findings internally reflects best practices, the strategies identified by our study participants to improve video visit use by all of the patient families reflected in our study are consistent with strategies being promoted by national public agencies. The Centers for Disease Control and Prevention COVID-19 Response Health Equity Strategy emphasizes the importance of disseminating materials that are tailored to be culturally relevant and linguistically relevant for diverse groups (31). Similarly, a recent publication on disparities in telehealth access for vulnerable populations recommended key actions that are similar to the solution-based themes from our present study (14). These recommendations included identifying potential disparities in access (e.g., monitor data), mitigating digital literacy and resource barriers (e.g., educate and train patients in digital skills), removing health system-created barriers (e.g., offer video visits to every patients), and advocating for changes to support sustained and equitable access (e.g., expanded low-cost or free broadband).

The findings in our study were specific to our medical center and may reflect circumstances and contextual factors that were unique to our setting. Other medical centers might not identify the same patterns that we found in our study. Nevertheless, many of the findings are likely transferable to other pediatric ambulatory practices, and our study highlights the importance of conducting such investigations that explore potential disparities in video visit access and areas for improvement. Another limitation in our study was that the appropriateness of the type of visit was not assessed. We thus could not determine if a video visit vs. in-person visit was warranted for a particular encounter. The qualitative findings represent only the perceptions from our group of participants. However, we interviewed a diverse group with respect to their clinical roles and experiences. Interview participants shared their perceptions of patient and parent experiences; however, we did not include patients or parents in this study. Gathering data from the perspectives of patients and parents was beyond the scope of this present study but should be explored in future research. Addressing patient families' unique needs requires their input and perspectives. Importantly, future research that gathers data from patients and parents should ensure diversity in participants in order to understand how to best support diverse populations with telehealth services. Furthermore, participants who agreed to participate could also have extreme perceptions. Despite these limitations, this mixed methods study provided useful information to inform interventions to improve the pediatric video visit program and mitigate access inequities.

In conclusion, our profile of pediatric ambulatory video visit use by patient characteristics during COVID-19 identified differences, with lower odds of video visit use among non-English-speaking and publicly insured patients. Our mixed-methods approach allowed for the perspectives of our interview participants to contextualize the finding and lead to suggestions for improvement. We found that expanded reach of video visit promotions, standardized offering of video visits, enhanced resources to overcome digital literacy barriers, expanded resources to support all patient families, and engagement of providers to address inequities are potential strategies that may be incorporated to improve equal access to video visits among our diverse patient population. Therefore, both our findings and the approach to obtaining them present models for other health systems to ensure that all patients and families receive equal opportunity to reap the benefits of video visits, during the COVID-19 pandemic and thereafter.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because of patient anonymity. Requests to access the datasets should be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of California Davis IRB. Written informed consent from the participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements. Written informed consent was not obtained from the minor(s)' legal guardian/next of kin for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

JR conceptualized and designed the study, conducted interviews, analyzed the data and interpreted the results, drafted the initial manuscript, and revised and approved the final manuscript as submitted. CO conceptualized and designed the study, conducted interviews, interpreted the results, and revised and approved the final manuscript as submitted. AS and EFG analyzed the data, interpreted the results, and revised and approved the final manuscript as submitted. All authors contributed to the article and approved the submitted version.

FUNDING

JR received support from the Eunice Kennedy Shriver National Institute of Child Health and Human Development, National Institutes of Health (Grant no. K23HD101550).

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fped.2021.645236/full#supplementary-material

REFERENCES

1. American Telemedicine Association. *Telemedicine Glossary*. Avaialble online at: http://hub.americantelemed.org/resources/telemedicine-glossary (accessed October 5, 2016).
2. Smith AC, Gray LC. Telemedicine across the ages. *Med J Aust.* (2009) 190:15–9. doi: 10.5694/j.1326-5377.2009.tb02255.x
3. Chiang LC, Chen WC, Dai YT, Ho YL. The effectiveness of telehealth care on caregiver burden, mastery of stress, and family function among family caregivers of heart failure patients: a quasi-experimental study. *Int J Nurs Stud.* (2012) 49:1230–42. doi: 10.1016/j.ijnurstu.2012.04.013
4. Myers CR. Using telehealth to remediate rural mental health and healthcare disparities. *Issues Ment Health Nurs.* (2019) 40:233–9. doi: 10.1080/01612840.2018.1499157
5. Committee on Pediatric Workforce. The use of telemedicine to address access and physician workforce shortages. *Pediatrics.* (2015) 136:202–9. doi: 10.1542/peds.2015-1253
6. Nagata JM. Rapid scale-up of telehealth during the COVID-19 pandemic and implications for subspecialty care in rural areas. *J Rural Health.* (2020) 37:145. doi: 10.1111/jrh.12433
7. Coombs B. Telehealth visits are booming as doctors and patients embrace distancing amid the coronavirus crisis. *CNBC.* (2020). Available online at: https://www.cnbc.com/2020/04/03/telehealth-visits-could-top-1-billion-in-2020-amid-the-coronavirus-crisis.html (accessed June 30, 2020).
8. Artandi M, Thomas S, Shah NR, Srinivasan M. Rapid system transformation to more than 75% primary care video visits within three weeks at stanford: response to public safety crisis during a pandemic. *NEJM Catal Innov Care Deliv.* (2020) 1:1–11. doi: 10.1056/CAT.20.0100
9. Mehrotra A, Ray K, Brockmeyer DM, Barnett ML, Bender JA. Rapidly converting to "virtual practices": outpatient care in the era of Covid-19. *NEJM Catal Innov Care Deliv.* (2020) 1:1–5. doi: 10.1056/CAT.20.0091
10. American Academy of Pediatrics. Guidance on the Necessary Use of Telehealth During the COVID-19 Pandemic. Avaialble online at: https://services.aap.org/en/pages/2019-novel-coronavirus-covid-19-infections/clinical-guidance/guidance-on-the-necessary-use-of-telehealth-during-the-covid-19-pandemic/ (accessed December 18, 2020).
11. Centers for Medicare and Medicaid Services. *Medicare Telemedicine Health Care Provider Fact Sheet.* (2020). Avaialble online at: https://www.cms.gov/newsroom/fact-sheets/medicare-telemedicinehealth-care-provider-fact-sheet (accessed June 30, 2020).
12. Center for Connected Health Policy. *COVID-19 Related State Actions.* Avaialble online at: https://www.cchpca.org/resources/covid-19-related-state-actions (accessed June 30, 2020).
13. Centers for Medicare and Medicaid Services. *COVID-19 Emergency Declaration Health Care Providers Fact Sheet.* (2020). Avaialble online

at: https://www.cms.gov/files/document/covid19-emergency-declaration-health-care-providers-factsheet.pdf (accessed June 30, 2020).
14. Nouri S, Khoong EC, Lyles CR, Karliner L. Addressing equity in telemedicine for chronic disease management during the Covid-19 pandemic. *NEJM Catal Innov Care Deliv*. (2020) 1:1–13. doi: 10.1056/CAT.20.0123
15. Sundar KR. A patient with COVID-19 is left behind as care goes virtual. *Health Affairs*. (2020) 39:1453–5. doi: 10.1377/hlthaff.2020.00447
16. Rodriguez JA, Clark CR, Bates DW. Digital health equity as a necessity in the 21st century cures act Era. *JAMA*. (2020) 323:2381–2. doi: 10.1001/jama.2020.7858
17. Centers for Disease Control and Prevention. *Using Telehealth to Expand Access to Essential Health Services During the COVID-19 Pandemic*. (2020). Avaialble online at: https://www.cdc.gov/coronavirus/2019-ncov/hcp/telehealth.html (accessed December 16, 2020).
18. Fetters MD, Curry LA, Creswell JW. Achieving integration in mixed methods designs—principles and practices. *Health Serv Res*. (2013) 48:2134–56. doi: 10.1111/1475-6773.12117
19. Tongco MDC. Purposive sampling as a tool for informant selection. *Ethnobot Res Appl*. (2007) 5:147–58. doi: 10.17348/era.5.0.147-158
20. Ghaljaie F, Naderifar M, Goli H. Snowball sampling: a purposeful method of sampling in qualitative research. *Strides Dev Med Educ*. (2017) 14:e67670. doi: 10.5812/sdme.67670
21. Azungah T. Qualitative research: deductive and inductive approaches to data analysis. *Qual Res J*. (2018) 18:383–400. doi: 10.1108/QRJ-D-18-00035
22. Charmaz K. *Constructing Grounded Theory*. 2nd ed. Thousand Oaks, CA: SAGE Publications (2014).
23. Corbin JM, Strauss A. Grounded theory research: Procedures, canons, and evaluative criteria. *Qual Sociol*. (1990) 13:3–21. doi: 10.1007/BF00988593
24. Patton MQ. Enhancing the quality and credibility of qualitative analysis. *Health Serv Res*. (1999) 34(5 Pt 2):1189.
25. Creswell JW, Clark VLP. *Designing and Conducting Mixed Methods Research*. Thousand Oaks, CA: SAGE Publications (2017).
26. ATLAS.ti Scientific Software Development GmbH. *ATLAS.ti. Version 7 [Computer Software]*. Berlin.
27. Roberts ET, Mehrotra A. Assessment of disparities in digital access among medicare beneficiaries and implications for telemedicine. *JAMA intern Med*. (2020) 180:1386–9. doi: 10.1001/jamainternmed.2020.2666
28. Lu J, Bollinger L. Navigating telehealth in limited english proficiency populations. *EthnoMed*. (2020). Avaialble online at: https://ethnomed.org/resource/navigating-telehealth-in-limited-english-proficiency-populations/
29. Rametta SC, Fridinger SE, Gonzalez AK, Xian J, Galer PD, Kaufman M, et al. Analyzing 2,589 child neurology telehealth encounters necessitated by the COVID-19 pandemic. *Neurology*. (2020) 95:e1257–66. doi: 10.1212/WNL.0000000000010010
30. Jiang W, Magit AE, Carvalho D. Equal access to telemedicine during COVID-19 pandemic: a pediatric otolaryngology perspective. *Laryngoscope*. (2020) 131:1175–9. doi: 10.1002/lary.29164
31. Centers for Disease Control and Prevention. *CDC COVID-19 Response Health Equity Strategy: Accelerating Progress Towards Reducing COVID-19 Disparities and Achieving Health Equity*. (2020). Avaialble online at: https://www.cdc.gov/coronavirus/2019-ncov/downloads/community/CDC-Strategy.pdf (accessed December 16, 2020).

Disclaimer: The content is solely the authors' responsibility and does not necessarily represent the official views of the National Institutes of Health.

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Pediatrics

ORIGINAL RESEARCH
published: 19 August 2021
doi: 10.3389/fped.2021.720203

Check for updates

OPEN ACCESS

Edited by:
*Mark Lo,
University of Washington,
United States*

Reviewed by:
*Lokesh Tiwari,
All India Institute of Medical
Sciences, India
Jihad Zahraa,
King Fahd Medical City, Saudi Arabia
Sheikh Minhaj Ahmed,
Lilavati Hospital and Research
Centre, India*

***Correspondence:**
*Amr Jamal
amrjamal@ksu.edu.sa;
med.researcher.2020@gmail.com*

*† These authors have contributed
equally to this work*

‡ORCID:
*Mohamad-Hani Temsah
orcid.org/0000-0002-4389-9322
Ali Alhboob
orcid.org/0000-0003-2126-7874
Noura Abouammoh
orcid.org/0000-0002-1951-8323
Ayman Al-Eyadhy
orcid.org/0000-0002-6051-9125
Fadi Aljamaan
orcid.org/0000-0001-8404-6652
Fahad Alsohime
orcid.org/0000-0002-4979-3895
Ahmad Ashry
orcid.org/0000-0003-1119-8457
Amr Jamal
orcid.org/0000-0002-4051-6592
Khalid Alhasan
orcid.org/0000-0002-4291-8536
Jaffar A. Al-Tawfiq
orcid.org/0000-0002-5752-2235
Mazin Barry
orcid.org/0000-0003-2274-007X*

Specialty section:
*This article was submitted to
Pediatric Critical Care,
a section of the journal
Frontiers in Pediatrics*

Received: *03 June 2021*
Accepted: *21 July 2021*
Published: *19 August 2021*

Pediatric Intensive Care Hybrid-Style Clinical Round During COVID-19 Pandemic: A Pilot Study

Mohamad-Hani Temsah[1,2†‡], Ali Alhboob[1,2†‡], Noura Abouammoh[1,3‡], Ayman Al-Eyadhy[1,2‡], Fadi Aljamaan[1,4‡], Fahad Alsohime[1,2‡], Majed Alabdulhafid[1,2], Ahmad Ashry[2‡], Ahmad Bukhari[2], Omer ElTahir[5], Amr Jamal[1,3,6*‡], Rabih Halwani[7,8], Khalid Alhasan[1,2‡], Adi Alherbish[1,2], Reem Temsah[9], Jaffar A. Al-Tawfiq[10,11,12‡] and Mazin Barry[1,13‡]

[1] College of Medicine, King Saud University, Riyadh, Saudi Arabia, [2] Pediatric Intensive Care Unit, Department of Pediatrics, King Saud University Medical City, King Saud University, Riyadh, Saudi Arabia, [3] Department of Family and Community Medicine, King Saud University, Riyadh, Saudi Arabia, [4] Critical Care Department, King Saud University Medical City, Riyadh, Saudi Arabia, [5] Department of Medicine and Clinical Pharmacology, University of Medical Sciences and Technology (UMST), Khartoum, Sudan, [6] Evidence-Based Health Care and Knowledge Translation Research Chair, King Saud University, Riyadh, Saudi Arabia, [7] Sharjah Institute of Medical Research, University of Sharjah, Sharjah, United Arab Emirates, [8] Department of Clinical Sciences, College of Medicine, University of Sharjah, Sharjah, United Arab Emirates, [9] College of Pharmacy, Alfaisal University, Riyadh, Saudi Arabia, [10] Specialty Internal Medicine and Quality Department, Johns Hopkins Aramco Healthcare, Dhahran, Saudi Arabia, [11] Infectious Disease Division, Department of Medicine, Indiana University School of Medicine, Indianapolis, IN, United States, [12] Infectious Disease Division, Department of Medicine, Johns Hopkins University School of Medicine, Baltimore, MD, United States, [13] Division of Infectious Diseases, Department of Internal Medicine, College of Medicine, King Saud University and King Saud University Medical City, Riyadh, Saudi Arabia

Objectives: With the evolving COVID-19 pandemic and the emphasis on social distancing to decrease the spread of SARS-CoV-2 among healthcare workers (HCWs), our pediatric intensive care unit (PICU) piloted the integration of Zoom meetings into clinical rounds. We aimed to explore the feasibility of these hybrid virtual and physical clinical rounds for PICU patients.

Design: Mixed quantitative and qualitative deductive thematic content analysis of narrative responses.

Setting: PICU, single tertiary-care academic center.

Participants: Multidisciplinary PICU HCWs.

Interventions: Integration of Zoom meeting into clinical daily PICU rounds.

Measurements: For the quantitative part, we gathered the details of daily PICU hybrid rounds in terms of times, number of HCWs, and type of files shared through Zoom. For the qualitative part, open-ended questions were used.

Main Results: The physical round took statistically significantly less time (34.68 ± 14.842 min) as compared with the Zoom round (72.45 ± 22.59 min), $p < 0.001$. The most shared component in the virtual round was chest X-rays (93.5%). Thirty-one HCWs participated in focus group discussions and were included in the analysis. Some of the HCWs' perceived advantages of the hybrid rounds were enabling multidisciplinary discussions, fewer round interruptions, and practicality of virtual discussions. The perceived challenges were the difficulty of the bedside nurse attending the virtual round, decreased teaching opportunities for the trainees, and decreased interactions among the team members, especially if video streaming was not utilized.

Conclusions: Multidisciplinary hybrid virtual and physical clinical rounds in the PICU were perceived as feasible by HCWs. The virtual rounds decreased the physical contact between the HCWs, which could decrease the possibility of SARS-CoV-2 spread among the treating team. Still, several components of the hybrid round should be optimized to facilitate the virtual team-members' interactions and enhance the teaching experience.

Keywords: PICU hybrid rounds, PICU videoconferencing through Zoom, PICU Zoom teleconferencing, PICU multidisciplinary virtual round, Zoom clinical rounds

INTRODUCTION

SARS-CoV-2 infections continue to surge with more than 140 million confirmed cases of COVID-19, including more than 2 million deaths, as reported to the World Health Organization (1). With the second and third waves surging in multiple countries and several SARS-CoV-2 variants posing more challenges, the healthcare system needs more innovations to mitigate the surge in cases and protect the healthcare workers (HCWs) on the front lines (2, 3). Some healthcare systems emphasize the importance of infection prevention for the HCWs even outside the clinical areas due to their vital value (4).

Social distancing is one of the pillars of infection control measures, which may seem difficult to apply in daily hospital rounds, during which the whole healthcare team meets at the bedside, discussing the new clinical developments and best management approach for each patient. Previous research shows that most activities on attending rounds do not actually need to take place at the bedside (5). Another similarly important aspect of these bedside rounds is the clinical teaching and multidisciplinary interactions that are vital to the ongoing process of perfecting the healthcare professionals of the future with better utilization of healthcare resources, which also does not necessarily require close gathering at the bedside (6).

After successfully implementing the virtual handover process of our pediatric intensive care unit (PICU) patients during the COVID-19 crisis (7), we planned to explore the feasibility of a hybrid morning daily clinical round in the PICU that was implemented in September 2020 (**Appendix 1**). This pilot study explores whether this hybrid round style decreased the timing of the physical proximity between the HCWs. Another aim was to facilitate multidisciplinary team discussions, especially when several team members were not attending the hospital daily during the pandemic crisis.

METHOD

Study Design

This study is a mixed quantitative and qualitative deductive thematic content analysis of the narrative responses from various HCWs in the PICU. The main aim of the qualitative component is to seek future potentials for this novel, hybrid-style PICU round application. We choose the focus group (F.G.) method to clarify issues that may be difficult to raise in one-to-one interviews, such as dissatisfaction with services provided (8).

Setting

The HCWs of the PICU at King Saud University Medical City (KSUMC) include six consultants, eight registrars, four to six training residents, two PICU fellows, 45 nurses, one pharmacist, one clinical dietician, one social worker, and rotating respiratory therapists. The PICU team serves 15 ventilated beds.

The hybrid rounds were newly implemented on May 15, 2020. Their structure consisted of starting the daily clinical round with a Zoom® meeting involving all the members of the PICU, including the physicians, bedside nurses, pharmacist, dietician, respiratory therapist, and social worker. The Zoom® meeting was mainly devoted to discussing all the patients, including all the clinical data from all involved disciplines; the suggested management plan; and the educational aspect needed for specific clinical issues. After the virtual meeting, the on-call team, bedside nurses, and whoever is needed in the PICU attends the physical rounds at the bedside for the issues requiring addressing there and counseling the parents about their child's status.

Sampling and Recruitment

HCWs from various PICU backgrounds were invited to participate in this F.G. on November 12, 2020.

Data Collection

Open-ended questions were used as per **Appendix 2**.

Data Analysis

The first step in the analysis involved reading and familiarization with the participants' range of responses. Categories were established, and two authors (NA and MT) developed codes independently. NA, an expert in qualitative methodology working in family and community medicine, introduced an etic perspective of the topic, and MT, a PICU consultant, introduced an emic perspective.

The developed codes were similar and were discussed before a consensus on the coding frame was established. All themes were *a priori* themes; however, the range of responses under each subtheme was derived from the data. Qualitative data management was conducted using NVivo 10®.

After obtaining institutional review board approval, we invited PICU physicians of KSUMC, who had been working in a hybrid manner using Zoom®, to describe their experience

Abbreviations: CDC, Centers for Disease Control and Prevention; COVID-19, coronavirus disease 2019; EHR, electronic health records; ePPE, electronic personal protective equipment; KSUMC, King Saud University Medical City; PICU, Pediatric Intensive Care Unit; RT, respiratory therapist; WHO, World Health Organization.

through a qualitative F.G. virtual meeting. Content analysis was used to analyze the participants' responses. The results were used as a part of the quality improvement project and shared with the pediatric department quality committee.

Statistical Analysis

Descriptive statistics were used to summarize the data. For the categorical data, we used frequencies and descriptive procedures (minimum, maximum, mean, and S.D). A line chart connecting a series of data points with a continuous line is used to show the trend over time.

RESULTS

Quantitative Part

Our analysis shows a clear difference between the time spent during the Zoom® rounds and physical rounds as shown in **Table 1**. Additionally, over the 1-month pilot study period, the time spent during zoom rounds has dropped from around 60 min in the beginning to around 40 min at the end of the month although the number of patients was almost consistent throughout the month. This trend was also observed for the physical rounds as time spent dropped from 38 to 18 min (**Figure 1**).

The paired-samples *t*-test was used to compare the duration of the round (minutes) between physical and virtual rounds; the analysis shows that the physical rounds required significantly less time (M = 34.68, SD = 14.84) than the virtual Zoom part (M = 72.45, SD = 22.6), $p < 0.001$.

