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Commentary: Accessing 3D Printed Vascular Phantoms for Procedural Simulation

Som P. Singh, Fahad M. Qureshi and Farhan Baig*

Department of Biomedical Sciences, University of Missouri - Kansas City School of Medicine, Kansas, MO, United States

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*Correspondence:
Som Singh
somsingh@mail.umkc.edu

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INTRODUCTION

Vascular disease remains a global health concern despite continued innovation in its diagnosis and management (1). Given the rise in endovascular therapeutic intervention options for patients with vascular pathologies, there has been a tremendous improvement in postoperative outcomes throughout diagnosis patterns (2, 3). A primary factor behind the improved postoperative outcomes is due to the minimally invasive nature of such procedures which allow for less metabolic strain for patients during the recovery process (4). In particular, abdominal aortic aneurysms (AAA) - a pathological dilation of the abdominal aorta - have experienced statistical decreases in morbidity and mortality rates among patients who undergo endovascular repair when compared to open procedures (4, 5). Let alone, the innovation behind AAA endovascular repair has led to a growth in these therapeutic modalities used in emergent settings as well (6). However, like any therapeutic modality, the risk of developing complications still exists. For example, injuries to the access vessels have the potential for development of other complications such as vessel rupture, occlusion, and possible need for additional acute vascular interventions to repair the complications (2). These risks make it imperative for the healthcare field to continue to seek options to evaluate and innovate the continuum of medical training of interventionists and vascular surgeons for the goal of optimal patient outcomes. In particular, the aim of this commentary is to examine 3D printed phantoms as an innovation in vascular surgery.

APPLICATION OF 3D PRINTED MODELS IN PREOPERATIVE CARE

Historically, 3D printing was developed as a form of additive manufacturing in the 20th century. Initially, the use of 3D printing was isolated to industrial purposes. However, 3D printing has created an indelible impact in healthcare in the form of anatomical models for medical training, implantable prothesis, and surgical preparation through image guidance in an array of surgical subspecialties including vascular, orthopedic, and urological surgeries (6–17). Moreover, the use of patient-specific surgical models has led to the rise in use of these additive manufacturing modalities for improving surgical planning since its initial investigation in the 1990s. These models allow for ample time for proceduralists to prepare for potential complex anatomy which may not be initially observed through more common 2D imagining modalities. In addition, 3D printed models afford trainees to grow a repository of procedural simulations which amplifies the total exposure per trainee through these artificial models in addition to their clinical experiences. Ultimately, the primary benefit of this preparation is to improve workflow efficiency as discussed in previous literature (18, 19). In fact, this workflow efficiency has been shown to save greater than $1000 per case due to reduced operating room time requirements (20).

3D PRINTED VASCULAR PHANTOMS

In a recent methods article by Coles-Black et al. in 2021, the authors of this article developed a workflow methodology of developing 3D printed vascular phantoms from CT angiograms (18). This study introduced a thorough and efficient protocol that could potentially be translated into other healthcare practices given greater availability of 3D printing resources over time. Additionally, a key emphasis provided in the article was in description of the utility of patient-specific CT angiography, and the vested interest in the models which have a more complex anatomy at baseline which can contribute to improving surgical decision making. Moreover, the use of these 3D vascular phantoms can benefit vascular trainee confidence through simulation practice as discussed. Additionally, the authors discussed the potential for 3D printing services based in hospitals itself to provide a centralized process for project implementation.

