Harnessing AI for public health: India's roadmap

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Present scenario of AI in public health

Artificial Intelligence (AI), defined as the simulation of human intelligence processes by machines, especially computer systems, has emerged as a transformative force across various sectors, including public health. Currently, the application of AI in Public Health cuts across data visualization and predicting health outcomes, including patterns and likelihood of diseases (1, 2). AI algorithms can now be used to analyze complex data and manage health records (2). Following a study among Spanish-speaking individuals by the National Institutes of Health, an AI chatbot was 90% accurate in predicting the risk of developing type 2 diabetes. The chatbots collected and analyzed patients' data, physical activities, dietary habits, and social media information to arrive at this result (3).

With the use of AI tools, patients can access medical services remotely and obtain information to improve their mental health (3). From a public health perspective, AI helps improve health education and promotion by providing personalized health advice to users according to their preferences, medical history, and lifestyle (4). AI chatbots have been beneficial in healthcare training and virtual simulation in a human-friendly approach (5). Thus, the use of AI in health promotion and disease prevention is noteworthy in disease management and rehabilitation (3).

Largely, AI can facilitate data collection, analyze causes and effects, summarize patient information, reduce health disparities, and promote public health services (3, 6, 7). However, due to the nascency of modern AI technology, AI use may result in unforeseeable circumstances, such as misinterpretation, especially when it is not used effectively or is heavily relied on. Therefore, public health professionals must be discerning and learn to interpret and use AI appropriately (1).

Public health challenges in India

This paper aims to specifically explore the application of AI in the Indian public health context by considering its unique socio-cultural and economic landscape. India's public health dynamics are shaped by diverse factors, including its vast socio-cultural diversity, demographic variations, economic disparities, and environmental challenges (8). This complexity presents a dual challenge: the persistent burden of communicable diseases alongside the rapid rise of non-communicable diseases (NCDs). Communicable diseases such as respiratory infections, Tuberculosis, Malaria, and HIV/AIDS remain significant public health concerns. At the same time, the prevalence of NCDs, including cardiovascular

diseases and diabetes, is on a steep upswing (9). Alarming indicators in maternal and child health, such as high rates of maternal and neonatal mortality and child malnutrition, further underscore the severity of the situation (10).

The rise of non-communicable diseases, particularly diabetes, is of special concern in India, which is known as the 'diabetes capital of the world'. The Indian Council of Medical Research reports a staggering 101 million diagnosed cases of diabetes, further compounded by an additional 136 million individuals classified as pre-diabetic (11). This prevalence emphasizes the urgent need for preventive measures that are tailored to the Indian context. Additionally, the upward trends in hypertension and obesity rates highlight the broader public health challenges facing India (12, 13).

AI for India's public health scenario

In India, the utilization of artificial intelligence (AI) for addressing public health challenges has emerged as a promising avenue, offering innovative solutions to improve healthcare delivery and outcomes. AI technologies have been particularly instrumental in predictive healthcare analysis and the automatic diagnosis and screening of diseases (14). Predictive healthcare analysis leverages AI algorithms to analyze vast datasets comprising patient demographics, clinical records, environmental factors, and socio-economic indicators to forecast disease trends, identify high-risk populations, and inform proactive intervention strategies (15). By analyzing historical data and identifying patterns, AI can predict disease outbreaks, epidemics, and emerging health threats with greater accuracy and timeliness, enabling public health authorities to allocate resources efficiently and implement targeted preventive measures (2, 16).

For non-communicable diseases like diabetes, AI offers unique advantages. Unlike other NCDs such as smoking-related diseases, diabetes management in India requires a tailored approach that considers the country's dietary habits, physical activity levels, and access to healthcare services. AI can aid in personalized treatment planning by analyzing patient data, including lifestyle, genetic factors, and social determinants of health. For example, AI can predict individual risk factors and offer customized interventions, such as dietary recommendations or reminders for physical activities, which are culturally appropriate and feasible for the Indian population. This personalized approach is crucial in a country where health literacy varies widely and access to healthcare services is uneven.