Regarding the number of staff who attended the hybrid rounds, our results show that the number of HCWs attending the Zoom® part increased steadily over the study period, from seven in the beginning to more than 15 at the end of the month, and the number of the staff who attended the physical (in-hospital) part remained somewhat stable over the study period (five to seven) as shown in **Figure 2** and **Table 2**. During the Zoom meetings, the most commonly shared files were chest X-rays that were shared almost daily (**Figure 3**).

Qualitative Part

Twelve PICU HCWs joined the F.G.: three consultants, three specialists, two training residents, two nurses, a pharmacist, and a dietician. During the meeting, participants discussed factors that affected their practice as a result of online rounds. The following presents the themes that were discussed during the F.G.

PERCEIVED ADVANTAGES OF HYBRID ROUND

Besides lowering the chances of being infected with COVID-19, participants mentioned other advantages they perceived as a result of using hybrid rounds. The following represents subthemes of perceived advantages.

Multidisciplinary Meeting

All participants believed that one of the most significant advantages of Zoom meetings is the opportunity to assemble people from different specialties at the same time to discuss patients' conditions.

"The only thing that I think Zoom probably has an advantage in is for the multidisciplinary meetings regarding patients with different subspecialties joining. Otherwise, we do have difficulty arranging a meeting that suits everybody" P10.

The participants appreciated the convenience of inviting colleagues from other disciplines to discuss PICU cases. "You can invite any subspecialty, who could attend with us... if we need to discuss a specific patient for a specific concern" P1.

Family Involvement

All participants appreciated the benefits they encountered regarding online communication between the PICU team and families. According to them, not having several family members at the bedside made them better focus on their clinical rounds, finish on time, and give families their undivided attention when discussing their children's medical status.

One participant remarked, "Now we focus more and avoid distractions from overcrowding areas... just avoid noisy areas with families gathering or interrupting the round" P8.

Another one added, "We have a special link for the families. Also, that is really very helpful for us because otherwise the families are coming during COVID crisis and interrupting the team dynamics, it is helpful for the PICU workflow" P2.

The Practicality of Online Meetings

Participants mentioned many points related to the practicality of online rounds. All participants agreed that having online meetings from their offices was more convenient. "It's very convenient that you could be sitting all the time discussing things you could have your cup of tea or coffee in your office while you're in the round" P10.

Four of them also expressed being more efficient after the introduction of online rounds. For example, "My computer is in front of me, so I'm checking the patient during the Zoom round. I can check the labs, check the literature while they discuss the patient's condition... When we finished the rounds, I can promptly put the orders in the EHR. Previously, with the physical rounds, I had to wait until we finish, and then I would go to my office and start doing the orders for the patients, which is more time-consuming" P5.

Another participant added, "For us, Zoom meetings are effective: we can finish our task during the rounds. We can finish the orders swiftly" P11.

PERCEIVED CHALLENGES OF HYBRID ROUND

Participants in the F.G. addressed some challenges that they faced during hybrid rounds. The following presents the subthemes that emerged from the discussion.

Nursing Duties

During the F.G., both nurses agreed on the difficulty of keeping up with online rounds and patient care at the same time.

TABLE 1 | PICU Zoom round and physical round times (in minutes).

	N	Minimum	Maximum	Mean	Median	Std. Deviation	Sum
Zoom time	31	45	122	72.45	65	22.590	2,246
Physical round time	31	10	70	34.68	33	14.842	1,075

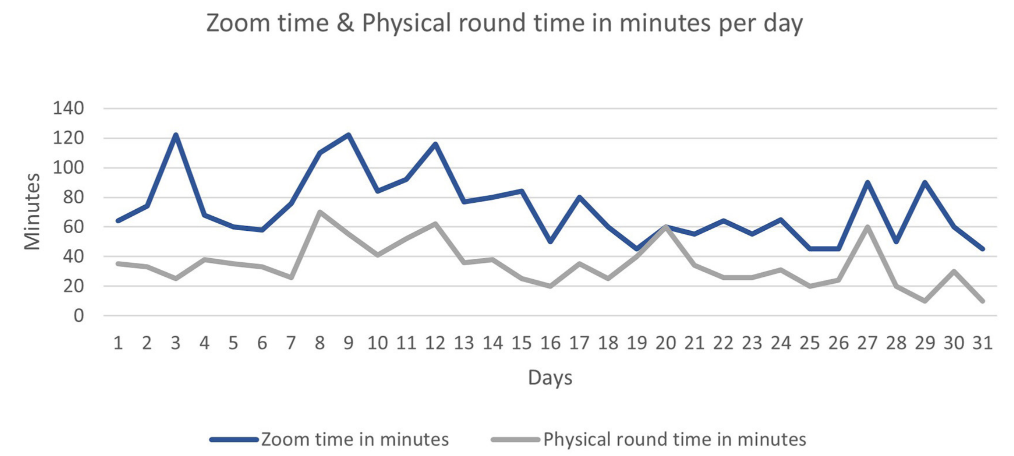

FIGURE 1 | Zoom time and physical round time in minutes per day. *ECG, electrocardiogram; EHR Electronic Health Records; CXR, chest X-rays.

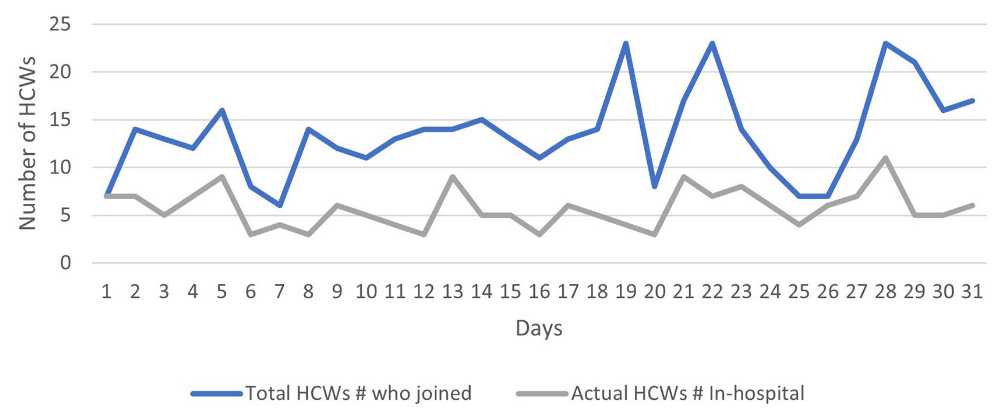

FIGURE 2 | Total number HCWs who joined both the Zoom and the physical (in-hospital) part of hybrid rounds per day.

TABLE 2 | Total number of HCWs who joined the Zoom part of the hybrid PICU round and the actual HCWs who joined the subsequent physical round.

	Minimum	Maximum	Mean	Median	Std. Deviation
Total number of HCWs who joined Zoom part of hybrid rounds	6	23	14	15	4.224
Actual in-hospital HCWs attending the physical part of hybrid rounds	3	21	6	5	2.053

However, this is similar to the previous PICU rounds, when the nurses used to attend frequently to the patient's needs while the charge nurse would continue with the round. This was explained by one of the participants: "The charge nurse should be present throughout the hybrid round…And the assigned nurse for each patient before the pandemic will be involved in the rounds when her assigned patient is being discussed. Now, if we are asking nurses to attend the whole Zoom rounds, that could be less time attending their patients?" P5.

A head nurse added, "Sometimes while we attend the Zoom round, something may happen to the patient, and the bedside nurse has to go inside the room immediately…so, when not

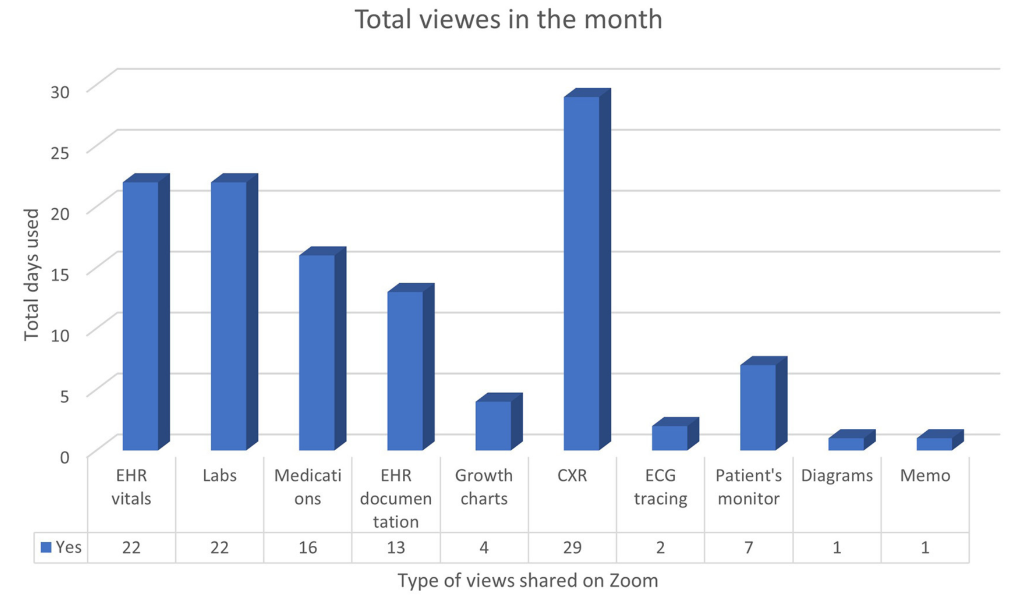

FIGURE 3 | Total views per type shared on the Zoom round over the month. EHR, electronic health records; CXR, chest x-rays.

discussing their cases, there is no point in attending the whole Zoom round" P3.

The time nurses spent on online rounds was sometimes lengthy yet justified from their perspective: "It's different from day to day, but it's around one or one and a half hours. According to the number of patients we have and the severity of the cases and if they may need a lot of discussions or have multiple teaching points" P3.

This challenge experienced by the nurses made some other participants look for a solution to overcome it. A resident commented, "I suggest that we can have sequence numbering of patients that we are discussing. Number one would be the first patient to discuss, can be the sickest one. Number two, the less sick…and like that. The nurse would be able to know the order of when they are discussing her patient and be prepared to log in on time" P6.

Another consultant noted, "So, if they can share with the nurses through one dedicated device with the charge nurse handing it to each assignment nurse. So when we are discussing patient X, the device will be with the nurse assigned to patient X. They would attend for 15–20 min, then they will be focusing on patient care" P12.

Teaching Opportunities

Both residents within the F.G. were concerned about learning and commented on the effect of hybrid rounds on teaching opportunities. "Previously, there was more discussion and more teaching points to be addressed. I lost that sense in the hybrid rounds" P11.

One participant compared the discussions held at the bedside with those online; she explained, "Usually, bedside teachings were better. There's more discussion and more brainstorming and motivates me…" P8.

She continued, "When things occurred during the round, the whole team is involved, to reflect on what happened…and how we manage it…This aspect of the teaching: we lost because we are sitting away from the patients during the round, just to be able to focus more and avoid all distractions" P8.

Furthermore, residents commented on the effect of hybrid rounds on "X-ray rounds," one participant explained, "Previously, we used to start our PICU rounds with X-ray rounds, for 20 min discussing only all radiological exams of PICU patients. Nowadays, during COVID, we're having Zoom rounds, we will show some X-rays, we will share the screen for the X-ray and sometimes pass it quickly" P5.

Participating consultants approved their residents' concerns and explained their point of view on teaching using online methods. One of the consultants noted, "Sometimes, I don't feel motivated enough to teach during the rounds compared to the usual rounds. You can easily change your tone. You see the facial expressions you see who want to get more of your teaching. So that would all motivate you to give more" P10.

Another consultant added, "It [bedside rounds] used to be much more interactive with the application of knowledge rather than just didactic lecturing online or just answer the questions rather than building confidence into the solid background of the theoretical and practical approaches…people get "pulled away" from teaching if they are just facing a screen instead of reflecting on a patient look or patient monitor or ventilator or even something in the equipment has changed our approach to the medications. It's [face-to-face teaching] totally much more engaging" P9.

Furthermore, teaching was affected by the number of residents attending during the pandemic: "During COVID, it's really affected bedside teaching, especially for the residents. Daily, the hospital decreased the number of residents attending daily to enhance social distancing. Only three residents (from six or seven) attending inside the PICU. So, the clinical teaching is really compromised during this time" P12.

Another participant added, "Still, some residents outside the hospital had the chance to participate in the Zoom round, so that could be a chance for more educational interactions even when they were not there in the physical rounds" P9.

Discussions and Interactions

Although it was recommended that participants use their cameras during virtual rounds, they mostly did not.

According to a consultant, "We tell people inside the hospital: please turn on your camera to make more interactions, especially for teaching or discussions. But mostly, they are not listening; they just open their mics when they decide to talk" P4.

During the rounds, proper engagement and interactions from the team members were limited for reasons related to not seeing the speakers. A participant noted, "The engagement and reading people body languages, getting people attention, focusing on what people need, reflecting on and building on ideas gradually as a group. This is usually done much better face-to-face, compared to just online…The online style maybe limiting the team's interactions" P9.

A consultant noted, "I think this sometimes may compromise a patient's care if the nurse doesn't speak up during the online meeting. During most of the online meetings, the nurses' interaction seemed less compared as to the face-to-face or physical rounds" P9.

Another participant added, "The Zoom becomes sometimes boring. Sorry to say that because, as with lectures, hearing is not like hearing and seeing, so you cannot fully concentrate and interact like when you are in physical rounds. You will also feel distracted since you are in your office; you can do other things while you are attending the round" P7.

The Need to See Patients in the PICU by All Team Members

There were different opinions among the care team members about the utility of the virtual rounds as relates to the patient care. Physicians within the group thought that online meetings could not be blamed for compromising patient care as explained in the following quotes:

"Physicians who are assigned with the patients, they are coming to the bedside" P3.

"There are several physicians who are already available in the unit for the patients, so their care is not affected at all" P2.

On the other hand, the nutritionist thought that she needs to see the patient to provide a better service. She illustrated, "I go look at the patient and see if he/she is wasted or overweight and well-nourished. Now I miss those things because I don't go to the PICU as before COVID. So, I depend on the numbers, like height and weight, which are sometimes not accurate, so I must check with the doctors and nurses about the patient's physical appearance" P5.

Role of R.T.s in the Online Rounds

Despite participants' acknowledgment of the convenience of multidisciplinary meetings using online methods, this did not facilitate involving R.T.s, whose roles were perceived as crucial for patient care quality in the PICU. One of the consultants clarified, "Before we are having dedicated R.T. to the PICU. Yeah. Now, during the COVID crisis, the R.T.s are shared with two or three other units, there is more demand for their services during the pandemic. It's mainly a respiratory pandemic. So that's a problem…it was another challenge to invite them because the R.T. has very valid points to raise when we talk about mechanical ventilation. We need them for the full respiratory management of these children" P9.

DISCUSSION

In this pilot study, the physical PICU clinical round time was significantly less than the Zoom component. Close contact with SARS-COV-2 carriers becomes riskier as more time is spent in such encounters. The Center for Disease Control and Prevention (CDC) reported in its Morbidity and Mortality Weekly Report (MMWR) on April 14, 2020, about HCWs who developed COVID-19 after having longer durations of exposure to the index COVID-19 patient (9). These findings underscore the heightened COVID-19 transmission risk associated with prolonged, unprotected patient contact. The CDC recently reported that recurring brief encounters could lead to COVID-19 transmission (9). This could be an additional risk for HCWs in the acute care areas who manage COVID-19 suspected patients. Furthermore, asymptomatic SARS-COV-2 infection was reported in 14.3% of HCWs, implying that strict infection measures among HCWs are needed to reduce transmission risks to other HCWs and patients (10).

The implementation of the Zoom hybrid round was feasible yet challenging in our PICU setting. The utilization of technology as a novel communication tool during the pandemic and tele-ICU was advocated in recent literature (7, 11, 12). During times of physical distancing, HCWs may find it helpful to use videoconferencing services to sustain professional meetings and continue educational activities using online platforms (11). Recent policy changes in telemedicine during the COVID-19 pandemic have generated technology-based clinical tool opportunities, which could help conserve personal protective equipment (PPE) and protect HCWs (13). Such a new approach was labeled electronic PPE (ePPE), which would maintain clinical services, preserve the actual PPE, and keep HCWs safe (13).

Virtual rounds in our pilot period replaced 60% of the physical round. The estimated time saved was utilized to enhance and augment the discussion about the patients' conditions, laboratory findings, and teaching. Such rounds are essential aspects of the education and teaching of medical students, interns, and residents, allowing them to understand key information and develop clinical reasoning (14). Virtual rounds may also decrease the embarrassment that students may have due to the presence of patients. However, one drawback is the lack of patient–learner interactions (14, 15). Other studies show that virtual rounds specifically designed to manage COVID-19 patients had a favorable assessment by patients and learners (16). It is also shown that virtual teaching is effective and may further enhance education by the availability of different specialties (17).

Our hybrid clinical round setting allowed multidisciplinary teams, reaching up to 23 HCW at the same time while maintaining social distancing. In a perspective piece on remote pediatric healthcare delivery during the pandemic, researchers highlighted the different variations and innovations in adaptation and called for integrating telemedicine and virtual health (18). Our hybrid approach can be adapted and validated by other PICUs in which the number of HCWs may exceed ours and when physical distancing may not be feasible. Although vaccination of HCWs is being rolled out with excellent efficacy (19, 20), the emergence of mutant variants (21–23) will continue to challenge HCWs and still imply continued universal masking and physical distancing (24).

Our study participants commented about the need for flexibility in the hybrid round to allow for patient care as needed. ICU nursing staff are under unprecedented pressure during the pandemic and show resilience and continued patient care despite all stresses and pressure (25); this type of hybrid round would help alleviate some of that pressure without compromising patient care.

Some overwhelmed clinical services, such as R.T.s, were unable to join the Zoom part of the rounds in our setting. With the overwhelming number of critical care patients requiring respiratory support, a surge in demand for respiratory therapists was seen with safety, treatment, and staffing recommendations published (26) and evaluating tools on R.T. extended comfort with mechanical ventilation during the pandemic, a hybrid type of round may help alleviate such pressure on R.T.s allowing them to have more time to tend to their patients (27).

This study shows that the most shared items during the virtual clinical round were radiography, EHR vitals, and laboratory data. The ability to share radiographs is an essential aspect of the Zoom clinical rounds. In one study, radiology residents could transition the teaching conference and educational lectures entirely to a virtual format (28). Of course, as indicated previously, one possible extension of this feature is that trainees may seek input from more senior physicians using Zoom methods (28). This feature was highly appreciated by the residents who were involved in our study. In addition, it is very convenient to read out or share screens to discuss other patients' related data, such as laboratory data and vital signs either as data points or utilizing any graphic presentations, provided the patient's confidentiality is maintained with Zoom's end-to-end encryption (29).

Although telehealth has multiple advantages, it also has its pitfalls. One such pitfall is that physical examination might not be optimal, especially for new physicians. In one study, telemedicine demonstrated poor agreement with an in-person examination of patients with tonsilitis (30). Few studies are addressing the validity of virtual examinations (31). Because it is likely that telemedicine for examination will continue beyond the pandemic, some studies are looking at proposals for such examinations (32). This requires additional skills of the individuals using telemedicine, including robust communication skills and the ability to perform such examinations remotely and accurately.

Participants suggest that clinical teaching for the training residents was compromised during COVID-19, especially for those outside the hospital. The Zoom round seemed to have both negative and positive impacts on the teachings but needs to be optimized. It is crucial to build telemedicine into the residency program's curriculum and to expose medical students to the advantages and disadvantages of telemedicine (33). In addition, it is essential to address technical proficiency, history taking, examination skills, and communication (34). In addition, it is important to combine both telemedicine and in-person clinical rounds as a hybrid activity. A pilot study of the use of telemedicine in primary care shows general acceptability with logistics and other concerns. It is important to note the exposure to telemedicine by medical students, and 17.4% of students had prior telemedicine exposure (35). Such integration of telemedicine into medical education is of paramount importance (36).

The presence of the family during rounds and sharing decisions will increase family satisfaction during admission and may enhance the communication between the treating team and parents (37). However, frequent parental interruptions of the PICU round increases the round time and affects the team dynamics (37, 38). Hybrid rounds started initially before in-person rounds, and this can gather information about the patient and sharing decisions among medical team, providing a teaching opportunity for the rotators without interruption from the family (39). Still, the possibility of a decrease in the quality of face-to-face interactions between the residents could affect the interactive family scenarios in the PICU (40).

LIMITATIONS

This single-center experience needs to be validated in other settings. Training may be more challenging in other hospitals as our PICU team was already using videoconferencing by Zoom for patient handover. Although we did notice a decrease in the time of the hybrid round over the 1-month study period for the same number of PICU patients, this observation might still point to the team's learning curve, which has improved over time with the new hybrid system of daily rounds. However, this study was not designed to examine the HCWs' learning curve, and reporting learning curves in health profession research is deficient and often underutilizes their desired properties (41). Also, in our F.G., representativeness was not a goal for the qualitative part of this study. Therefore, further research could benefit from getting more nurses' input on the nature of their involvement with their PICU patients and families.