APPLICATION OF 3D PRINTED MODELS IN MEDICAL EDUCATION

The methodology proved by Coles-Black et al. provides a foundation for further exploration in the utility of these models in healthcare. In addition, this commentary would like to build upon this discussion by introducing the potential for 3D printed vascular phantoms for the utilization of medical school curriculum. This furthers the educational potential of 3D vascular models to grow beyond vascular surgery training. Moreover, the medical student training proposal benefits include a focus on introducing complex anatomy and developing greater understanding on the nuances of how imaging modalities can function (19–21). 3D printed models can be embedded into the curriculum of medical education within preclinical years (often the first-half of medical school years), which can allow for better anatomic visualization. Moreover, the literature on the effects of 3D visualization programs in student curriculum has shown promise in potentially improving memory recall of anatomy and spatial understanding (18–24). However, the concerns regarding cost of implementation may serve as a potential barrier towards widespread implementation in medical student curriculum (23–25). This provides a further direction for future studies to investigate the cost-benefit analysis of implementing such a curriculum design. Furthermore, the utility of 3D printing implementation in school curriculum has been widely investigated in developing pathology curriculum as well. This evidence may further support the idea of its implementation in a medical school curriculum.

CONCLUSION

3D vascular phantoms and the overall concept of 3D printing has numerous capabilities in healthcare and medical training. In this commentary, the primary areas of examination were on its utility in presurgical planning as seen in a variety of surgical subspecialties as well as in medical education. With regard to medical education, there may be potential utility in implementing vascular phantoms and 3D printing curriculum in medical school education as well. Future directions ought to include a greater degree of 3D printed vascular phantoms in medical care.

AUTHOR CONTRIBUTIONS

All authors contributed to the article and approved the submitted version.

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REFERENCES

1. Shamaki GR, Markson F, Soji-Ayoade D, Agwuegbo CC, Bamgbose MO, Tamunoinemi BM. Peripheral artery disease: a comprehensive updated review. *Curr Probl Cardiol*. (2021):101082. doi: 10.1016/j.cpcardiol.2021.101082. [Epub ahead of print]
2. Couto M, Figueróa A, Sotolongo A, Pérez R, Ojeda JM. Endovascular intervention in the treatment of peripheral artery disease. *Bol Asoc Med P R*. (2015) 107(3):47–51. PMID: 26742196
3. Thukkani AK, Kinlay S. Endovascular intervention for peripheral artery disease. *Circ Res*. (2015) 116(9):1599–613. doi: 10.1161/CIRCRESAHA.116.303503
4. Schmitz-Rixen T, Böckler D, Vogl TJ, Grundmann RT. Endovascular and open repair of abdominal aortic aneurysm. *Dtsch Arztebl Int*. (2020) 117 (48):813–9. doi: 10.3238/arztebl.2020.0813
5. Paravastu SC, Jayarajasingam R, Cottam R, Palfreyman SJ, Michaels JA, Thomas SM. Endovascular repair of abdominal aortic aneurysm. *Cochrane Database Syst Rev*. (2014) (1):CD004178. doi: 10.1002/14651858. [Epub ahead of print]