In addition, further research is required to focus on predefined patient outcomes in a multicenter prospective trial. The current pilot study was intended to check the feasibility of this hybrid style, and the PICU rounds' time depends on multiple factors, such as the number and complexity of the PICU patients and the interdisciplinary team dynamics, and other factors that may be different from day to day. Thus, it could be best to examine the direct effect of a virtual clinical round on reducing the duration of the physical rounds in future research.

CONCLUSION

Hybrid-style rounds in the PICU were feasible and decreased the timing of the physical round. The virtual component of the daily hospital rounds facilitated multidisciplinary discussions and trainees' interactions both inside and out of the hospital setting. However, there were concerns about the quality of teaching and team members' interactions, especially when the cameras were not used. More studies are needed to explore if the virtual part of the clinical round is best suited for the patients' management and HCWs' experience.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Materials**, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by IRB, College of Medicine, King Saud University, Riyadh, Saudi Arabia. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

M-HT, AAlhb, NA, JA-T, FAlj, AA-E, MB, and AAs conceptualized the study, analyzed the data, and wrote the manuscript. FAls, AJ, MA, OE, and RT contributed to the study design, collected, analyzed, interpreted data, and edited the manuscript. KA contributed to the study design, interpretation, and edited the manuscript. AB, AAlhe, and RH interpreted the data and finalized the manuscript. All authors contributed to drafting, reviewing, and approving the final version of the manuscript.

ACKNOWLEDGMENTS

We are grateful to all the PICU team and all HCWs on the front lines of COVID-19. We are also thankful to Dr. Samia Ismail for her valuable efforts, and to Consulla Data analysis and statistical consulting for their support. The authors are grateful to the Deanship of Scientific Research, King Saud University, for funding through the Vice Deanship of Scientific Research Chairs.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fped.2021.720203/full#supplementary-material

Appendix A1 | Details of the PICU hybrid-style round.

Appendix A2 | The F.G. themes and questions.

REFERENCES

1. Organization WH. *WHO Coronavirus (COVID-19) Dashboard*. (2021). Available online at: https://covid19.who.int/ (accessed April 18, 2021).
2. Lancet T. COVID-19: protecting health-care workers. *Lancet.* (2020) 395:922. doi: 10.1016/S0140-6736(20)30644-9
3. Nguyen LH, Drew DA, Graham MS, Joshi AD, Guo CG, Ma W, et al. Risk of COVID-19 among front-line health-care workers and the general community: a prospective cohort study. *Lancet Public Health.* (2020) 5:e475–83. doi: 10.1101/2020.04.29.20084111
4. Ling L, Wong WT, Wan WTP, Choi G, Joynt MG. Infection control in non-clinical areas during the COVID-19 pandemic. *Anaesthesia.* (2020) 75:962–3. doi: 10.1111/anae.15075
5. Stickrath C, Noble M, Prochazka A, Anderson M, Griffiths M, Manheim J, et al. Attending rounds in the current Era: what is and is not happening. *JAMA Internal Med.* (2013) 173:1084–9. doi: 10.1001/jamainternmed.2013.6041
6. Dutton RP, Cooper C, Jones A, Leone S, Kramer ME, Scalea MT. Daily multidisciplinary rounds shorten length of stay for trauma patients. *J Trauma Acute Care Surg.* (2003) 55:913–9. doi: 10.1097/01.TA.0000093395.34097.56
7. Temsah M-H, Abouammoh N, Ashry A, Al-Eyadhy A, Alhaboob A, Alsohime F, et al. Virtual handover of patients in the pediatric intensive care unit during the Covid-19 crisis. *J Multidiscipl Healthcare.* (2021) 14:1571–81. doi: 10.2147/JMDH.S310028
8. Green J. Qualitative methods. *Community Eye Health.* (1999) 12:46–7.
9. CDC. *COVID-19 in a Correctional Facility Employee Following Multiple Brief Exposures to Persons with COVID-19 – Vermont.* (2020). Available online at: https://www.cdc.gov/mmwr/volumes/69/wr/mm6943e1.htm (accessed April 18, 2021).
10. Abdelmoniem R, Fouad R, Shawky S, Amer K, Elnagdy T, Hassan WA, et al. SARS-CoV-2 infection among asymptomatic healthcare workers of the emergency department in a tertiary care facility. *Journal of Clinical Virology.* (2021) 134:104710. doi: 10.1016/j.jcv.2020.104710
11. Garfin DR. Technology as a coping tool during the coronavirus disease 2019 (COVID-19) pandemic: Implications and recommendations. *Stress Health.* (2020) 36:555–9. doi: 10.1002/smi.2975
12. Chandra S, Hertz C, Khurana H, Doerfler EM. Collaboration between tele-ICU programs has the potential to rapidly increase the availability of critical care physicians-our experience was during coronavirus disease 2019 nomenclature. *Crit Care Explorat.* (2021) 3:e0363. doi: 10.1097/CCE.0000000000000363
13. Turer RW, Jones I, Rosenbloom ST, Slovis C, Ward JM. Electronic personal protective equipment: A strategy to protect emergency department providers in the age of COVID-19. *J Am Med Inform Assoc.* (2020) 27:967–71. doi: 10.1093/jamia/ocaa048
14. Hagana A, Behranwala R, Aojula N, Houbby N. Digitalising medical education: virtual ward rounds during COVID-19 and beyond. *BMJ.* (2020) 7:742. doi: 10.1136/bmjstel-2020-000742
15. Vogel D, Harendza S. Basic practical skills teaching and learning in undergraduate medical education - a review on methodological evidence. *GMS J Med Educ.* (2016) 33:Doc64. doi: 10.3205/zma001063
16. Hofmann H, Harding C, Youm J, Wiechmann W. Virtual bedside teaching rounds with patients with COVID-19. *Med Educ.* (2020) 54:959–60. doi: 10.1111/medu.14223

17. Wilcha RJ. Effectiveness of virtual medical teaching during the COVID-19 crisis: systematic review. *JMIR Med Educ*. (2020) 6:e20963. doi: 10.2196/20963
18. Badawy SM, Radovic A. Digital approaches to remote pediatric health care delivery during the COVID-19 pandemic: existing evidence and a call for further research. *JMIR Pediatr Parent*. (2020) 3:e20049. doi: 10.2196/20049
19. Hall VJ, Foulkes S, Saei A, Andrews N, Oguti B, Charlett A, et al. COVID-19 vaccine coverage in health-care workers in England and effectiveness of BNT162b2 mRNA vaccine against infection (SIREN): a prospective, multicentre, cohort study. *Lancet*. (2021) 397:1725–35. doi: 10.1016/S0140-6736(21)00790-X
20. Thompson MG, Burgess JL, Naleway AL, Tyner HL, Yoon SK, Meece J, et al. Interim estimates of vaccine effectiveness of BNT162b2 and mRNA-1273 COVID-19 vaccines in preventing SARS-CoV-2 infection among health care personnel, first responders, and other essential and frontline workers - eight locations US. December 2020-March 2021. *MMWR Morb Mortal Wkly Rep*. (2021) 70:495–500. doi: 10.15585/mmwr.mm7013e3
21. Hacisuleyman E, Hale C, Saito Y, Blachere NE, Bergh M, Conlon EG, et al. Vaccine Breakthrough Infections with SARS-CoV-2 Variants. *N Engl J Med*. (2021) 384:2212–8. doi: 10.1056/NEJMoa2105000
22. Cavanaugh AM, Fortier S, Lewis P, Arora V, Johnson M, George K, et al. COVID-19 outbreak associated with a SARS-CoV-2 R.1 lineage variant in a skilled nursing facility after vaccination program - Kentucky, March 2021. *MMWR Morb Mortal Wkly Rep*. (2021) 70:639–43. doi: 10.15585/mmwr.mm7017e2
23. Teran RA, Walblay KA, Shane EL, Xydis S, Gretsch S, Gagner A, et al. Postvaccination SARS-CoV-2 infections among skilled nursing facility residents and staff members - Chicago, Illinois, December 2020-March (2021). *MMWR Morb Mortal Wkly Rep*. (2021) 70:632–8. doi: 10.15585/mmwr.mm7017e1
24. CDC. *Interim Public Health Recommendations for Fully Vaccinated People*. (2021). Available online at: https://www.cdc.gov/coronavirus/2019-ncov/vaccines/fully-vaccinated-guidance.html#print (accessed May 30, 2021).
25. Thusini S. Critical care nursing during the COVID-19 pandemic: a story of resilience. *Br J Nurs*. (2020) 29:1232–6. doi: 10.12968/bjon.2020.29.21.1232
26. Vitacca M, Carone M, Clini EM, Paneroni M, Lazzeri M, Lanza A, et al. Joint statement on the role of respiratory rehabilitation in the COVID-19 crisis: the Italian position paper. *Respiration*. (2020) 99:493–9. doi: 10.1159/000508399
27. Roberts KJ, Johnson B, Morgan HM, Vrontisis JM, Young KM, Czerpak E, et al. Evaluation of respiratory therapist extender comfort with mechanical ventilation during COVID-19 pandemic. *Respir Care*. (2021) 66:199–204. doi: 10.4187/respcare.08459
28. Li CH, Rajamohan AG, Acharya PT, Liu CJ, Patel V, Go JL, et al. Virtual read-out: radiology education for the 21st century during the COVID-19 pandemic. *Acad Radiol*. (2020) 27:872–81. doi: 10.1016/j.acra.2020.04.028
29. Yuan ES. *End-to-End Encryption Update. Zoom Blog*. (2020). Available online at: https://blog.zoom.us/end-to-end-encryption-update/ (accessed July 26, 2020).
30. Akhtar M, Van Heukelom PG, Ahmed A, Tranter RD, White E, Shekem N, et al. Telemedicine physical examination utilizing a consumer device demonstrates poor concordance with in-person physical examination in emergency department patients with sore throat: a prospective blinded study. *Telemed J E Health*. (2018) 24:790–6. doi: 10.1089/tmj.2017.0240
31. Ansary AM, Martinez JN, Scott DJ. The virtual physical exam in the 21st century. *J Telemed Telecare*. (2019) 2019:1357633x19878330. doi: 10.1177/1357633X19878330
32. Benziger CP, Huffman MD, Sweis RN, Stone JN. The telehealth ten: a guide for a patient-assisted virtual physical examination. *Am J Med*. (2021) 134:48–51. doi: 10.1016/j.amjmed.2020.06.015
33. Jumreornvong O, Yang E, Race J, Appel J. Telemedicine and medical education in the age of COVID-19. *Acad Med*. (2020) 95:1838–43. doi: 10.1097/ACM.0000000000003711
34. Lawrence K, Hanley K, Adams J, Sartori DJ, Greene R, Zabar S. Building telemedicine capacity for trainees during the novel coronavirus outbreak: a case study and lessons learned. *J Gen Intern Med*. (2020) 35:2675–9. doi: 10.1007/s11606-020-05979-9
35. Fleming DA, Riley SL, Boren S, Hoffman KG, Edison KE, Brooks SC. Incorporating telehealth into primary care resident outpatient training. *Telemed J E Health*. (2009) 15:277–82. doi: 10.1089/tmj.2008.0113
36. Lee MS, Nambudiri V. Integrating telemedicine into training: adding value to graduate medical education through electronic consultations. *J Grad Med Educ*. (2019) 11:251–4. doi: 10.4300/JGME-D-18-00754.1
37. Grzyb MJ, Coo H, Rühland L, Dow K. Views of parents and health-care providers regarding parental presence at bedside rounds in a neonatal intensive care unit. *J Perinatol*. (2014) 34:143–8. doi: 10.1038/jp.2013.144
38. Ingram TC, Kamat P, Coopersmith CM, Vats A. Intensivist perceptions of family-centered rounds and its impact on physician comfort, staff involvement, teaching, and efficiency. *J Crit Care*. (2014) 29:915–8. doi: 10.1016/j.jcrc.2014.07.015
39. Gupta PR, Perkins RS, Hascall RL, Shelak CF, Demirel S, Buchholz TM. The effect of family presence on rounding duration in the PICU. *Hosp Pediatr*. (2017) 7:103–7. doi: 10.1542/hpeds.2016-0091
40. Gaulton J, Ziegler K, Chang E. Virtual practices transform the care delivery model in an intensive care unit during the coronavirus pandemic. *NEJM Catalyst*. (2020) 1–11. doi: 10.1056/CAT.20.0169
41. Howard NM, Cook DA, Hatala R, Pusic VM. Learning curves in health professions education simulation research: a systematic review. *Simul Healthc*. (2021) 16:128–35. doi: 10.1097/SIH.0000000000000477

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Citation: Temsah M-H, Alhboob A, Abouammoh N, Al-Eyadhy A, Aljamaan F, Alsohime F, Alabdulhafid M, Ashry A, Bukhari A, ElTahir O, Jamal A, Halwani R, Alhasan K, Alherbish A, Temsah R, Al-Tawfiq JA and Barry M (2021) Pediatric Intensive Care Hybrid-Style Clinical Round During COVID-19 Pandemic: A Pilot Study. Front. Pediatr. 9:720203. doi: 10.3389/fped.2021.720203

frontiers in Pediatrics

ORIGINAL RESEARCH
published: 17 September 2021
doi: 10.3389/fped.2021.642089

Check for updates

Pediatric Telehealth Expansion in Response to COVID-19

*Stormee Williams[1,2], Kristina Hill[2,3], Luyu Xie[2,3], M. Sunil Mathew[2,3], Ashley Ofori[2,3], Tamara Perry[1], Danielle Wesley[1] and Sarah E. Messiah[2,3]**

[1] Children's Health System of Texas, Dallas, TX, United States, [2] School of Public Health, University of Texas Health Science Center at Houston, Dallas, TX, United States, [3] Center for Pediatric Population Health, Children's Health System of Texas and University of Texas Health Science Center, Dallas, TX, United States

Introduction: Telehealth utilization has been steadily increasing for the past two decades and has been recognized for its ability to access rural and underserved populations. The advent of COVID-19 in March 2020 limited the feasibility of in-person healthcare visits which in turn increased telehealth demand and use. However, the long-term impacts of COVID-19 on the telehealth sector of the healthcare industry, and particularly on pediatric healthcare volume demand and subsequent expansion, are yet to be determined.

Objective and Methods: To understand the impact of COVID-19 on telehealth utilization, volume demand, and expansion in one large pediatric healthcare system serving greater Dallas-Fort Worth, Texas, data on telehealth clinic visits by month, pre-COVID and post/current-COVID were compared. A quasi-experimental pretest-posttest design analysis compared telehealth visit counts from 54 ambulatory pediatric health specialties. Pre-post new patient counts were also analyzed via chi square.

Results: Total telehealth visit counts significantly increased between March–October 2019 (2,033 visits) compared to March-October 2020 (54,276 visits). Mean monthly telehealth visits increased by 6,530 visits, or 2,569.75% over the same time period ($p < 0.0001$). In October 2020, total telehealth visits were still 1,194.78% above 2019 levels (345 visits in 2019 vs. 4467 visits in 2020).

Discussion: Results here show a substantial volume increase in telehealth-delivered pediatric healthcare and resource utilization as a response to COVID-19. This provides a template for permanent adoption of pediatric telehealth delivery post pandemic. Further investigation is needed to determine impacts upon resource allocation, processes, and general models and standard of care to assist facilities and programs to better address the needs of the pediatric populations they serve in the post-COVID era.

Keywords: telehealth, pediatric, expansion, COVID-19, healthcare, children, adolescents

OPEN ACCESS

Edited by:
Raj Ratwani,
MedStar Health Research Institute (MHRI), United States

Reviewed by:
Amrita Dosanjh,
University of California, San Diego, United States
Galit Hirsh-Yechezkel,
Gertner Institute for Epidemiology and Health Policy Research, Israel

****Correspondence:***
Sarah E. Messiah
sarah.e.messiah@uth.tmc.edu;
sarah.messiah@utsouthwestern.edu

Specialty section:
This article was submitted to Children and Health, a section of the journal Frontiers in Pediatrics

Received: *15 December 2020*
Accepted: *13 August 2021*
Published: *17 September 2021*

Citation:
Williams S, Hill K, Xie L, Mathew MS, Ofori A, Perry T, Wesley D and Messiah SE (2021) Pediatric Telehealth Expansion in Response to COVID-19. Front. Pediatr. 9:642089. doi: 10.3389/fped.2021.642089

INTRODUCTION

Telehealth is the use of telecommunication technology to provide long distance health care services. In the past decade, there has been a dramatic expansion of telehealth services in the United States (1). Generally, telehealth services are delivered using technological tools such as live video teleconferencing, store-and-forward technology, remote patient monitoring, telephone, mobile health applications, text, and email (2, 3). These tools enable providers to deliver clinical services and treatment to patients remotely in an efficient manner.

Telehealth has proven to be effective in managing acute infections, rapid pediatric triage in the emergency department, and providing positive mental health, primary care, cardiology, and dermatology outcomes (4). According to Polinski et al. (4), many patients are satisfied with the quality of care they receive through telehealth and find that their quality of care is comparable to that of traditional in-person care. Many patients prefer the convenience of telehealth services to those of traditional hospital care (4). Consequently, telehealth utilization by hospital systems in the United States has increased from 35% to 76% from 2010 to 2017 (5). Additionally, telehealth insurance claims increased by 53% from 2016 to 2017 (5). Studies indicate that telehealth care is cost-effective, especially when used for psychiatric care, radiology, and home healthcare services (2). It is also effective in reducing cost of travel and time for medical care, hospital utilization, improved patient compliance, satisfaction, and chronic disease management (6).

The efficacy and effectiveness of telehealth has consequently facilitated the implementation of telehealth programs in many pediatric hospitals, child care centers, and schools (7, 8). The incorporation of telemedicine in pediatric settings and school-based programs has been shown to reduce absenteeism, improve patient satisfaction, provide cost savings, reduce emergency department visits, and offer time savings for parents (9). Currently, medical subspecialties such as pediatric dermatology, emergency medicine, intensive care, neonatology, cardiology, surgery, and psychiatry are commonly known to utilize telemedicine (7).

Despite the many advantages and the growing use of telehealth in pediatric health, several studies have suggested that pediatric healthcare volume demand and expansion have been stifled by restrictive laws and regulations, payment structures, and reimbursement issues (10–12). Only 15% of pediatricians in a 2016 study reported having used telehealth (12). The most commonly reported barriers to telehealth adoption were insufficient payments and billing issues.

With the advent and spread of the novel coronavirus disease 2019 (COVID-19) in March 2020—which has limited the feasibility of in-person healthcare visits across the United States—telehealth demand and use has become increasingly important to meeting pediatric health care needs nationwide. School closures have given telehealth particular relevance for the pediatric population. Indeed, in a guidance issued on March 18, 2020, by the American Academy of Pediatrics, pediatricians were directed to increase telehealth care services to meet health care demands. This recommendation facilitated coverage expansion and relaxation of telehealth regulations in many states, and the expansion of Medicaid programs and other insurance payers which previously were barriers to telehealth expansion for pediatricians (11, 12). Thus, this guidance has opened opportunities for a potential rapid surge in telehealth utilization in pediatric health care delivery.

Though many recent studies and reports have alluded to the reduction in barriers to telehealth, and its general increased usage due to COVID-19 restrictions, an estimate of telehealth volume demand pre-post COVID-19 for pediatric health delivery has not been widely reported. The goal of this study is to assess pediatric healthcare volume demand and subsequent expansion before and after the advent of COVID-19 within one large pediatric healthcare system serving greater Dallas-Fort Worth, Texas. Findings from this study could provide evidence and direction for extent of adoption of pediatric telehealth delivery post the COVID-19 pandemic.

METHODS

Study Design

In March 2020, as COVID-19 spread quickly across the world, leaders at Children's Health System of Texas acknowledged the benefit telehealth could bring to the thousands of children and families that are served locally and regionally. It was decided to expand telehealth offerings beyond the previous 15 service areas to include most, if not all, of the 70 ambulatory service lines within the health system. To understand the implications and impact of the COVID-19 pandemic on telehealth utilization within a major pediatric health care system, we performed a quasi-experimental pretest-posttest design analysis in which the number of telehealth visits and the number of pediatric specialties performing these visits were reviewed and compared.

Procedure

To expand telehealth services rapidly, we had to quickly make assessments of existing resources including technology needs, staffing—both clinical and non-clinical—and training materials, and align those with the policy/credentialing, regulatory, and management needs of the system. Prior to COVID-19, there were 15 service lines already able to use telemedicine. During the pandemic, that number extended to 54 individual service lines (**Table 1**). A systematic approach was utilized to ensure that the individual physicians and staff received the appropriate training and credentialing they needed to use the technology to provide telemedicine care. This approach utilized teams of hospital managers and clinical advisors that worked to prioritize which service lines would receive the training and credentialing, and in what order. Staff in multiple departments worked around the clock to compress the work activities necessary to get physicians and frontline staff ready to use telemedicine.

Working along with clinical leadership in the ambulatory clinics, a prioritized list was drafted for the development of each virtual clinic. Prioritization was determined by clinical care severity levels. Using this method, cardiology, neurology, and solid organ transplant were among the first clinics implemented. During this rapid deployment, there were no exclusion criteria for telehealth visits implemented as federal and state mandates were in place to open visits to both audio and video-based visits. In addition, all telehealth visits could be billed under the emergency status which broadened the visit type allowance. Generally, visits would need to be via video for billing and reimbursement to occur in the ambulatory clinical setting.

During the expansion and rollout of the telehealth clinics, monitoring was put in place to track metrics such as number of telehealth visits, visit type, length of video/audio consult, and connection issues (dropped calls, platform disconnects, inability to use video, etc.). Daily and weekly meetings were convened to

TABLE 1 | Ambulatory telemedicine groups/clinics, Children's Health System of Texas.

Group or Clinic	Group or Clinic
Allergy and Immunology	Nephrology
Andrews Institute Orthopedics and Sports Medicine	Neuroimmunology
Clinic for At Risk Children	Neuropsychology
Clinic for At Risk Children—Psychology	Nutrition
Audiology	Our Children's House Therapy Services
Autism and Developmental Disabilities	Orthopedic Surgery
Autism and Developmental Disabilities—Neurology	Orthopedics
Autism and Developmental Disabilities—Psychology	Pediatric (General) Surgery
Cardiology	Pediatric Cardio Surgery
Cardiology—Pediatric Cardiology Associates of Houston	Pediatric Neurology
Cardiology—Pediatric Health Specialists	Pediatric Neurosurgery
Cityville Neurology	Pediatric Urology
Complex Care	Plano Allergy/Ear, Nose and Throat
Dermatology	Plastic Surgery
Developmental and Behavioral Pediatrics	Pre-Operative
Dallas Physicians Medical Services for Children	Psychiatry
Endocrinology	Psychology
Ear, Nose and Throat	Physical/Occupational/Speech Therapy
Emergency Room Center	Pulmonology
The FETAL (Fetal Evaluation and Treatment Alliance) Center	Rheumatology
General Pediatrics	Sleep Clinic
Genetics	Solid Organ Transplant
Gastrointestinal	Speech Language Pathology—Cityville
Gynecology	Surgery Specialty Center
Hematology and Oncology	Foster Care Clinic
Infectious Diseases	Thrive Post-NICU Clinic
Medical District Primary Care	Virtual Health

discuss recent trends and to implement any necessary changes quickly as the need arose. These data were analyzed in this study to provide insight on the impact of COVID-19 on telehealth utilization.

Statistical Analysis

Descriptive analysis was performed for patients' characteristics including age, sex, race/ethnicities (non-Hispanic white [NHW], non-Hispanic black [NHB], Hispanic, and other), preferred languages (English, Spanish, and other), insurance (government, commercial, and self-pay) and major diagnostic categories.

Pre-COVID vs. post-COVID visit counts were analyzed via chi square using Stata (copyright 2020, StataCorp LLC). Telehealth visit counts were grouped bimonthly (January-February, March-April, etc.). Bimonthly counts were compared from January 2019 through October 2020 (the final month with data available at time of manuscript writing). The primary results were taken from the comparison of the telehealth visit counts at the same time of year between 2019 and 2020, in order to account for possible fluctuations independent of the influence of the pandemic in healthcare and/or telehealth usage due to time of year, which might skew results. March 2020 marked the advent of COVID-19 in the areas served by the Children's Health System of Texas, and the period of marked increase for pediatric telehealth visits; therefore, focus was given to March-October of 2020 as compared with the same period in 2019, to show the full impact of the telehealth expansion pre- and post-COVID onset.

RESULTS

Table 2 shows the telehealth patients' sociodemographic information and major diagnostic categories where available. There were 1,779 and 43,997 telehealth visits between January and October of 2019 and 2020, respectively (total $n = 45,772$) for which demographic data were collected. Mean age was 11.8 years (standard deviation 9.3), 50.7% of the population were male, and the majority were non-Hispanic White (32.8%) or Hispanic (31.8%). Most patients preferred to speak English (79.3%), lived in Texas (98.5%), and were covered by either government insurance (54.8%) or commercial insurance (44.5%). In 2019, all patients had urgent care telehealth visits, so the diagnostic information were not available. In 2020, from the onset of the pandemic onward, the primary diagnoses were mental or neurodevelopmental disorders (22.2%), followed by endocrine,

TABLE 2 | Characteristics of patients based on telehealth visits, Jan–Oct 2019 and 2020.

	2019 (n = 1,775)	2020 (n = 43,997)	Total (n = 45,772)[a]
Age at visit, years, mean (SD)	31.2 (11.7)	11.0 (8.1)	11.8 (9.3)
Sex, *n* (%)			
Female	1,353 (76.2)	21,200 (48.2)	22,553 (49.3)
Male	422 (23.8)	22,790 (51.8)	23,212 (50.7)
Unknown	0 (0)	7 (0.02)	7 (0.02)
Race/ethnicity, *n* (%)			
Non-Hispanic white	158 (8.9)	14,859 (33.8)	15,017 (32.8)
Non-Hispanic black	31 (1.8)	8,703 (19.8)	8,734 (19.1)
Hispanic	83 (4.7)	14,456 (32.9)	14,539 (31.8)
Other/unknown	1,503 (84.7)	5,979 (13.6)	7,482 (16.4)
Parent preferred language, *n* (%)			
English	333 (18.8)	35,977 (81.8)	36,310 (79.3)
Spanish	5 (0.3)	5,543 (12.6)	5,548 (12.1)
Other	1,437 (81.0)	2,477 (5.6)	3,914 (8.6)
State, *n* (%)			
Texas	1,761 (99.2)	43,341 (98.5)	45,102 (98.5)
Other	14 (0.8)	656 (1.5)	670 (1.5)
Insurance, *n* (%)			
Government	1 (0)	25,066 (56.9)	25,067 (54.8)
Commercial	1,769 (99.7)	18,584 (42.2)	20,353 (44.5)
Self-pay/unknown	5 (0.3)	347 (0.8)	352 (0.8)
Primary diagnosis, *n* (%)			
Infectious disease	N/A[b]	322 (0.7)	322 (0.7)
Neoplasms		339 (0.8)	339 (0.8)
Diseases of the blood and blood-forming organs		695 (1.6)	695 (1.5)
Endocrine, nutritional, and metabolic disease		6,776 (15.4)	6,776 (14.8)
Mental and neurodevelopmental disorders		9,782 (22.2)	9,782 (21.4)
Disease of eye and ear		1,173 (2.7)	1,173 (2.6)
Circulatory system disease		1,049 (2.4)	1,049 (2.3)
Respiratory system disease		4,070 (9.3)	4,070 (8.9)
Digestive system disease		4,415 (9.6)	4,415(9.6)

[a] *The total visits in this table do not include telehealth urgent care patient visits from 2019 and 2020.*
[b] *The primary diagnosis for telehealth visits in 2019 is not available in the electronic health record.*

nutritional, and metabolic disorders (15.4%), digestive disease (9.6%), and respiratory disease (9.3%).

Total telehealth visit counts significantly increased in the eight-month periods between March-October 2019 (2,033 total telehealth visits) compared to March-October 2020 (54,276 total telehealth visits). Mean monthly telehealth visits increased by 6,530 visits, or 2,569.75% when comparing the same two time periods (p <0.0001). In October 2020, total telehealth visits were still 1,194.78% above 2019 levels (345 visits in 2019 vs. 4,467 visits in 2019). Telehealth visit counts for January-October of both years are shown in **Table 3** and **Figure 1**.

Telehealth visit counts in 2019 were also compared in two-month groupings via Chi-square against the same 2 months in 2020. Differences were not significant between January/February 2019 and January/February 2020 (both periods pre-COVID; Chi-square value 0.3231, p-value = 0.570). However, differences were stark from March/April 2019 compared to March/April 2020 (Chi-square value 791.7409, p-value < 0.0001). This trend continued for all 2-month groups excepting July/August 2019 vs. July/August 2020 (Chi-square value 0.3240, p-value 0.569). Full results of these comparisons are shown in **Table 4**.

DISCUSSION

Results here show a substantial volume increase in telehealth-delivered pediatric healthcare and resource utilization as a response to COVID-19. The differences are not explained purely by year upon year increases in telehealth usage, as seen by the lack of statistical difference between January/February 2019 and January/February 2020 periods (both unimpacted by COVID-19) as opposed to the distinctions seen between the remainder of 2019 and the corresponding months in 2020. Trends in utilization of telehealth in pediatric care pre-COVID, already on the rise, have been accelerated dramatically by the pandemic (13, 14). Healthcare providers may benefit from a

TABLE 3 | Telehealth visit counts in 2019 vs. 2020.

Month	2019	2020	% change
Jan	298	343	15.10
Feb	301	369	22.59
Mar	322	1,094	239.75
Apr	283	8,163	2,784.45
May	275	10,751	3,809.45
Jun	168	8,823	5,151.79
Jul	217	8,086	3,626.27
Aug	188	6,614	3,418.09
Sep	235	6,278	2,571.49
Oct	345	4,467	1,194.78

template for permanent adoption of pediatric telehealth delivery post pandemic.

Children's Health System of Texas has a long history of providing telehealth services. Beginning in 2013 with its tele-neonatology and tele-emergency programs that focused on providing doctor-to-doctor e-consults to referring hospitals, and a robust school-based telehealth program that has served over 15,000 patients in North Texas since its inception, the focus of the telehealth offerings were aimed at strategic priorities—reducing unnecessary patient transfers and emergency department visits. In 2015, telehealth services expanded to include direct-to-consumer telehealth visits, first to employees then for community pediatric and adult patients within the state of Texas, providing both urgent care and behavioral health consults. It was during this time that telemedicine services were offered to various subspecialties within the health system, while facing the ever-evolving reimbursement and regulatory challenges that were common across the country. With these challenges, the uptake of telemedicine throughout the health system was less than ideal.

The COVID-19 pandemic increased patient demand for telehealth services dramatically, as well as our health system's need to shift our paradigm in order to help keep our patients and staff safe. Swift rollout of the telehealth service lines was crucial in this period. Typically, the training process for telehealth rollout takes 2–3 weeks to complete per service line. In the face of the pandemic, this timeline was shortened to <1 week for each service line. One of the changes in procedure which allowed this rapid ramp-up was to train and credential the providers by department, as opposed to individual physicians on a first-come, first-served basis. Additionally, virtual training courses were developed to shorten the training cycle and could be completed by the providers around the clock. Training occurred separately for each provider and included a virtual mock visit with a qualified staff member. As many as 2000 providers were trained in total during this period across the 54 clinical departments involved.

The need and demand for telehealth in our health system mimics that of myriad health centers throughout the country which have had to adapt to the ever-changing and uncertain environment brought about by the pandemic. The long-term impact on telehealth utilization across the country is yet to be seen, but given the shifts in infrastructure, process, and resourcing that have occurred, it is likely that our system, and many others nationwide, will be utilizing telehealth at much higher rates than pre-pandemic in the coming months and years.

Further investigation is needed to determine long-term impacts upon resource allocation, processes, and general models and standard of care that COVID-19 has wrought in pediatric healthcare in the relatively short period since March 2020, as well as upon patient outcomes and management of pediatric care, as patients and practitioners alike adjust to the positive and negative aspects of telehealth as opposed to in-clinic visits. Better understanding of these impacts and models of rapid change such as those described above may assist facilities and programs nationwide to better address the needs of the pediatric populations they serve through telehealth in the coming months, and beyond in the post-COVID era.

Study Limitations and Strengths

Analysis was generated from a single pediatric healthcare system and therefore may not be generalizable to all others. However, Children's Health System of Texas covers a very populous area, with pediatric population over 60% Medicaid and primarily ethnic minorities (non-Hispanic black and Hispanic patients combined). Other pediatric healthcare systems with similarly socioeconomically and racially diverse makeup may benefit from observation of the model described here. Detailed information on socioeconomic status of patients were not available for this analysis, nor were information on other clinical characteristics of the patient population. The results of the study were captured in the short term over just a few months. Long-term ramifications of this drastic increase in pediatric telehealth services will be observed over the coming months and years in our system as well as others. Needed adaptations to the model described here will undoubtedly surface over that period in the changing environment.

Although the primary diagnosis information from 2019 are not available to compare by service line against that from 2020 for the purposes of this study, it is nonetheless noteworthy that the telehealth program instituted across all service lines used video only, without peripheral devices that can aid in diagnostic capabilities. This limits the types of diagnoses that can be adequately assessed and treated remotely. For example, mental and neurological diseases make up a large proportion of all visits due to the feasibility of diagnosing over video and discussing through counseling via telehealth, as opposed to diseases in in which a hands-on physical exam is needed. As healthcare systems, including our own, assess the long-term impacts of COVID-19 on their telehealth programs, the technologies utilized may adapt to better address these current functional limitations and may lead to areas of future study.

A result of the study that may become clearer when summer 2021 data are available to compare against is related to the difference between July/August 2019 and July/August 2020, which lacks statistical significance as per **Table 4**. Although the reason for the lapse during these months is unknown, potential contributing factors include

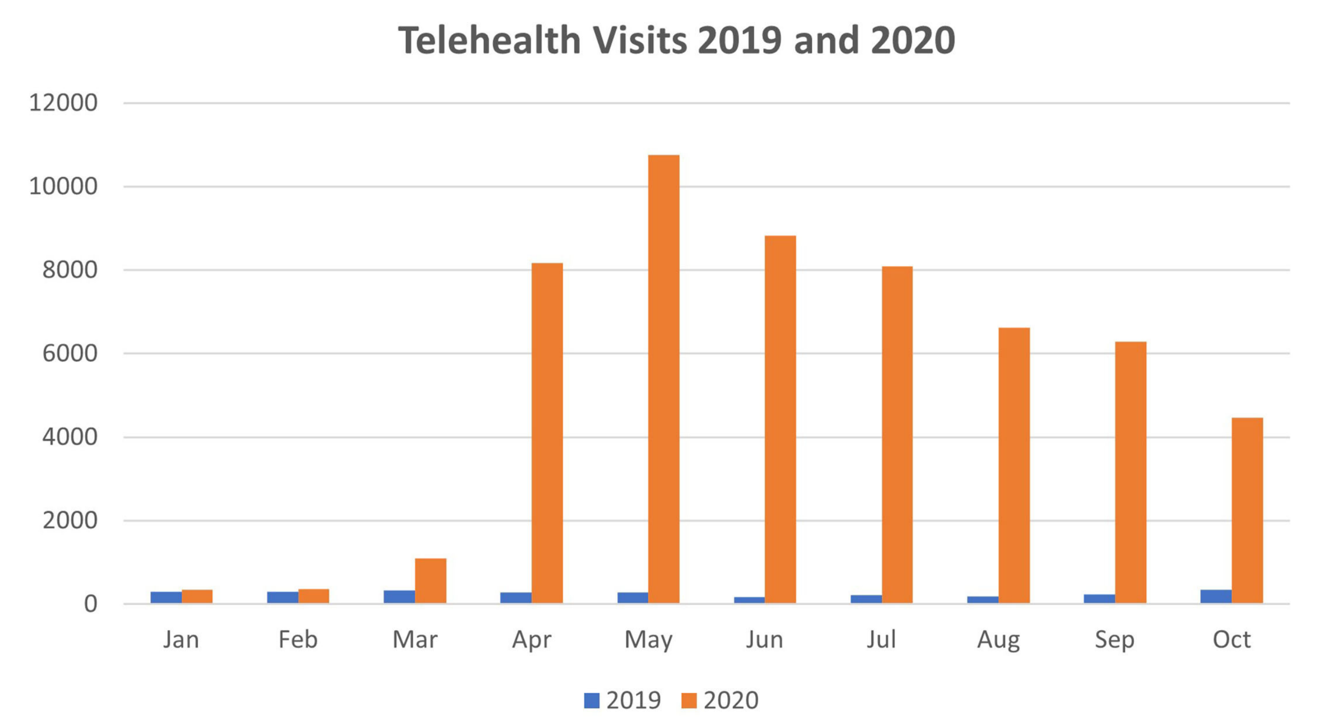

FIGURE 1 | Telehealth visits by month, 2019 and 2020.

TABLE 4 | Telehealth visit counts in 2019 and 2020*.

Month	Jan–Feb 2020		Mar–Apr 2020		May–Jun 2020		Jul–Aug 2020		Sep–Oct 2020	
	Chi-square statistics	*p*-values	Chi-square statistics	*p*-values	Chi-square statistics	*p*-values	Chi-square statistics	*p*-values	Chi-square statistics	*p*-values
Jan–Feb 2019	0.3231	0.570	667.3949	0.000	6.2841	0.012	6.4221	0.011	17.5348	0.000
Mar–Apr 2019	3.3355	0.068	791.7409	0.000	0.6863	0.407	0.7468	0.388	6.3738	0.012
May–Jun 2019	21.2175	0.000	880.9820	0.000	8.9556	0.003	8.6926	0.003	2.3354	0.126
Jul–Aug 2019	3.0179	0.082	577.0549	0.000	0.2898	0.590	0.3240	0.569	3.7703	0.052
Sep–Oct 2019	7.5797	0.006	384.7218	0.000	47.1565	0.000	47.2342	0.000	72.2360	0.000

**Chi-square statistics and p-values for the difference between bimonthly visit counts in 2019 and 2020.*

seasonal downtick in telemedicine usage generally and downtick in COVID-19 transmission during the warmer months of summer 2020.

Future potential areas of study outside the scope and reach of this project include analyses of the utilization and impact on condition control between separate specialty clinics employing telehealth; vaccination rates of telehealth patients vs. those among in-clinic patients; and relevant prescription information related to these telehealth visits as compared with in-clinic visits. In addition, long-term diagnosis and demographic patterns tracked as the telehealth program continues to expand may be illustrative of areas for further study within the patient population addressed here.

CONCLUSIONS

Results here show a substantial volume increase in telehealth-delivered pediatric healthcare and resource utilization as a response to COVID-19 in one of the largest pediatric health care systems in the United States. This provides a template for permanent adoption of pediatric telehealth delivery post pandemic. Further investigation is needed to determine impacts upon resource allocation, processes, and general models and standard of care to assist facilities and programs to better address the needs of the pediatric populations they serve in the post-COVID era. New models of care, including expanded telehealth, arising as the result of the pandemic should be evaluated for effectiveness, return on investment, and impact on quality, in order to determine standards for the new paradigm that best protect the interests of patients and other stakeholders involved in pediatric healthcare.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

SW and SM conceptualized the study. KH and LX conducted the analysis with oversight from SM. MSM and AO oversaw all data management and IRB aspects of the study. TP and DW oversaw all legal aspects of the project. All authors contributed intellectual property, writing to the final manuscript, and approved submission of the final manuscript.