6. Alsac JM, Desgranges P, Kobeiter H, Becquemin JP. Emergency endovascular repair for ruptured abdominal aortic aneurysms: feasibility and comparison of early results with conventional open repair. *Eur J Vasc Endovasc Surg*. (2005) 30(6):632–9. doi: 10.1016/j.ejvs.2005.06.010
7. Morineau T, Morandi X, Le Moëllic N, Diabira S, Riffaud L, Haegelen C, et al. Decision making during preoperative surgical planning. *Hum Factors*. (2009) 51(1):67–77. doi: 10.1177/0018720809332847
8. Yi ZQ, Li L, Mo DP, Zhang JY, Zhang Y, Bao SD. Preoperative surgical planning and simulation of complex cranial base tumors in virtual reality. *Chin Med J (Engl)*. (2008) 121(12):1134–6. doi: 10.1097/00029330-200806020-00019
9. Alemayehu DG, Zhang Z, Tahir E, Gateau D, Zhang DF, Ma X. Preoperative planning using 3D printing technology in orthopedic surgery. *Biomed Res Int*. (2021) 2021:7940242. doi: 10.1155/2021/7940242
10. Ganguli A, Pagan-Diaz GJ, Grant L, Cvetkovic C, Bramlet M, Vozenilek J, et al. 3D printing for preoperative planning and surgical training: a review. *Biomed Microdevices*. (2018) 20(3):65. doi: 10.1007/s10544-018-0301-9
11. Tejo-Otero A, Buj-Corral I, Fenollosa-Artés F. 3D printing in medicine for preoperative surgical planning: a review. *Ann Biomed Eng*. (2020) 48 (2):536–55. doi: 10.1007/s10439-019-02411-0
12. Yang S, Lin H, Luo C. Meta-Analysis of 3D printing applications in traumatic fractures. *Front Surg*. (2021) 8:696391. doi: 10.3389/fsurg.2021.696391
13. Singh SP, Varghese KJ, Qureshi FM. Commentary: meta-analysis of 3D printing applications in traumatic fractures. *Front Surg*. (2021) 8:783743. doi: 10.3389/fsurg.2021.783743
14. Eltes PE, Bartos M, Hajnal B, Pokorni AJ, Kiss L, Lacroix D, et al. Development of a computer-aided design and finite element analysis combined method for affordable spine surgical navigation with 3D-printed customized template. *Front Surg*. (2021) 7:583386. doi: 10.3389/fsurg.2020.583386
15. Singh SP, Borthwick KG, Qureshi FM. Commentary: development of a computer-aided design and finite element analysis combined method for affordable spine surgical navigation with 3D-printed customized template. *Front Surg*. (2021) 8:743290. doi: 10.3389/fsurg.2021.743290
16. Celi S, Gasparotti E, Capellini K, Vignali E, Fanni BM, Ali LA, et al. 3D printing in modern cardiology. *Curr Pharm Des*. (2021) 27(16):1918–30. doi: 10.2174/1381612826666200622132440
17. Coles-Black J, Ong S, Teh J, Kearns P, Ischia J, Bolton D, et al. 3D printed patient-specific prostate cancer models to guide nerve-sparing robot-assisted radical prostatectomy: a systematic review. *J Robot Surg*. (2022). doi: 10.1007/s11701-022-01401-0. [Epub ahead of print]
18. Coles-Black J, Bolton D, Chuen J. Accessing 3D printed vascular phantoms for procedural simulation. *Front Surg*. (2021) 7:626212. doi: 10.3389/fsurg.2020.626212
19. Shilo D, Emodi O, Blanc O, Noy D, Rachmiel A. Printing the future-updates in 3D printing for surgical applications. *Rambam Maimonides Med J*. (2018) 9(3):e0020. doi: 10.5041/RMMJ.10343
20. Ballard DH, Mills P, Jr DR, Weisman JA, Rybicki FJ, Woodard PK. Medical 3D printing cost-savings in orthopedic and maxillofacial surgery: cost analysis of operating room time saved with 3D printed anatomic models and surgical guides. *Acad Radiol*. (2020) 27(8):1103–13. doi: 10.1016/j.acra.2019.08.011. Epub 2019 Sep 18
21. Gunderman RB, Stephens CD. Teaching medical students about imaging techniques. *AJR Am J Roentgenol*. (2009) 192(4):859–61. doi: 10.2214/AJR.08.1738
22. Weeks JK, Pakpoor J, Park BJ, Robinson NJ, Rubinstein NA, Prouty SM, et al. Harnessing augmented reality and CT to teach first-year medical students head and neck anatomy. *Acad Radiol*. (2021) 28(6):871–6. doi: 10.1016/j.acra.2020.07.008
23. Serrano C, Fontenay S, van den Brink H, Pineau J, Prognon P, Martelli N. Evaluation of 3D printing costs in surgery: a systematic review. *Int J Technol Assess Health Care*. (2020):1–7. doi: 10.1017/S0266462320000331. [Epub ahead of print]
24. Choonara YE, du Toit LC, Kumar P, Kondiah PP, Pillay V. 3D-printing and the effect on medical costs: a new era? *Expert Rev Pharmacoecon Outcomes Res*. (2016) 16(1):23–32. doi: 10.1586/14737167.2016.1138860
25. Yuen J. What is the role of 3D printing in undergraduate anatomy education? A scoping review of current literature and recommendations. *Med Sci Educ*. (2020) 30(3):1321–9. doi: 10.1007/s40670-020-00990-5

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