REFERENCES

1. Roine R, Ohinmaa A, Hailey D. Assessing telemedicine: a systematic review of the literature. *CMAJ.* (2001) 165:765–71.
2. Charles BL. Telemedicine can lower costs and improve access. *Healthcare Financ Manage.* (2000) 54:66
3. Lurie N, Carr BG. The role of telehealth in the medical response to disasters. *JAMA Intern Med.* (2018) 178:745–6. doi: 10.1001/jamainternmed.2018.1314
4. Polinski JM, Barker T, Gagliano N, Sussman A, Brennan TA, Shrank WH. Patients' satisfaction with and preference for telehealth visits. *J Gen Intern Med.* (2016) 31:269–75. doi: 10.1007/s11606-015-3489-x
5. Kichloo A, Albosta M, Dettloff K, Wani F, El-Amir Z, Singh J, et al. Telemedicine, the current COVID-19 pandemic and the future: a narrative review and perspectives moving forward in the USA. *Fam Med Community Health.* (2020) 8:e000530. doi: 10.1136/fmch-2020-000530
6. Ekeland AG, Bowes A, Flottorp S. Effectiveness of telemedicine: a systematic review of reviews. *Int J Med Inform.* (2010) 79:736–71. doi: 10.1016/j.ijmedinf.2010.08.006
7. Chandler AL, Beavers JC, Hall RW. Telemedicine in pediatrics: possibilities and pitfalls. *Pediatr Rev.* (2020) 41:376–8. doi: 10.1542/pir.2019-0171
8. Love H, Panchal N, Schlitt J, Behr C, Soleimanpour S. The use of telehealth in school-based health centers. *Glob Pediatr Health.* (2019) 6:2333794X19884194. doi: 10.1177/2333794X19884194
9. Spooner SA, Gotlieb EM. Telemedicine: pediatric applications. *Pediatrics.* (2004) 113:e639–43. doi: 10.1542/peds.113.6.e639
10. Fiks AG, Jenssen BP, Ray KN. A defining moment for pediatric primary care telehealth. *JAMA Pediatr.* (2020) 175:9–10. doi: 10.1001/jamapediatrics.2020.1881
11. Olson CA, McSwain SD, Curfman AL, Chuo J. The current pediatric telehealth landscape. *Pediatrics.* (2018) 141:e20172334. doi: 10.1542/peds.2017-2334
12. Sisk B, Alexander J, Bodnar C, Curfman A, Garber K, McSwain SD, et al. Pediatrician attitudes toward and experiences with telehealth use: Results from a national survey. *Acad Pediatr.* (2020) 20:628–35. doi: 10.1016/j.acap.2020.05.004
13. Patel PD, Cobb J, Wright D, Turer RW, Jordan T, Humphrey A, et al. Rapid development of telehealth capabilities within pediatric patient portal infrastructure for COVID-19 care: barriers, solutions, results. *J Am Med Inform Assoc.* (2020) 27:1116–20. doi: 10.1093/jamia/ocaa065
14. Badawy SM, Radovic A. Digital approaches to remote pediatric health care delivery during the COVID-19 pandemic: existing evidence and a call for further research. *JMIR Pediatr Parent.* (2020) 3:e20049. doi: 10.2196/20049

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers in Pediatrics

ORIGINAL RESEARCH
published: 18 October 2021
doi: 10.3389/fped.2021.745687

Factors Influencing the Acceptance of Pediatric Telemedicine Services in China: A Cross-Sectional Study

Jingjin Shi[1,2], *Xueming Yan*[3], *Miao Wang*[3], *Ping Lei*[4*†] *and Guangjun Yu*[1,3*†]

[1] School of Public Health, Shanghai Jiao Tong University School of Medicine, Shanghai, China, [2] International Peace Maternity and Child Health Hospital, School of Medicine, Shanghai Jiao Tong University, Shanghai, China, [3] Shanghai Children's Hospital, Shanghai Jiao Tong University, Shanghai, China, [4] Institut Franco-Chinois pour la Santé, Chambéry, France

OPEN ACCESS

Edited by:
Mark Lo,
University of Washington,
United States

Reviewed by:
James Marcin,
UC Davis Health, United States
Richard Boxer,
UCLA David Geffen School of Medicine, United States

****Correspondence:***
Guangjun Yu
sh_etyy@163.com
Ping Lei
plei@ifcsante.com

†These authors have contributed equally to this work and share last authorship

Specialty section:
This article was submitted to General Pediatrics and Pediatric Emergency Care,
a section of the journal Frontiers in Pediatrics

Received: *22 July 2021*
Accepted: *15 September 2021*
Published: *18 October 2021*

Citation:
Shi J, Yan X, Wang M, Lei P and Yu G (2021) Factors Influencing the Acceptance of Pediatric Telemedicine Services in China: A Cross-Sectional Study. Front. Pediatr. 9:745687. doi: 10.3389/fped.2021.745687

Background: Pediatrician workforce shortages have aroused great attention from health authorities in China. Telemedicine services have been known to enhance the management of children's health, yet the rate of adoption and usage in Chinese hospitals still at a quite low level, and the factors influencing the acceptance of telemedicine services remains unclear.

Objective: The purpose of this empirical study was to evaluate the reliability and validity of a technology acceptance measurement instrument applied in healthcare, to investigate the perception of telemedicine services on the provider-side and demand-side, and to determine the factors that may drive individuals to adopt telemedicine services.

Methods: A cross-sectional survey study based at Shanghai Children's Hospital, Shanghai Jiao Tong University, was conducted in March 2020. A total of 456 valid responses were obtained by convenience sampling. The internal consistency of items was assessed by Cronbach's alpha (α), composite reliability (CR) and average variance extracted (AVE) to evaluate both the reliability and validity of the questionnaire. Structural equation modeling analysis was used to test and verify the interrelationships among relevant variables.

Results: Price value is the strongest predictor ($\beta = 0.30$, $p = 0.02$), facilitating conditions ($\beta = 0.28$, $p = 0.01$) and hedonic motivation ($\beta = 0.13$, $p = 0.04$) also have significantly positive direct effects on telemedicine acceptance. The results showed the perception of child patients' families were significantly more acceptable to telemedicine services than pediatricians ($t = -2.99$, $p < 0.01$). Participants with no prior experience and lower education may be more willing to adopt telemedicine.

Conclusion: Telemedicine will likely continue to have an integral role in pediatric health care delivery, and the findings can assist policy makers and hospital administrators in determining the more valued characteristics of telemedicine services from a behavioral perspective. Future attention will be paid to the pricing, training and service quality of telemedicine in China.

Keywords: telemedicine, acceptance, influencing factor, pediatric hospital, China

INTRODUCTION

Telemedicine refers to the use of health information exchanged from one site to another via information and communications technology (ICT) for the health and education of the patient or medical personnel with the intention of evaluating, diagnosing, treating, educating or managing patients (1, 2). With the rapid development of ICT, telemedicine has been used widely around the world as a new mode of medical service (3). As the largest developing country with a large population, medical resources in China are distributed with imbalanced and uneven quality, especially in pediatric medical resources (4). Facing a serious situation of high demand for medical resources and shortage of pediatricians, telemedicine has been considered a crucial solution by Chinese health authorities to alleviate healthcare disparities and to improve the accessibility, affordability and quality of medical resources in urban and rural areas. To date, telemedicine has a history of more than 30 years in China since it began to develop in the 1980s. The outbreak of the COVID-19 epidemic has enhanced and accelerated the worldwide development of telemedicine, which has helped reduce the chances of cross-infection and overcome the geographical limitations of medical treatment (5). It is disappointing that the adoption of telemedicine has not been consistent with its technological advancements (6). There has been a growing need, but few studies have explored factors affecting the willingness to use telemedicine services in pediatric hospitals. To achieve this goal, the measurement instrument based on the unified theory of the acceptance and use of technology 2 (UTAUT 2), which is recognized as the most comprehensive theory in measuring individual technology acceptance (7, 8), was employed to investigate the interrelationships between the constructs and behavioral intention and to estimate the significance of path coefficients so that we could better understand the factors that may influence the willingness to accept telemedicine services.

Theoretical Background and Hypothesis Development

UTAUT 2 provides a more thorough understanding of the factors that influence users' willingness to use new technology than is possible with other technology acceptance models. A systematic review has shown that UTAUT 2 is an efficient theory, with the minimum explained variance of behavioral intention being 35% and the maximum value being 94% (9). Although the UTAUT 2 model was not specifically developed for healthcare, it is perceived to be a robust integrative theory focused on medical providers and users (10). Through induction and summary, we have defined the model variables; the measurement items and model construction of each research variable in the model have also been proposed, as seen in **Table 1**. The hypothesized research model is depicted in **Figure 1**.

Abbreviations: AVE, average variance extracted; BI, behavioral intention; CR, composite reliability coefficient; EE, effort expectancy; FC, facilitating condition; H1, hypothesis 1; H2, hypothesis 2; H3, hypothesis 3, H4, hypothesis 4; H5, hypothesis 5; H6, hypothesis 6; HM, hedonic motivation; ICT, information and communication technology; ns, non-significant; PE, performance expectancy; PV, price value; UTAUT, unified theory of the acceptance and use of technology; UTAUT2, unified theory of the acceptance and use of technology 2; SD, standard deviation; SI, social influence.

METHODS

Study Design and Sampling

This is a cross-sectional study investigating hospital users' willingness to use telemedicine services. At present, telemedicine service centers are mainly situated in the most developed cities in China, such as Beijing, Shanghai, and Guangzhou (23). Similar facilities are not available in many less developed cities and regions. This research setting was a tertiary pediatric specialized hospital in Shanghai, a mega-city with the largest population (nearly 25 million) in China. This survey was initiated in March and concluded in May 2020 at Shanghai Children's Hospital, which is the first established specialized children hospital in China. The target population are the end-users of telemedicine system, such as pediatricians and family members of pediatric patients. Family member refers to the parent or guardian of the child patient. Considering the low awareness and utilization rate of telemedicine services, the target group participants filled out the electronic questionnaire by scanning the code on their mobile phones through posted flyers on the nurse stations of Shanghai Children Hospital. The electronic questionnaires were answered anonymously and were collected on the spot. The inclusion criteria for participants included the following: (1) ability to fill out the questionnaire independently, with clear consciousness and no obvious cognitive impairment; (2) willingness to voluntarily participate in this study; and (3) age range of 18–60 years. The exclusion criteria included the following: (1) having a mental disorder that prevented normal communication and (2) refusing to participate in this investigation. Prior to the survey, trained investigators explained telemedicine services to the respondents to assist them in understanding the meaning of the survey questions. A sample of 456 valid questionnaires was eventually collected. This study was approved by the Ethics Review Committee, Shanghai Children's Hospital, Shanghai Jiao Tong University (file number 2021R077-E01).

Measurements

All of the items were based on the UTAUT 2 model measuring the acceptance of new information technologies, which was adopted from Venkatesh et al. (18) and Gao et al. (22) with necessary validation and wording changes tailored to the telemedicine service and healthcare context. The items are shown in **Supplementary Material**. The questionnaire was administered in Chinese through a web hosting service after being translated by a professional translator. To ensure that the content did not lose its original meaning, a back-translation was made from the Chinese instrument to English, again by a professional translator, and compared to the original (24). All questions were measured using a 7-point Likert scale ranging from 1 (completely disagree) to 7 (completely agree). A draft set of survey questions was refined by employing cognitive interviews and a pretest. Interviewees ($n = 5$) who were postgraduates majoring in health informatics or end users of telemedicine services were asked to verbalize the mental process entailed in providing answers. The

TABLE 1 | Construct definitions and model assumptions.

Model variable	Definition	Model assumptions	References
Performance expectancy	Refers to the degree to which an individual believes that using a specific technological application will help him or her to improve job performance	Performance expectancy has a positive direct effect on hospital users' willingness to use telemedicine services	(11, 12)
Effort expectancy	Refers to the degree of simplicity associated with an individual's perception of a given system	Effort expectancy has a positive direct effect on hospital users' willingness to use telemedicine services	(13)
Social influence	Refers to how an individual perceives that "important others" view them in affecting whether they should use the technology	Social influence has a positive direct effect on hospital users' willingness to use telemedicine services	(14, 15)
Facilitating conditions	Refers to the degree to which an individual believes that an organizational and technical infrastructure supports the implementation of a technology	Facilitating conditions have a positive direct effect on hospital users' willingness to use telemedicine services	(16–18)
Hedonic motivation	Refers to the fun or pleasure derived from using a technology	Hedonic motivation has a positive direct effect on hospital users' willingness to use telemedicine services	(19)
Price value	Refers to the cognitive tradeoff between the perceived benefits of a given system and the monetary cost of using them	Price value has a positive direct effect on hospital users' willingness to use telemedicine services	(20–22)

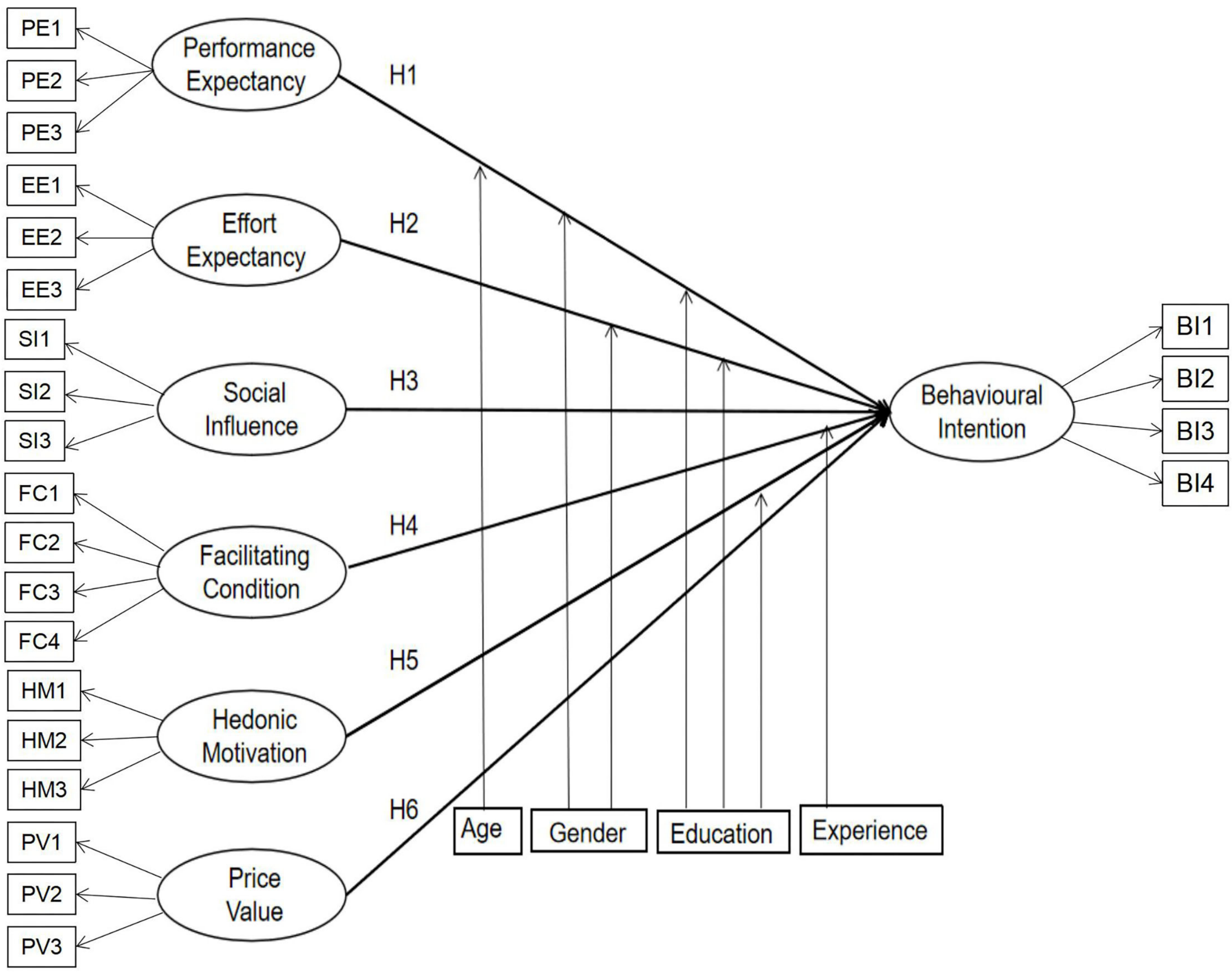

FIGURE 1 | Research framework.

wording of the questions that were difficult to understand or that generated ambiguity was subsequently modified based on the feedback from 50 respondents in the pretest.

Statistical Analysis

Once the primary collection was completed through a structured electronic questionnaire, the data were coded, cleaned, labeled, and verified with regard to missing values. A two-step approach was employed for structural equation modeling (25). The reliability and validity of the measurement model was examined in the first step, and the structural model was tested in step two. Confirmatory factor analysis was performed to validate the measurement model, and the hypothesized paths were examined using structural equation modeling. The moderating effects of three end-user traits among the hypothesized paths within the core research model were tested using logistic regression analysis and multiple group analysis. Additionally, independent t-tests were conducted to test differences in perception and intention to use between physicians and family members of patients. According to the degree of consistency between the theoretical model and the actual data, the theoretical model is evaluated to achieve the goals of quantitative research on actual problems. Structural equation modeling overcomes the shortcomings of multiple regression analysis method. It not only explains the relationship between variables but also allows the existence of measurement error of the variables. It can realize the estimation of factor structure and relationship as well as the simultaneous estimation of the degree of model fitting. All analyses were conducted using SPSS Statistics, version 24.0 (IBM Corp), and SPSS Amos, version 24.0 (IBM Corp) software.

RESULTS

Study Population

In this study, a total of 456 respondents completed the survey, including physicians (53.5%) and family members of patients (46.5%). As shown in **Table 2,** 18% of the respondents were men, and 82% were women. The largest age group was 30–40 years (42.3%). The group with the highest level of education had bachelor's degrees (51.3%).

TABLE 2 | Demographics of the respondents ($N = 456$).

Measure	Items	Frequency	Percentage (%)
Gender	Male	82	18.0
	Female	374	82.0
Age	20–30	127	27.9
	31–40	193	42.3
	41–50	90	19.7
	51–60	46	10.1
Status	Pediatricians	244	53.5
	Family member of pediatric patients	212	46.5
Level of education	High school or below	72	15.8
	College	89	19.5
	Bachelor	234	51.3
	Master	51	11.2
	Doctor	10	2.2

Reliability and Validity of Measurement Instrument

The 23-item scale appeared to be internally consistent. The Cronbach α for the 7 subscales ranged from 0.890 to 0.957, indicating that the measurement scale had good reliability (see **Supplementary Table 1**). Convergent validity was adequate when the factor loading and the composite reliability (CR) were above the recommended threshold of 0.7 and the AVE was greater than 0.5 (26) (see **Supplementary Table 2**). Discriminant validity was also confirmed when the square root of the AVE for each construct was larger than the corresponding inter-construct correlations (27). Hence, this measurement model achieved acceptable levels of reliability and validity. Additionally, confirmatory factor analysis indicated a good fit, as the fit indices for the measurement model exceeded the critical level of 0.80, and the chi-square/degree of freedom equals to 2.714, which was below the suggested value of 3.0 (28). The indicators were as follows: goodness-of-fit index (GFI) = 0.904, normed fit index (NFI) = 0.957, comparative fit index (CFI) = 0.972, root mean square residual (RMR) = 0.062, root mean square error of approximation (RMSEA) = 0.061. It can be seen that the variables had good discriminant validity. According to the degree of consistency between the theoretical model and the actual data, the theoretical model was evaluated to achieve the goals of quantitative research on actual problems. In sum, our results indicated the appropriateness of the measurement model.

Perceptions of Telemedicine Services

A two-independent samples t-test was carried out focused on physicians and family members of patients in relation to the perception of influencing factors on the acceptance of telemedicine services. Overall, there was a positive perception of telemedicine services in a Chinese pediatric hospital among the participants with all mean scores larger than 5. The findings indicate that family member of pediatric patients reported a more positive and optimistic perception toward telemedicine services vs. pediatricians in all subscales of measurement. **Table 3** reported on the means and standard deviations of perception of telemedicine services. The mean scores of facilitating conditions ($t = -2.19$, $p = 0.03$), hedonic motivation ($t = -2.65$, $p < 0.01$), price value ($t = -3.26$, $p < 0.01$) and intention to use telemedicine ($t = -2.99$, $p < 0.01$) were significantly higher on the demand-side than on the provider-side. Respondents were the most positive about the performance expectancy (mean = 6.09, SD = 1.08). However, respondents reported the lowest mean score (mean = 5.24, SD = 1.48) on the hedonic motivation.

Hypothesis Testing

In this study, model verification of the parameters of the initial hypothetical model was carried out to analyse the relationship between the variables and the mechanisms of influence (see **Table 4**). A P value <0.05 was considered statistically significant.

TABLE 3 | Perception of telemedicine services by pediatricians and family members of patients.

UTAUT 2 constructs	All	Pediatricians	Family member of pediatric patients	*t*-test	*P*-value
	Mean (SD)	Mean (SD)	Mean (SD)		
PE	6.09 (1.08)	6.01 (1.08)	6.19 (1.07)	−1.76	0.08
EE	5.89 (1.25)	5.78 (1.18)	6.01 (1.31)	−1.96	0.05
SI	5.42 (1.50)	5.35 (1.35)	5.49 (1.67)	−1.01	0.31
FC	5.69 (1.31)	5.56 (1.23)	5.83 (1.38)	−2.19	0.03
HM	5.24 (1.48)	5.07 (1.33)	5.44 (1.61)	−2.65	<0.01
PV	5.68 (1.24)	5.51 (1.22)	5.89 (1.25)	−3.26	<0.01
BI	5.51 (1.38)	5.33 (1.28)	5.72 (1.47)	−2.99	<0.01

PE, performance expectancy; EE, effort expectancy; SI, social influence; FC, facilitating condition; HM, hedonic motivation; PV, price value; BI, behavior intention; SD, standard deviation.

TABLE 4 | Results of hypothesis testing.

Hypotheses	Path	Estimate	Standard error	*P*-value	Findings
H1	PE→ BI	0.09	0.07	0.09	n.s.
H2	EE→ BI	0.08	0.08	0.32	n.s.
H3	SI→ BI	0.04	0.07	0.58	n.s.
H4	FC→ BI	0.28	0.11	0.01	Supported
H5	HM→ BI	0.13	0.07	0.04	Supported
H6	PV→ BI	0.30	0.13	0.02	Supported

PE, performance expectancy; EE, effort expectancy; SI, social influence; FC, facilitating condition; HM, hedonic motivation; PV, price value; BI, behavior intention. n.s., not significant.

To explain the variance of the constructs, the R^2 values were examined. With an R^2 value of 0.737, our model explains 73.7% of the variance in behavioral intention determined by three variables: facilitating conditions (H4: $\beta = 0.280$, $p = 0.008$), hedonic motivation (H5: $\beta = 0.131$, $p = 0.040$) and price value (H6: $\beta = 0.302$, $p = 0.016$). Given the significance of the model path coefficient (β), H4, H5, and H6 are accepted, while the other variables of the model, such as performance expectancy (H1), effort expectancy (H2), and social influence (H3), are rejected. **Table 6** clearly shows that facilitating conditions, hedonic motivation, and price value are the three main factors affecting pediatric hospital users' behavioral intention to adopt telemedicine services. They all had a positive impact on behavioral intention, and among the three factors, price value seems to be the most powerful influencing factor.

Moderating Effects of Age, Gender and Experience

First, we conducted a separate test by establishing a logistic regression model to measure the relationship between gender, age, education level, experience, and willingness to use telemedicine service (**Table 5**). Participants with no prior experience and lower education may be more willing to adopt telemedicine service. Second, we performed an individual estimation for age (younger or older), gender (male or female) and experience (none or experienced), education level (lower or higher) and then conducted a multi-group analysis to determine whether the moderating effects of hypothesized paths were different between sub-groups. The chi-square differences between the unconstrained model and constrained model are presented in **Table 6**. In the unconstrained model, all paths were unconstrained between the two sub-groups. In the constrained model, each path was constrained as equal and was hypothesized to be moderated across two sub-groups. We found that the path between PE and BI was significantly stronger for males than for females ($\Delta\chi^2 = 3.82$, $p = 0.05$) and for older than for younger individuals ($\Delta\chi^2 = 8.63$, $p < 0.001$). The moderating effect of age and gender on the relationship between FC and BI was not significant, but the results for individuals who were younger ($\beta = 0.35$, $p = 0.01$) and female ($\beta = 0.30$, $p = 0.02$) showed a statistically stronger relationship between FC and BI. The moderating effect of experience on the relationship between FC and BI ($\Delta\chi^2 = 6.02$, $p = 0.01$) was significant, and the path coefficient for not experienced participants ($\beta = 0.45$, $p < 0.001$) was larger than that for those who had already used telemedicine services ($\beta = -0.03$, $p = 0.83$). In the age results, although the path from PV to BI was stronger for the younger group, the standardized path coefficient was not statistically significant. In the gender results, the path from EE and HM to BI was stronger for the female group, and the standardized path coefficient was statistically significant. In addition, the multi-group analysis indicated that the difference in chi-square values was statistically significant between EE and BI ($\Delta\chi^2 = 4.67$, $p = 0.03$) but not between FC, HM and BI. With respect to the new moderator, the moderating effect of education level on the relationship between PE ($\Delta\chi^2 =$

TABLE 5 | The relationship between demographic characteristics and behavior intention to use telemedicine.

Variable	*B*	SE	Wald value	*P*-value	Odds ratio (95%CI)
Gender[a]	−0.08	0.27	0.09	0.76	0.92 (0.55–1.56)
Age	−0.07	0.11	0.43	0.51	0.93 (0.75–1.15)
Experience	−0.74	0.20	13.20	<0.001	0.48 (0.32–0.71)
Education level	−0.25	0.12	4.05	0.04	0.78 (0.62–0.99)

[a]*Male as the reference group.*

TABLE 6 | Results for moderating effects models.

Moderator	Path	X^2(df)	ΔX^2	Standardized path coefficient	
Age				Younger (<40 years)	Older (>40 years)
	Unconstrained model	932.27(414)			
	Constrained model: PE→ BI	936.09(415)	3.82*	0.001	0.24*
	Constrained model: EE→ BI	933.27(415)	1.00	0.15	−0.04
	Constrained model: FC→ BI	932.65(415)	0.38	0.35*	0.25
	Constrained model: HM→ BI	932.43(415)	0.16	0.09	0.15
	Constrained model: PV→ BI	932.57(415)	0.30	0.36*	0.20
Gender				Male	Female
	Unconstrained model	980.11(414)			
	Constrained model: PE→ BI	988.74(415)	8.63**	0.40**	0.001
	Constrained model: EE→ BI	984.78(415)	4.67*	−0.65	0.23*
	Constrained model: FC→ BI	980.12(415)	0.01	0.27	0.30*
	Constrained model: HM→ BI	980.17(415)	0.06	0.13	0.16*
	Constrained model: PV→ BI	980.79(415)	0.68	0.52	0.20
Experience				Experienced	No experience
	Unconstrained model	912.65(414)			
	Constrained model: PE→ BI	912.69(415)	0.05	0.16	0.09
	Constrained model: EE→ BI	912.70(415)	0.06	0.14	0.06
	Constrained model: FC→ BI	918.66(415)	6.02**	−0.03	0.45**
	Constrained model: HM→ BI	912.74(415)	0.09	0.23	0.10
	Constrained model: PV→ BI	912.75(415)	0.10	0.16	0.18
Education level				Lower	Higher
	Unconstrained model	1104.94(414)			
	Constrained model: PE→ BI	1110.18(415)	5.24*	−0.18	0.14*
	Constrained model: EE→ BI	1111.21(415)	6.27**	0.41**	0.001
	Constrained model: FC→ BI	1105.19(415)	0.25	0.33	0.23*
	Constrained model: HM→ BI	1110.30(415)	5.36*	0.40**	0.04
	Constrained model: PV→ BI	1106.29(415)	1.35	0.03	0.42*

PE, performance expectancy; EE, effort expectancy; FC, facilitating condition; HM, hedonic motivation; PV, price value; BI, behavior intention.
$^*p < 0.05$.
$^{**}p < 0.01$.

5.24, p=0.02), EE ($\Delta\chi^2 = 6.27$, $p = 0.01$), and HM ($\Delta\chi^2 = 5.36$, $p = 0.02$) toward adopting telemedcine service was significant and participants with lower education showed a stronger relationship.

DISCUSSION

Telemedicine has the potential to benefit pediatric care by increasing access to pediatric specialists and remotely delivering high-quality health services, including radiology, mental health, dermatology, cardiology, pathology, patient education, chronic diseases, pediatric dentistry, and neonatal ophthalmology (29, 30). In China, the current operational mode of telemedicine is limited in the business-to-business context and for common and chronic diseases (4, 31); therefore, the functions of telemedicine services are not yet fully used. This study aimed to determine which factors influence the acceptance of telemedicine services in a Chinese pediatric specialized hospital.

Price Value

In our study, price value is the most important influential factor, particularly for younger users, which aligns with previous research on the same topics (32, 33). However, some studies based on the UTAUT 2 model did not include PV as a predictor for the acceptance of a new technology (22, 34). Meanwhile, it is noteworthy that the path coefficient between PV and behavioral intention had some differences among countries. Comparing the path coefficients of 0.130 in the United States (33), 0.147 in France (12), 0.320 in Iran (32), and 0.302 in China, one may conclude that price value may have a greater impact in less developed countries. Payer reimbursement was the leading influencer of anticipated future use of telemedicine (35). To date, telemedicine services have not been covered by medical insurance payments in China, and the prices vary from province to province. However, insurers in the United States have expanded their coverage and reimbursement of various types of telemedicine services. Scholars believe that if the price of certain technological services is very low or free of charge, it probably will not have a strong influence on behavioral intention (4, 36). Physicians and patients are more likely to take advantage of telemedicine if their perception of its value is higher, such as saving them money and time by avoiding an out-of-town trip to the hospital (11). Telemedicine charges and reimbursement standards should be constructed to meet the actual local needs, and the labor value of telemedicine service providers should be reasonably compensated, including material and spiritual, monetary and non-monetary compensation incentive strategies.

Facilitating Conditions

Facilitating conditions were also a significant predictor of the intention to use telemedicine in this study, which was consistent with previous studies (37). Training can not only increase the confidence of telemedicine users but also strengthen collaboration between patients and physicians. In terms of external conditions, the infrastructure, system interface, image quality, network signal and transmission speed of telemedicine systems all need to be ready and periodically maintained, especially in rural areas. In terms of internal conditions, the service process should be optimized to shorten the waiting time. The content of cooperation, service processes, rights and obligations, risks and responsibilities between medical

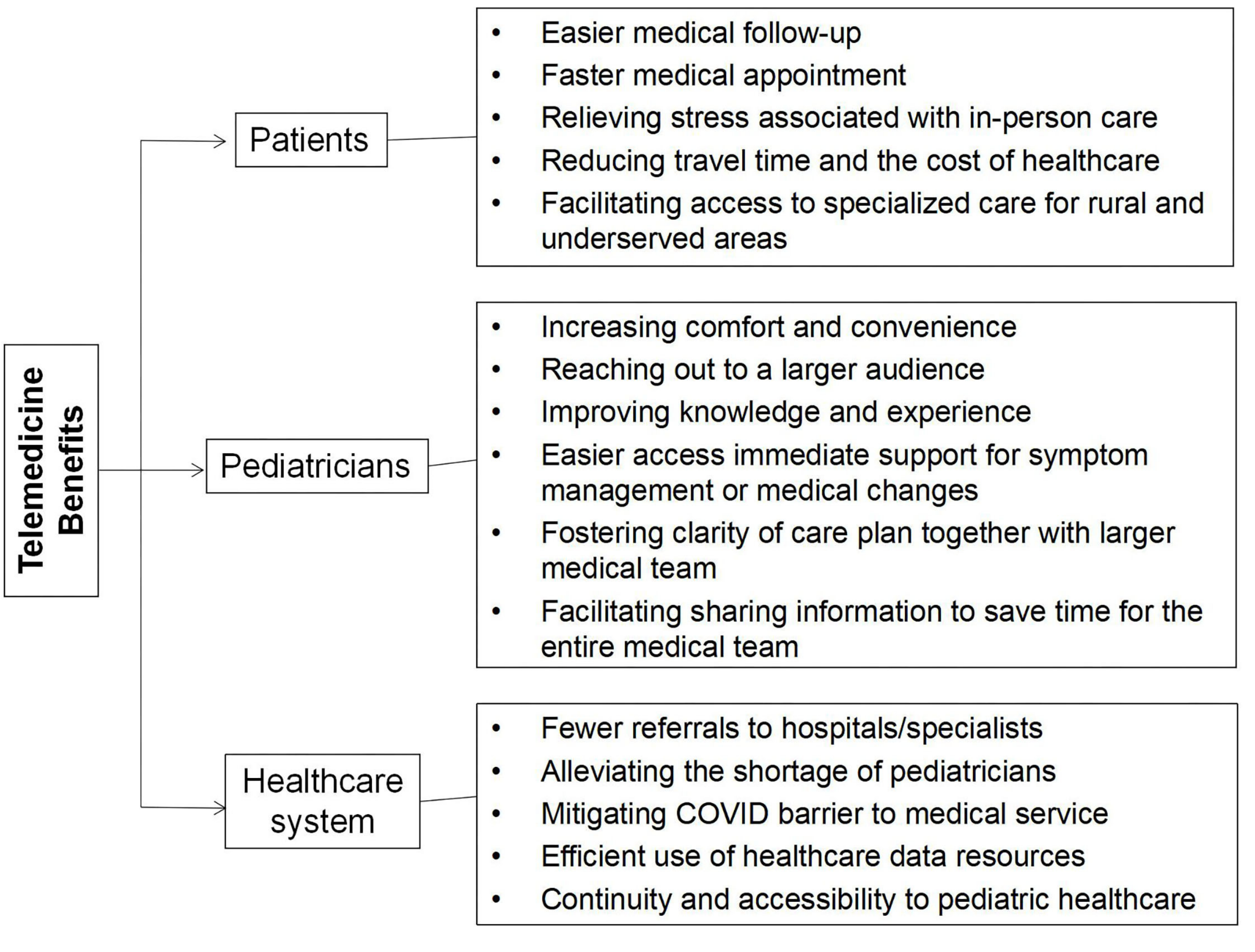

FIGURE 2 | Telemedicine benefits for patients, pediatricians and healthcare system.

institutions should be determined in a formal agreement before the launch of telemedicine services. Considering the moderating effects of age, gender and experience, female and young users without experience had more positive behavior intention of adopting telemedicine services. Male and older experienced users need more organizational and technical infrastructure supports for the implementation of telemedicine services.

Hedonic Motivation

Hedonic motivation also had a positive impact on behavioral intention (38). The adoption of a product based on hedonic motivation is not long term. Once adopters acquire experience with it, its effectiveness outweighs all its other attributes (18). Telemedicine has just taken off in China in recent years. Early adopters pay more attention to its convenience but easily overlook the importance of medical quality. However, telemedicine cannot be merely considered a pleasure-oriented service but is perceived as more of a utilitarian solution (18). Hospitals should provide telemedicine services on the premise of ensuring medical safety and being closely connected with offline medical treatment.

Performance Expectancy, Effort Expectancy, Social Influence and Moderators

From our results, pediatricians and family members of patients were consistently agreed performance expectancy and effort expectancy as important factors of adopting telemedicine service. Even though these positive effects on behavior intention have not been validated in this study. This may be because users have not yet changed their traditional perceptions and are not fully aware of the usefulness of telemedicine services. Pediatric patients have difficulty operating the system and communicating with physicians due to their limited understanding. In a tertiary hospital in China, clinicians are often constrained by their busy work schedules and therefore have limited energy for learning how to work with new technologies. To solve this problem, hospitals could equip technical assistants responsible for communication and system operation. Individuals could also be impacted by people who are important to them when adopting a new technological product (39). We speculate that healthcare and medical treatment for minors is a very personal and private issue; therefore, SI had limited impact in our study, and previous studies found the same results (40).

In addition, certain attributes may influence users' decisions. In healthcare studies, gender and age were found to be moderators of acceptance (41, 42). Regarding experience, users and non-users showed significant differences regarding PE, EE, SI and FC in the acceptance of mobile health monitoring services (1, 43). The results of moderating effects of age, gender and experience deepen our understanding of underlying differences in telemedicine services adoption behavior. We found that gender moderates the relationships of PE→ BI and EE→ BI. This finding is similar to what Duyck et al. (44) suggested: PE is a stronger factor for males than for females. The relation between EE and BI is stronger for women, which is consistent with previous research (15). Participants with no prior experience and lower education with telemedicine may be more willing to try this new type of technology. The results suggest that hospital administrators should focus more on increasing publicity to enhance user awareness of telemedicine, strengthening homogeneous management of online and offline medical quality, so that acquiring positive feedback from respondents who have used it.

Limitations and Future Research

The study has some limitations that can be regarded as opportunities for future research. First, this study recruited a cross-sectional sample of participants in Shanghai; it may not universally reflect the willingness of all users to adopt telemedicine services in Chinese pediatric hospitals, especially in rural areas. Further research in different regions will provide more accurate evidence if the results depend on socioeconomic factors. Second, telemedicine involves the privacy protection and information security of personal health data, and future research should incorporate perceived risk and trust factors to further extend the theoretical model. Third, females were over-represented in the respondent groups, and respondents younger than 40 years old accounting for 70% in the context of pediatric hospital. Further studies should collect data following the gender and age ratios of the general population.

CONCLUSION

Price value was the strongest factor influencing telemedicine acceptance in a Chinese pediatric hospital. Higher-quality service should be provided relative to its perceived cost in order to price offerings appropriately to acquire and retain users. There is no doubt that now more than ever, is underscoring the importance of leveraging telemedicine service to optimize pediatric health care delivery in the current global COVID-19 pandemic. The finding of this study was to identify variables that may affect the adoption of telemedicine in order to determine actions and regulations that can be enacted to benefit all patients, healthcare providers and policymakers (**Figure 2**). Allied with relevant stakeholders in addressing ongoing and future challenges as well as cultural, logistical, technological, and financial barriers will be key for success. To guarantee the best experience possible for children, pediatricians, child patients, and their families, hospital administrators will have to take a leadership role in creating a standardized workflow, provide required technical support, and pay careful attention to integrating the training into workflows, enhancing service quality, durability, and user satisfaction of telemedicine services.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

JS conceptualized the study, carried out the data analysis, drafted the initial manuscript, and reviewed and revised the manuscript. XY conceptualized the study, designed the data collection instrument, and supervised data collection. MW designed the data collection instrument, supervised data collection, and carried out the data analysis. PL conceptualized the study, designed the data collection instrument, carried out the data analysis, and reviewed and revised the manuscript. GY conceptualized the study, designed the data collection instrument, reviewed and revised the manuscript, and final approval of manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

FUNDING

This research was sponsored by National Natural Science Foundation of China (grant no: 72074146) and Science and Technology Commission of Shanghai Municipality-Shanghai Sailing Program (grant no: 21YF1451600).

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fped.2021.745687/full#supplementary-material

REFERENCES

1. Rho MJ, Kim HS, Chung K, Choi IY. Factors influencing the acceptance of telemedicine for diabetes management. *Cluster Comput*. (2014) 18:321–31. doi: 10.1007/s10586-014-0356-1
2. Bashshur RL, Shannon GW, Smith BR, et al. The empirical evidence for the telemedicine intervention in diabetes management. *Telemed J E Health*. (2015) 21:321–54. doi: 10.1089/tmj.2015.0029
3. Uscher-Pines L, Mulcahy A, Cowling D, Hunter G, Burns R, Mehrotra A. Access and quality of care in direct-to-consumer telemedicine. *Telemed E Health*. (2016) 22:282–7. doi: 10.1089/tmj.2015.0079
4. Wang H, Liang L, Du C, Wu Y. Implementation of online hospitals and factors influencing the adoption of mobile medical services in China: cross-sectional survey study. *JMIR Mhealth Uhealth*. (2021) 9:e25960. doi: 10.2196/25960
5. He D, Gu Y, Shi Y, Wang M, Lou Z, Jin C. COVID-19 in China: the role and activities of Internet-based healthcare platforms. *Glob Health Med*. (2020) 2:89–95. doi: 10.35772/ghm.2020.01017
6. Bensink M, Hailey D, Wootton R. A systematic review of successes and failures in home telehealth: preliminary results. *J Telemed Telecare*. (2006) 12:8–16. doi: 10.1258/135763306779380174
7. Tamilmani K, Rana NP, Dwivedi YK. Consumer acceptance and use of information technology: a meta-analytic evaluation of UTAUT2. *Inf Syst Front*. (2020) 23:987–1005. doi: 10.1007/s10796-020-10007-6
8. Tamilmani K, Rana NP, Wamba SF, Dwivedi R. The extended Unified Theory of Acceptance and Use of Technology (UTAUT2): a systematic literature review and theory evaluation. *Int J Inf Manag*. (2021) 57:102269 doi: 10.1016/j.ijinfomgt.2020.102269
9. Kuak JP, Trojanowski M, Barmentloo E, A. Literature Review of the Partial Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) model. *Annales Universitatis Mariae Curie-Skłodowska sectio H Oeconomia*. (2019) 53:101. doi: 10.17951/h.2019.53.4.101-113
10. Dwivedi YK, Rana NP, Chen H, Williams MD. A meta-analysis of the Unified Theory of Acceptance and Use of Technology (UTAUT). *Governance Sustain Inf Syst*. (2011) 366:155. doi: 10.1007/978-3-642-24148-2_10
11. Alpay LL, Henkemans OB, Otten W, Rövekamp T, Dumay A. E-health applications and services for patient empowerment: directions for best practices in The Netherlands. *Telemed J E Health*. (2010) 16:787–91. doi: 10.1089/tmj.2009.0156
12. Baudier P, Kondrateva G, Ammi C. The future of telemedicine cabin? The case of the French students' acceptability. *Futures*. (2020) 122:102595. doi: 10.1016/j.futures.2020.102595
13. Kohnke A, Cole ML, Bush R. Incorporating UTAUT predictors for understanding home care patients' and clinician's acceptance of healthcare telemedicine equipment. *J Technol Manag Innov*. (2014) 9:29–41. doi: 10.4067/S0718-27242014000200003
14. Chang IC, Hwang HG, Hung WF, Li YC. Physicians' acceptance of pharmacokinetics-based clinical decision support systems. *Expert Syst Appl*. (2007) 33:296–303. doi: 10.1016/j.eswa.2006.05.001
15. Venkatesh V, Morris MG, Davis GB, Davis FD. User acceptance of information technology: toward a unified view. *MIS Q*. (2003) 27:425–78. doi: 10.2307/30036540
16. Basoglu N, Daim TU, Topacan U. Determining patient preferences for remote monitoring. *J Med Syst*. (2012) 36:1389–401. doi: 10.1007/s10916-010-9601-1
17. Hsu CL, Tseng KC, Chuang YH. Predictors of future use of telehomecare health services by middle-aged people in Taiwan. *Social Behav Pers*. (2011) 39:1251–61. doi: 10.2224/sbp.2011.39.9.1251
18. Venkatesh V, Thong J, Xin X. Consumer acceptance and use of information technology: extending the unified theory of acceptance and use of technology. *MIS Q*. (2012) 36:157–78. doi: 10.2307/41410412
19. Davis FD, Bagozzi RP, Warshaw PR. Extrinsic and intrinsic motivation to use computers in the workplace1. *J Appl Soc Psychol*. (2010) 22:1111–32. doi: 10.1111/j.1559-1816.1992.tb00945.x
20. Van Riel ACR, Pura M. Linking perceived value and loyalty in location-based mobile services. *Manag Serv Q*. (2012) 15:509–38. doi: 10.1108/09604520510634005
21. Zeithaml VA. Consumer perceptions of price, quality, and value: a means-end model and synthesis of evidence. *J Mark*. (1988) 52:2–22. doi: 10.1177/002224298805200302
22. Gao YW, Li H, Luo Y. An empirical study of wearable technology acceptance in healthcare. *Indus Manag Data Syst*. (2015) 115:1704–23. doi: 10.1108/IMDS-03-2015-0087
23. Cai H, Wang H, Guo T, Bao G. Application of telemedicine in Gansu province of China. *PLoS ONE*. (2016) 11:e0158026. doi: 10.1371/journal.pone.0158026
24. Brislin RW. Back-Translation for cross-cultural research. *J Cross Cult Psychol*. (1970) 1:185–216.
25. Anderson JC, Gerbing DW. Structural equation modeling in practice: A review and recommended two-step approach. *Psychol. Bull*. (1988) 103:411–23.
26. Nunnally JC. *Psychometric Theory*. McGraw-Hill Series in Psychology.
27. Preston DS, Karahanna E. Antecedents of IS strategic alignment: a nomological network. *Inf Syst Res*. (2009) 20:159–79. doi: 10.1287/isre.1070.0159
28. Martynova E, West SG, Liu Y. Principles and practice of structural equation modeling. *Struct Equation Model Multidisciplinary J*. (2018) 25:325–9. doi: 10.1080/10705511.2017.1401932
29. Spooner SA, Gotlieb EM, Committee on Clinical Information T, Committee on Medical L. Telemedicine: pediatric applications. *Pediatrics*. (2004) 113:e639–43. doi: 10.1542/peds.113.6.e639
30. Burke BL, Hall RW, Section on Telehealth C. Telemedicine: pediatric applications. *Pediatrics*. (2015) 136:e293–308. doi: 10.1542/peds.2015-1517
31. Bashshur R, Shannon G, Krupinski E, Grigsby J. The taxonomy of telemedicine. *Telemed E Health*. (2011) 17:484–94. doi: 10.1089/tmj.2011.0103
32. Ravangard R, Kazemi Z, Zaker Abbasali S, Sharifian R, Monem H. Development of the UTAUT2 model to measure the acceptance of medical laboratory portals by patients in Shiraz. *Electron Physician*. (2017) 9:3862–9. doi: 10.19082/3862

33. Yuan S, Ma W, Kanthawala S, Peng W. Keep using my health apps: discover users' perception of health and fitness apps with the UTAUT2 model. *Telemed J E Health.* (2015) 21:735. doi: 10.1089/tmj.2014.0148
34. Weinhard A, Hauser M, Thiesse F, editors. *Explaining Adoption of Pervasive Retail Systems with a Model based on UTAUT2 and the Extended Privacy Calculus. 21st Pacific Asia Conference on Information Systems* (2017).
35. Schinasi DA, Foster CC, Bohling MK, et al. Attitudes and perceptions of telemedicine in response to the COVID-19 pandemic: a survey of naïve healthcare providers. *Front Pediatr.* (2021) 9:647937. doi: 10.3389/fped.2021.647937
36. Kim EH, Gellis ZD, Bradway CK, Kenaley B. Depression care services and telehealth technology use for homebound elderly in the United States. *Aging Ment Health*. (2019) 23:1164–73. doi: 10.1080/13607863.2018.1481925
37. Mair FS, Hiscock J, Beaton SC. Understanding factors that inhibit or promote the utilization of telecare in chronic lung disease. *Chronic Illn.* (2008) 4:110. doi: 10.1177/1742395308092482
38. Childers TL, Christopher L, et al. Hedonic and utilitarian motivations for online retail shopping behavior. *J Retailing*. (2001) 77:1–535. doi: 10.1016/S0022-4359(01)00056-2
39. Chaouali W. Once a user, always a user: enablers and inhibitors of continuance intention of mobile social networking sites. *Telemat Inform.* (2016) 33:1022–33. doi: 10.1016/j.tele.2016.03.006
40. Chau P, Hu P. Examining a model for information technology acceptance by individual professionals: an exploratory study. *J Manage Inf Syst.* (2002) 18:191–229. doi: 10.1080/07421222.2002.11045699
41. Chang IC, Hsu HM. Predicting medical staff intention to use an online reporting system with modified unified theory of acceptance and use of technology. *Telemed J E Health.* (2012) 18:67–73. doi: 10.1089/tmj.2011.0048
42. Ward R, Stevens C, Brentnall P, Briddon J. The attitudes of health care staff to information technology: a comprehensive review of the research literature. *Health Inf Libr J.* (2010) 25:81–97. doi: 10.1111/j.1471-1842.2008.00777.x
43. Lee J, Rho MJ. Perception of influencing factors on acceptance of mobile health monitoring service: a comparison between users and non-users. *Healthc Inform Res.* (2013) 19:167–76. doi: 10.4258/hir.2013.19.3.167
44. Duyck P, Pynoo B, Devolder P, Voet T, Adang L, Ovaere D, et al. Monitoring the PACS implementation process in a large university hospital-discrepancies between radiologists and physicians. *J Digital Imaging*. (2010) 23:73–80. doi: 10.1007/s10278-008-9163-7

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers in Pediatrics

ORIGINAL RESEARCH
published: 22 October 2021
doi: 10.3389/fped.2021.713930

COVID-19 Era Effect on Pandemic and Post-pandemic Pediatric Telemedicine Use: A Survey of the European Academy of Pediatrics Research in Ambulatory Settings Network

Stephen M. Reingold[1*], *Adamos Hadjipanayis*[2], *Diego van Esso*[3], *Stefano del Torso*[4], *Hans Jürgen Dornbusch*[5], *Ann de Guchtenaere*[6,7], *Rouzha Pancheva*[8], *Aida Mujkic*[9], *Garyfallia Syridou*[10], *Arunas Valiulis*[11], *Artur Mazur*[12], *Joana Rios*[13], *Mateja Vintar Spreitzer*[14], *Marina Mamenko*[15], *Antonio D'Avino*[16], *Gabriela Kubatova*[17], *Karin Geitmann*[18], *Corrine Wyder*[19], *Peter Altorjai*[20], *Kyriaki Michailidou*[21] and *Zachi Grossman*[22,23]

[1] Meuhedet Health Services, Tel Aviv-Yafo, Israel, [2] Department of Medicine, European University Cyprus, Nicosia, Cyprus, [3] Centro Médico Pere Grau, Barcelona, Spain, [4] Pediatria, Childcare Worldwide, Padova, Italy, [5] Department of Pediatrics, Medical University Graz, Graz, Austria, [6] Department of Paediatrics, University Hospital Ghent, Ghent, Belgium, [7] Department of Paediatrics, Regional Hospital AZ Damiaan, Ostend, Belgium, [8] Department of Hygiene and Epidemiology, Faculty of Public Health, Medical University of Varna, Varna, Bulgaria, [9] Andrija Štampar School of Public Health, School of Medicine, Univeristy of Zagreb, Zagreb, Croatia, [10] Department of Pediatrics, School of Medicine, National and Kapodistrian University of Athens, Athens, Greece, [11] Institute of Clinical Medicine, Medical Faculty, Vilnius University, Vilnius, Lithuania, [12] Department of Pediatrics and Pediatric Endocrinology and Diabetes, Medical College, University of Rzeszow, Rzeszow, Poland, [13] Department of Pediatrics, Hospital Beatriz Ângelo, Loures, Portugal, [14] Health Center Domžale, Domžale, Slovenia, [15] Department of Pediatrics, Shupyk National Medical Academy of Post-graduate Education, Kyiv, Ukraine, [16] Pediatria di Famiglia, Federazione Italiana Medici Pediatri FIMP, Naples, Italy, [17] Paediatric Clinic, Prague, Czechia, [18] Paediatric Clinic, Hagen, Germany, [19] Kinderaerzte Kurwerk, Burgdorf, Switzerland, [20] Paediatric Clinic, Budapest, Hungary, [21] Biostatistics Unit, Cyprus Institute of Neurology and Genetics, Nicosia, Cyprus, [22] Adelson School of Medicine, Ariel University, Ariel, Israel, [23] Maccabi Healthcare Services, Tel Aviv-Yafo, Israel

OPEN ACCESS

Edited by:
Mark Lo,
University of Washington,
United States

Reviewed by:
Tomasz Szczepanski,
Medical University of Silesia, Poland
Ehrenfried Schindler,
University of Bonn, Germany

****Correspondence:***
Stephen M. Reingold
sreingold@gmail.com

Specialty section:
This article was submitted to General Pediatrics and Pediatric Emergency Care, a section of the journal Frontiers in Pediatrics

Received: *24 May 2021*
Accepted: *16 September 2021*
Published: *22 October 2021*

Citation:
Reingold SM, Hadjipanayis A, van Esso D, del Torso S, Dornbusch HJ, de Guchtenaere A, Pancheva R, Mujkic A, Syridou G, Valiulis A, Mazur A, Rios J, Spreitzer MV, Mamenko M, D'Avino A, Kubatova G, Geitmann K, Wyder C, Altorjai P, Michailidou K and Grossman Z (2021) COVID-19 Era Effect on Pandemic and Post-pandemic Pediatric Telemedicine Use: A Survey of the European Academy of Pediatrics Research in Ambulatory Settings Network. Front. Pediatr. 9:713930. doi: 10.3389/fped.2021.713930

Background: During the COVID-19 pandemic, telemedicine use has increased within community pediatrics. This trend runs counter to reluctance to adaptation of the new mode of healthcare that existed prior to the pandemic. Little is known about what we can expect after the pandemic: if physicians will opt for telemedicine modalities and if tele-pediatrics will continue to be a significant mode of community pediatric care.

Objective: The goal of this study was to survey primary pediatric care providers as to their experiences and clinical decision making with telemedicine modalities prior to and during the COVID-19 pandemic, as well as their projected use after the pandemic ends.

Material and methods: Using the EAPRASnet database we surveyed pediatricians throughout Europe, using a web-based questionnaire. The survey was performed during the COVID-19 pandemic (June–July 2020), assessed telemedicine use for several modalities, prior to and during the pandemic as well as predicted use after the pandemic will have resolved. Participants were also surveyed regarding clinical decision making in two hypothetical clinical scenarios managed by telemedicine.

Results: A total of 710 physicians participated, 76% were pediatricians. The percentage of respondents who reported daily use for at least 50% of all encounters *via* telemedicine modalities increased during the pandemic: phone calls (4% prior to the pandemic to 52% during the pandemic), emails (2–9%), text messages (1–6%), social media (3–11%), cell-phone pictures/video (1–9%), and video conferencing (1–7%) ($p < 0.005$). The predicted post-pandemic use of these modalities partially declined to 19, 4, 3, 6, 9, and 4%, respectively ($p < 0.005$), yet demonstrating a prospectively sustained use of pictures/videos after the pandemic. Reported high likelihood of remotely treating suspected pneumonia and acute otitis media with antibiotics decreased from 8 to 16% during the pandemic to an assumed 2 and 4% after the pandemic, respectively ($p < 0.005$).

Conclusions: This study demonstrates an increased utilization of telemedicine by pediatric providers during the COVID-19 pandemic, as well as a partially sustained effect that will promote telemedicine use as part of a hybrid care provision after the pandemic will have resolved.

Keywords: pediatrics, telemedicine, COVID-19, tele-pediatrics, hybrid medicine

INTRODUCTION

Telehealth is the delivery of medical care by remote technology. Telemedicine refers particularly to the patient-physician clinical encounter *via* remote technology (1). Prior to 2020, these modalities of medical care have been slowly developing, with limited application and use in community pediatrics (2).

During the COVID-19 pandemic, unprecedented changes were made in the delivery of care in the ambulatory setting. Telehealth has proven its utility, as the use of telemedicine modalities increased during times of social distancing (3). In-person visits to the physician's office declined due to social distancing measures, and as such, telehealth practiced increased. Cautious of in-person interactions, many physicians and patients gravitated to the burgeoning telemedicine options as an alternative to in-office visits (4–6). National guidelines supported this trend, promoting telehealth to mitigate the pandemic while maintaining medical services (7–9).

The European Pediatric Association, Union of National European Pediatric Societies and Associations, demonstrated that pediatric care was sustained during the pandemic through the compensatory use of telemedicine. However, periodic health screening visits and screening programs were significantly reduced (10).

Telemedicine modalities, such as telephone calls, text messages, image or video transfers, video conferencing, or tele-diagnostic devices, are not identical to the traditional "hands-on" approach that physicians were trained to practice. Resistance to change is prevalent among physicians, as is controversy regarding the accuracy of telediagnosis. Previous reports describe overmedication with remote prescribing and raise concern of the deterioration of the physician-patient relationship and the service-oriented nature of medicine that may ensue (11–14).

Prior to the COVID-19 pandemic, telehealth has been promoted globally, at the very least, to provide care to improve accessibility to medical care, and at the most, to ultimately usher in a new model for ideal medical care (15). However, during 2020, telehealth has nevertheless "thrown down the gauntlet," as it may, challenging today's physicians to accept new technology here and now, in providing primary care.

This change may alter physician's attitudes toward these new modalities to provide medical care and lead to greater utilization of telemedicine modalities in the future (16). Published results of a survey among Israeli physicians demonstrate a limited, albeit significant change in physician's willingness to adapt to telemedicine (17). Previous reports state that clinicians' acceptance of change is the pivotal factor to adaptation (18). The question remains, what lasting effect will the telemedicine experience during this pandemic have on physician behavior and the way care is delivered.

In this study we ascertain physician's impression of telemedicine, inquiring as to their use of telemedicine prior to and during the pandemic, as well as to what extent they expect telemedicine to remain part of their medical practice in the future, after the pandemic.

METHODS

Study Sample

During the early phases of the pandemic, we utilized the EAPRAS network to conduct a survey of primary care pediatric care providers throughout the continent. The European Academy of Pediatrics Research in Ambulatory Settings Network (EAPRASnet), established in 2009, is a practice-based research network of primary care pediatricians affiliated with the European Academy of Pediatrics. The network has previously been involved in studies performed in primary care (19–22).

Data Collection

Data were collected using a web-based questionnaire that was posted on the home page of the EAPRASnet during June-July 2020. Only registered physicians were permitted to participate. Respondents were invited to participate *via* email using a mailing list that had been created for previous EAPRASnet projects. Pediatric care providers not belonging to the network were invited by national EAPRASnet coordinators to complete the questionnaire. Three reminders were sent out *via* email, and data were collected till the end of July 2020.

Socio-Demographic Details

Participants were asked for their gender, age, years in practice, medical specialty, and place of work.

Use of Telemedicine Modalities

The first part of the survey inquired about frequency of use of various telemedicine modalities prior to and during the epidemic, as well-expected use after the epidemic. Participants were asked specifically regarding phone calls, text messages, photo/video, email, and video conferencing.

Clinical Scenarios

The latter part of the survey consisted of two hypothetical scenarios and evaluated the decision to manage remotely.

Case 1, a suspected pneumonia, was presented as:

"The parents of a 7-year-old girl contact you and report that the child has had 4 days of high fever, cough, and nasal congestion. The child is not in distress, has mild anorexia, no vomiting and passed two loose stools today."

Respondents were asked to rate the likelihood of making an empiric diagnosis, prescribing antibiotic treatment, prescribing symptomatic treatment, referring for a chest X-ray, referring to an emergency room, and in the case of wheezing, prescribing corticosteroids.

Case 2, a suspected otitis media, was presented as:

"The parents of a 2-year-old boy contact you and report that the child has had fever for 2 days, mild upper respiratory symptoms and left ear pain. The child is vigorous, eating well, had one loose stool, but slept poorly last night."

Respondents were asked to rate the likelihood of making an empiric diagnosis, prescribing antibiotic treatment, and prescribing symptomatic treatment.

In both scenarios, respondents were to assume that the patient is known to the respondent and that there is no suspicion of COVID-19 for the case. Participants were asked to answer each question as if they would have practiced prior to the pandemic, currently practice during the pandemic and how they foresee themselves practicing after the pandemic. Responses were evaluated using a 5-point Likert scale ranging from "certainly not" to "certainly will."

TABLE 1 | Demographic characteristics of participant physicians.

		***N* = 710**	**%**
Age			
	≤40	198	28
	41–50	141	20
	51–60	218	31
	61–70	136	19
	>70	17	2.4
Gender			
	Male	165	23
	Female	545	77
Years of experience			
	≤10	166	23
	11–20	146	21
	21–30	206	29
	>30	192	27
Specialty			
	Pediatrics	537	76
	Family practice/GP	123	17
	Internal medicine	6	0.8
	Other	44	6.2

Data Analysis

Demographic data were presented as percentages of the total responses. Evaluation of the answers to the use of telemedicine technologies and responses to the two clinical scenarios between pre-, during and post-COVID-19 periods were compared using chi-square tests. Statistical significance was considered if the p-value was <0.05. Analyses were performed using R statistical software. The raw data is available in the **Supplementary Material**.

RESULTS

Demographic Data

A total of 710 physicians responded to the survey, 77% were female, 76% were pediatricians, and 17% were family or general practitioners. Details regarding age, specialty and years of experience are presented on **Table 1**. Geographic distribution of respondents is presented on **Figure 1**.

Use of Telemedicine Modalities

Table 2 represents the use of telemedicine modalities for at least 50% of all daily encounters, including phone calls, emails, text messages, social media, cell-phone picture/video, and video conferencing. Usage is reported for prior to the pandemic and during the pandemic, as well as projected use after the pandemic.

Reported use of all telemedicine modalities increased significantly during the pandemic. For all modalities except for pictures/video, the degree of use is predicted to decrease after the pandemic yet remain significantly greater than prior to the pandemic. Post-pandemic predicted picture/video use is not only higher than pre-pandemic use but is predicted to remain at the same level as pandemic era use.

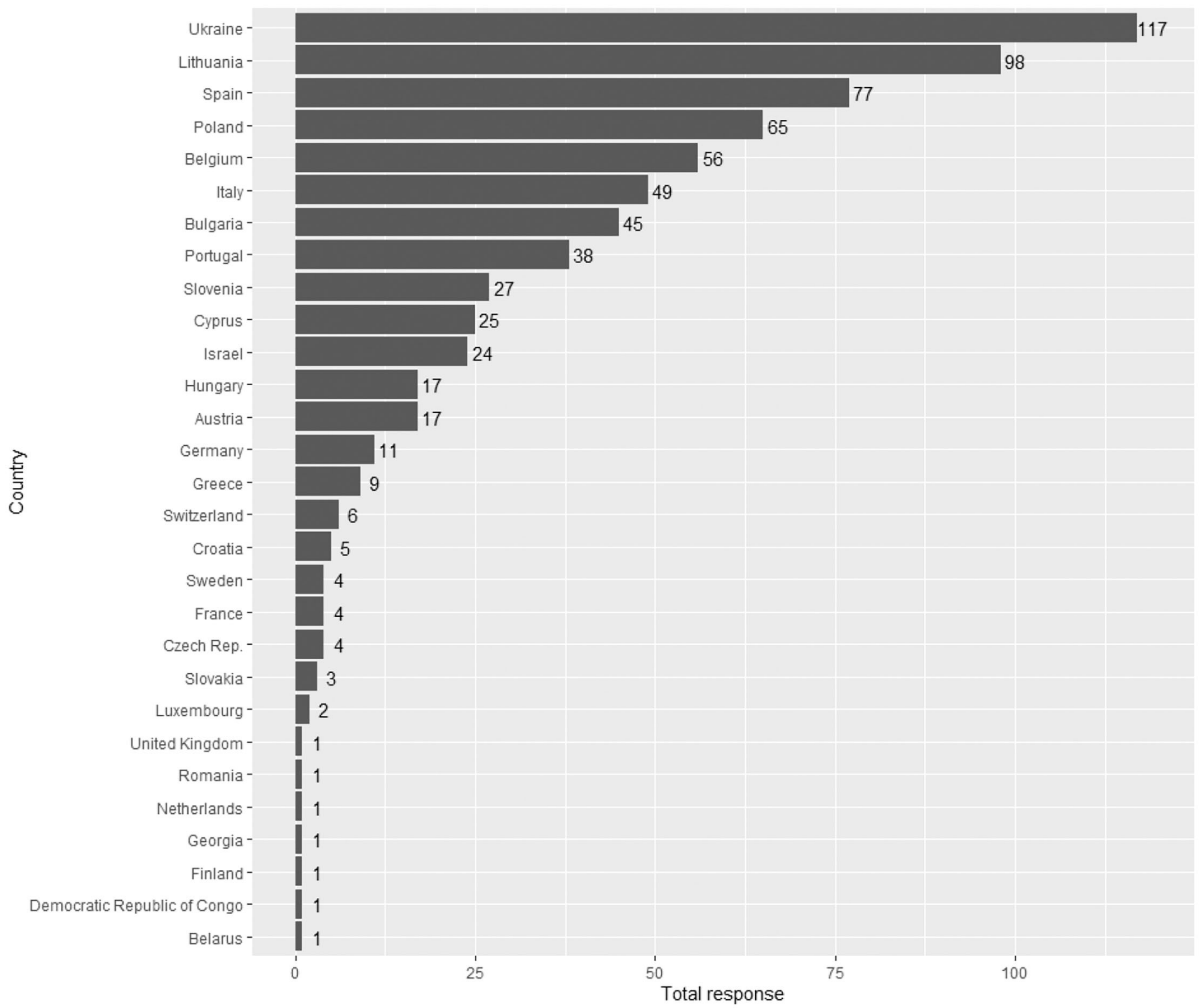

FIGURE 1 | Distribution of participants per country.

Scenario 1

Table 3 demonstrates clinical decision-making patterns for Scenario 1, the high-likelihood (likely to or certainly will) to manage remotely, and more specifically, to provide antibiotics, provide symptomatic care, refer for chest X-ray, refer to the ED, or prescribe steroids, all without having seen the patient in-person. All management options *via* telemedicine increased in frequency during the pandemic and yet all are predicted to reduce in frequency after the pandemic. The option to manage remotely is predicted to return to near pre-pandemic frequency, as are most management options. Only referrals to X-ray and the ED are predicted to have any increase in frequency sustained after the pandemic, when compared to pre-pandemic levels.

Scenario 2

Table 4 demonstrates clinical decision-making patterns for Scenario 2, the high-likelihood (likely to or certainly will) to manage remotely, and more specifically, to provide antibiotics or symptomatic care without an in-person visit. Managing and treating *via* telemedicine increased significantly during the pandemic when compared to the pre-pandemic rates. Predicted use of telemedicine to manage and provide symptomatic care after the pandemic dropped significantly; however, when compared to pre-pandemic patterns, a significant increase in frequency is still sustained. Yet, post-pandemic antibiotic prescribing *via* telemedicine is predicted to return to near pre-pandemic levels, with no significant change predicted for the time after the pandemic, when compared to the pre-pandemic period.

DISCUSSION

Our study demonstrates increased utilization of telemedicine for outpatient pediatric care during the COVID-19 pandemic. This

TABLE 2 | Use of telemedicine modalities for at least 50% of daily encounters.

Modality	Respondents *N* = 710					
	Before COVID-19		During COVID-19		After COVID-19	
	N	%	*N*	%	*N*	%
Phone calls	28	4	371	52*,+	135	19#
Emails	11	2	65	9*,+	31	4#
Text messages	8	1	46	6*,+	19	3#
Social media	21	3	78	11*,+	46	6#
Cell-phone pictures/video	10	1	64	9*	64	9#
Video conference	7	1	53	7*,+	25	4#

*During vs. before, $p < 0.05$.
+During vs. after, $p < 0.05$.
#After vs. before, $p < 0.05$.

TABLE 3 | High likelihood pattern of clinical decision making in scenario 1.

Clinical decision making	Respondents *N* = 710					
	Before COVID-19		During COVID-19		After COVID-19	
	N	%	*N*	%	*N*	%
Manage remotely	130	18	258	36*,+	159	22
Provide antibiotics without examination	10	1.4	56	8*,+	16	2
Provide symptomatic care without examination	172	24	320	45*,+	205	29
Ask for an X-ray without examination	11	1.6	70	10*,+	30	4.2#
Refer to ED without examination	34	4.8	164	23*,+	61	8.6#
Prescribe steroids without examination	62	8.7	169	24*,+	84	12

*During vs. before, $p < 0.05$.
+During vs. after, $p < 0.05$.
#After vs. before, $p < 0.05$.

increase was reported for all modalities considered: telephone calls, text messages, photo/video clips, and video calls, both when considering overall use, as well as when applied to specific clinical scenarios. These findings are consistent with other studies demonstrating physician's willingness to quickly adapt to telemedicine practices during the pandemic (3–6). However, for the first time, according to our knowledge, we could demonstrate that the use of all telemedicine modalities was predicted to remain in increased use after the pandemic, when compared to pre-pandemic levels. Experience during the pandemic has brought primary pediatric care to the forefront of telemedicine use.

A similar survey was previously used in a study of Israeli participants demonstrating a similar adaptation to telemedicine during the pandemic, yet it could not demonstrate similar willingness to adopt such practices after the pandemic (17). The difference between the studies may be the result of population variances. Additionally, the smaller sample size of the Israeli study (170 pediatricians) may not have had the power to detect significant changes for the post-pandemic phase. However, there may be more at hand. This European study was performed in June and July 2020, immediately after the completion of the Israeli study (May 2020). Though only 2 months following, we surmise that as physicians continued to use telemedicine, they became more comfortable with the modality thereby increasing their willingness to use it under "normal" circumstances.

As medical care advances during the twenty-first century, a hybrid of physician-patient interactions is developing, consisting of both in-person and telemedicine visits. However, whereas previous goals may have been created to utilize telemedicine to access hard to reach patients, crossing distances or physical barriers, current COVID-19 era use has forged a new ideal. Current telemedicine use has demonstrated that a significant percentage of physician-patient encounters does not require an in-person visit. The convenience of interacting remotely may increase efficiency for certain aspects of primary pediatric care.

Prior to the COVID-19 pandemic, strides in telemedicine were lagging for community pediatrics. Previous studies demonstrate physician's resistance to telemedicine utilization for reasons that include: lack of reimbursement, lack of infrastructure, non-familiarity with new modalities, discomfort with adopting new technologies, lack of confidence in the accuracy of tele-diagnosis, ease of missing or delaying critical diagnoses (such as medical emergencies or cancer), predisposition to ancillary testing and antibiotic prescribing

TABLE 4 | High likelihood pattern of clinical decision making in scenario 2.

Clinical decision making	Respondents $N = 710$					
	Before COVID-19		During COVID-19		After COVID-19	
	N	%	*N*	%	*N*	%
Manage remotely	71	10	284	$40^{*,+}$	119	$17^{\#}$
Provide antibiotics without examination	17	2	113	$16^{*,+}$	31	4
Provide symptomatic care without examination	220	31	388	$55^{*,+}$	144	$20^{\#}$

*During vs. before, $p < 0.05$.
+During vs. after, $p < 0.05$.
#After vs. before, $p < 0.05$.

with telemedicine use, lack of human interaction and impaired interpersonal dialogue that is critical to the physician-patient relationship (23–26).

The current COVID-19 pandemic has forced the primary care pediatrician's hand in utilization of telemedicine for a lack of a better alternative. We predict that this recent use will engender favorable attitudes toward the modality and lead to sustained use after the pandemic resolves.

We suggest that increased use during this era has increased familiarity, reduced "techno-phobia," allowed for the learning of meaningful use, as well as demonstrated telemedicine's opportunities for efficiency and convenience. Experience during the pandemic allows for the development of meaningful use both on the individual and on the institutional level with the development of protocols and guidelines (27, 28).

Clinical scenarios that require the elucidation of physical findings for diagnostic accuracy pose a unique challenge to telemedicine. In the clinical scenarios we presented, physicians were willing to diagnose and prescribe empirically and without a physical exam only during the pandemic era and expect to return to in-patient visits after the pandemic. However, as new technologies offer "telediagnostics," whereby part of the physical exam may be performed remotely, expectations are likely to change. New devices allow for auscultation, otoscopy, and visualization of the oropharynx *via* a remote device. Such devices have recently proven to provide high quality sound and images, on par with traditional medical devices (29, 30).

External physical findings, such as dermatologic exams have demonstrated increased utility for telemedicine use. Of all modalities surveyed in our study, images/video clips is the only modality to have predicted future use to remain sustained at pandemic levels. Advanced cell-phone camera technology has made it easy for taking and sending quality photographs. Studies have demonstrated that most skin lesions in pediatric primary care attention could be managed by tele-dermatology (31, 32).

However, increased utilization of telemedicine during COVID-19 for the clinical scenarios presented elucidate a particular need for caution with telemedicine: over-prescription. Previous studies have shown an increased frequency in antibiotic prescribing *via* telemedicine as compared to in-person visits (26). This tendency was confirmed by our presented case scenarios, with an increase in tele-prescribing during the pandemic. One may counter-argue, however, that our study of pandemic era practices presents a unique phenomenon during necessary social distancing, one that would not necessarily hold true during "normal" circumstances.

Our study has several limitations. Subjective and predictive reporting of use does not reflect the same accuracy as objective measures. Those who responded may not actually represent the opinions of all physicians in pediatric primary care. Participation was not proportional across all countries, and this may alter the study's ability to represent all of Europe. However, the limitation of the sample representativeness should be considered in the context of a first study of its kind, bringing data originating from primary care pediatricians. The pandemic spread varied in different countries, which may have influenced survey results. Future use are predictions made in the earlier part of the pandemic. Predictions may not be entirely accurate as attitudes may change as the pandemic persists and use of telemedicine (now for almost 2 years) is prolonged.

Our study did not explore chronic care, preventive care, or behavioral and developmental pediatrics. Unlike the clinical acute care scenarios presented, chronic care, preventive care and behavioral and developmental management may have greater utility for telemedicine (33, 34).

Our study did not explore the "other side of the examination table," or how patients feel about telemedicine. Initial studies in pediatric telemedicine are optimistic, demonstrating significant patient satisfaction (35). This may drive pressure on physicians to provide a service that patients demand. Health maintenance organizations and other healthcare organizations may require such practice from their providers to save costs, improve quality of care, increase patient compliance or simply as a means to attract patients. The ethics of utilization must also be explored.

We suggest further studies that (1) assess *via* objective measures (2), differentiate between visits that focus more on a physical exam vs. those that relate to preventive, behavioral, developmental, or administrative issues, as well as chronic care (3), assess the use of pediatric telediagnostics, and (4) reassess over time.

Additional studies will be needed to assess the cost of telemedicine as well as physician and patient satisfaction with its use. Ethical use, the quality of its care and liability issues must be further explored, so that evidence-based guidelines and protocols can be developed to guide further telemedicine use (36, 37).

In conclusion, our study demonstrates an increased use of telemedicine in primary care pediatrics during the COVID-19 epidemic, as well as its predicted effect of greater telemedicine use in the future after the pandemic, compared to the pre-pandemic situation.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

SR and ZG conceived of and designed the study and composed the manuscript. KM performed statistical analysis. AH, DE, ST, and HD provided analytical and editorial review. AG, RP, AMu, GS, AV, AMa, JR, MS, MM, AD'A, GK, KG, CW, and PA coordinated data collection. All authors have discussed the results and contributed to the final manuscript.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fped.2021.713930/full#supplementary-material

REFERENCES

1. NEJM Catalyst. *What is Telehealth.* (2018). doi: 10.1056/CAT.18.0268
2. Harvey JB, Valenta S, Simpson K, Lyles M, McElligott J. Utilization of outpatient telehealth services in parity and nonparity states 2010–2015. *Telemed J E Health.* (2019) 25:132–6. doi: 10.1089/tmj.2017.0265
3. Wosik J, Fudim M, Cameron B, Gellad ZF, Cho A, Phinney D, et al. Telehealth transformation: COVID-19 and the rise of virtual care. *J Am Med Inform Assoc.* (2020) 27:957–62. doi: 10.1093/jamia/ocaa067
4. Ting DSW, Carin L, Dzau V, Wong TY. Digital technology and COVID-19. *Nat Med.* (2020) 26:458–64. doi: 10.1038/s41591-020-0824-5
5. Elkbuli A, Ehrlich H, McKenney M. The effective use of telemedicine to save lives and maintain structure in a healthcare system: current response to COVID-19. *Am J Emerg Med.* (2020) 44:468–9. doi: 10.1016/j.ajem.2020.04.003
6. Bashshur R, Doarn CR, Frenk JM, Kvedar JC, Woolliscroft JO. Telemedicine and the COVID-19 pandemic, lessons for the future. *Telemed J E Health.* (2020) 26:571–3. doi: 10.1089/tmj.2020.29040.rb
7. Coronavirus Disease. *Center for Medicare and Medicaid Services.* (2020). Available online at: http://www.cms.gov (accessed January 7, 2021).
8. Israel Pediatric Association. *Guidance for Community Pediatricians.* (2020). Available online at: https://www.pediatrics.org.il/clinical-guidelines (accessed Jan 7, 2021).
9. Royal College of Paediatrics and Child Health (RCPCH). *COVID-19 - Guidance for Community Settings.* (2020). Available online at: https://www.rcpch.ac.uk/resources/covid-19-guidance-community-settings (accessed June 4, 2020).
10. Somekh I, Somech R, Pettoello-Mantovani M, Somekh E. Changes in routine pediatric practice in light of coronavirus 2019 (COVID-19). *J Peds.* (2020) 224:190–3. doi: 10.1016/j.jpeds.2020.05.053
11. Ehrich J, Namazova-Baranova L, Pettoello-Mantovani M. Introduction to "diversity of child health care in Europe: a study of the European paediatric association/union of national European paediatric societies and associations." *J Pediatr*. (2016) 177S:S1–10. doi: 10.1016/j.jpeds.2016.04.036
12. Haimi M, Brammly Greenberg S, Baron Epel O, Waisman Y. Assessing patient safety in a pediatric telemedicine setting: a multi-methods study. *BMC Med Inform Decis Mak.* (2020) 20:63. doi: 10.1186/s12911-020-1074-7
13. Scott Kruse C, Karem P, Shifflett K, Vegi L, Ravi K, Brooks M. Evaluating barriers to adopting telemedicine worldwide: a systematic review. *J Telemed Telecare.* (2018) 24:4–12. doi: 10.1177/1357633X16674087
14. European Commission. *Market Study on Telemedicine.* (2018). Available online at: https://ec.europa.eu/health/sites/health/files/ehealth/docs/2018_provision_marketstudy_telemedicine_en.pdf (accessed January 18, 2021).
15. World Health Organization. *Global Health Observatory (GHO) Data.* (2016). https://www.who.int/gho/goe/telehealth/en/ (accessed January 7, 2021).
16. Gamus A, Chodick G. Telemedicine after COVID-19: the Israeli perspective. *Isr Med Assoc J.* (2020) 22:467–9.
17. Grossman Z, Chodick G, Reingold SM, Chapnick G, Ashkenazi S. The future of telemedicine visits after COVID-19: perceptions of primary care pediatricians. *Isr J Health Policy Res.* (2020) 9:53. doi: 10.1186/s13584-020-00414-0
18. Wade VA, Eliott JA, Hiller JE. Clinician acceptance is the key factor for sustainable telehealth services. *Qual Health Res.* (2014) 24:682–94. doi: 10.1177/1049732314528809
19. Del Torso S, Van Esso D, Gerber A, Drabik A, Hadjipanayis A, Nicholson A, et al. European academy of paediatrics research in ambulatory setting network (EAPRASnet): a multi-national general paediatric research network for better child health. *Child Care Health Dev*. (2010) 36:385–91. doi: 10.1111/j.1365-2214.2010.01086.x
20. Grossman Z, van Esso D, Del Torso S, Hadjipanayis A, Drabik A, Gerber A, et al. Primary care pediatricians' perceptions of vaccine refusal in Europe. *Pediatr Infect Dis J.* (2011) 30:255–6. doi: 10.1097/INF.0b013e3181faaaa3
21. Grossman Z. del Torso S, Hadjipanayis A, van Esso D, Drabik A, Sharland M. Antibiotic prescribing for upper respiratory infections: European primary paediatricians' knowledge, attitudes and practice. *Acta Paediatr.* (2012) 101:935–40. doi: 10.1111/j.1651-2227.2012.02754.x
22. van Esso D. del Torso S, Hadjipanayis A, Biver A, Jaeger-Roman E, Wettergren B, Nicholson A. Primary-secondary working group (PSWG) of European academy of paediatrics (EAP). Paediatric primary care in Europe: variation between countries. *Arch Dis Child.* (2010) 95:791–5. doi: 10.1136/adc.2009.178459
23. Sisk B, Alexander J, Bodnar C, Curfman A, Garber K, McSwain SD, et al. Pediatrician attitudes toward and experiences with telehealth use: results from a national survey. *Acad Pediatr.* (2020) 20:628–35. doi: 10.1016/j.acap.2020.05.004
24. Kane CK, Gillis K. The use of telemedicine by physicians: still the exception rather than the rule. *Health Aff.* (2018) 37:1923–30. doi: 10.1377/hlthaff.2018.05077
25. Olson CA, McSwain SD, Curfman AL. The current pediatric telehealth landscape. *Pediatrics.* (2018) 141:3. doi: 10.1542/peds.2017-2334
26. Ray KN, Shi Z, Gidengil CA, Poon SJ, Uscher-Pines L, Mehrotra A. Antibiotic prescribing during pediatric direct-to-consumer telemedicine visits. *Pediatrics.* (2019) 143:5. doi: 10.1542/peds.2018-2491
27. Pedrotti CHS, Accorsi TAD, De Amicis Lima K, Serpa Neto A, Lira MTSS, Morbeck RA, et al. Antibiotic stewardship in direct-to-consumer telemedicine consultations leads to high adherence to best practice guidelines and a low prescription rate. *Int J Infect Dis.* (2021) 105:130–4. doi: 10.1016/j.ijid.2021.02.020
28. Hersh WR, Wallace JA, Patterson PK, Shapiro SE, Kraemer DF, Eilers GM, et al. Telemedicine for the medicare population: pediatric, obstetric, and clinician-indirect home interventions. *Evid Rep Technol Assess*. (2001) 24:1–32. doi: 10.1186/1472-6947-1-5
29. McDaniel NL, Novicoff W, Gunnell B, Cattell Gordon D. Comparison of a novel handheld telehealth device with stand-alone

examination tools in a clinic setting. *Telemed J E Health.* (2019) 25:1225–30. doi: 10.1089/tmj.2018.0214
30. Erkkola-Anttinen N, Irjala H, Laine MK, Tähtinen PA, Löyttyniemi E, Ruohola A. Smartphone otoscopy performed by parents. *Telemed J E Health.* (2019) 25:477–84. doi: 10.1089/tmj.2018.0062
31. Bianchi MG, Santos AP, Cordioli E. The majority of skin lesions in pediatric primary care attention could be managed by tele-dermatology. *PLoS ONE.* (2019) 14:12. doi: 10.1371/journal.pone.0225479
32. O'Connor DM, Jew OS, Perman MJ, Castelo-Soccio LA, Winston FK, McMahon PJ. Diagnostic accuracy of pediatric teledermatology using parent-submitted photographs: a randomized clinical trial. *J Am Med Assoc Dermatol.* (2017) 153:1243–8. doi: 10.1001/jamadermatol.2017.4280
33. Mercuri E, Zampino G, Morsella A, Pane M, Onesimo R, Angioletti C, et al. Contactless: a new personalised telehealth model in chronic pediatric diseases and disability during the COVID-19 era. *Ital J Pediatr.* (2021) 47:29. doi: 10.1186/s13052-021-00975-z
34. Schweiberger K, Hoberman A, Iagnemma J, Schoemer P, Squire J, Taormina J, et al. Practice-level variation in telemedicine use in a pediatric primary care network during the covid-19 pandemic: retrospective analysis and survey study. *J Med Internet Res.* (2020) 22:12. doi: 10.2196/24345
35. Shah AC, Badawy SM. Telemedicine in pediatrics: systematic review of randomized controlled trials. *JMIR Pediatr Parent.* (2021) 4:1. doi: 10.2196/22696
36. Foster C, Martinez KA, Sabella C, Weaver GP, Rothberg MB. Patient satisfaction and antibiotic prescribing for respiratory infections by telemedicine. *Pediatrics.* (2019) 144:3. doi: 10.1542/peds.2019-0844
37. Nittari G, Khuman R, Baldoni S, Pallotta G, Battineni G, Sirignano A, et al. Telemedicine practice: review of the current ethical and legal challenges. *Telemed J E Health.* (2020) 26:1427–37. doi: 10.1089/tmj.2019.0158

Conflict of Interest: SR is a paid consultant of Tytocare.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Advantages of publishing in Frontiers

OPEN ACCESS
Articles are free to read for greatest visibility and readership

FAST PUBLICATION
Around 90 days from submission to decision

HIGH QUALITY PEER-REVIEW
Rigorous, collaborative, and constructive peer-review

TRANSPARENT PEER-REVIEW
Editors and reviewers acknowledged by name on published articles

Frontiers
Avenue du Tribunal-Fédéral 34
1005 Lausanne | Switzerland

Visit us: www.frontiersin.org
Contact us: frontiersin.org/about/contact

REPRODUCIBILITY OF RESEARCH
Support open data and methods to enhance research reproducibility

DIGITAL PUBLISHING
Articles designed for optimal readership across devices

FOLLOW US
@frontiersin

IMPACT METRICS
Advanced article metrics track visibility across digital media

EXTENSIVE PROMOTION
Marketing and promotion of impactful research

LOOP RESEARCH NETWORK
Our network increases your article's readership