Furthermore, AI-driven automatic diagnosis and disease screening hold significant promise in enhancing healthcare accessibility and efficiency, especially in resource-constrained settings such as India (17). Machine learning algorithms trained on large datasets of medical images, such as X-rays, MRIs, and CT scans, can assist healthcare providers in diagnosing various diseases, including tuberculosis, cancer, and diabetic retinopathy, with high accuracy and speed (18). These AI-enabled diagnostic tools have the potential to overcome challenges related to the shortage of trained healthcare professionals and the uneven distribution of medical expertise across different regions of India (19).

Moreover, AI technologies are being applied to streamline healthcare workflows, optimize treatment protocols, and personalize patient care. Natural language processing algorithms enable the automated analysis of unstructured clinical notes and medical literature, facilitating evidence-based decision-making and clinical guideline adherence (18). Additionally, AI-driven telemedicine platforms and mobile health applications empower patients to access healthcare services remotely, receive real-time health monitoring, and engage in self-management practices, thereby improving health outcomes and reducing healthcare disparities, particularly in rural and underserved areas (2). With its capabilities to address both preventive and therapeutic aspects of non-communicable diseases (NCDs), AI holds promise in alleviating the substantial burden of morbidity and mortality associated with NCDs in India. Furthermore, it offers multifaceted assistance in NCD management, encompassing disease prediction, patient monitoring, treatment adherence, and follow-up.

In the context of public health promotion, AI can also play a significant role in addressing malnutrition, particularly among vulnerable populations such as children and the older adult (20). Malnutrition remains a pressing issue in India, where undernutrition coexists with rising rates of obesity, particularly in urban areas (21). AI can help identify at-risk populations by analyzing factors such as income levels, access to food, and dietary habits. For instance, AI-powered tools can monitor the growth patterns of children and alert healthcare workers to early signs of malnutrition, enabling timely interventions (22). Similarly, AI can assist in developing personalized nutrition plans for the older adult, considering their specific dietary needs and potential health conditions, thereby improving their overall health outcomes (23).

Spatial modeling emerges as a crucial component of AI application in public health. Utilizing geographic data analysis, spatial modeling identifies health trends and predicts disease spread. Machine learning algorithms analyze extensive data, including satellite imagery, to aid in resource allocation and interventions (2). For instance, these techniques have been instrumental in forecasting the spread of diseases like Dengue fever (24). Infectious diseases exhibit spatial correlations, and spatial modeling enables visualization, clustering, hotspot detection, and risk factor identification, thereby enhancing surveillance and prevention strategies. India's diverse geography and disease distribution patterns offer ample opportunities for the implementation of spatial modeling. These models have proven particularly useful in understanding the spread factors of diseases such as COVID-19 at the district level in India (25).

Additionally, AI can monitor, organize, and visualize disease outbreaks based on geographical location, time, and infectious pathogens, utilizing real-time data from diverse sources such as social media, news reports, and official health reports. For example, "Arogya Setu" was developed by the Indian Government and stakeholders like the National Information Center to offer real-time contact tracing and self-assessment during critical periods like the COVID-19 pandemic. With 210 million downloads, it aided data-driven responses, saving lives (26).

However, despite the promising applications of AI in addressing public health challenges in India, several barriers and limitations exist. These include the need for robust data governance frameworks to ensure data privacy and security, the requirement

for skilled workforce development to effectively leverage AI technologies, and the necessity for regulatory oversight to ensure the safe and ethical deployment of AI-driven healthcare solutions (19). Furthermore, addressing issues related to algorithmic bias, interoperability of health information systems, and the digital divide among different population groups is crucial to maximize the impact of AI in public health in India.

Moreover, the strategy of nurturing partnerships between academia, industry, government, and nonprofit organizations, though beneficial, has limitations. For example, the complexity of diabetes management requires not just technological solutions but also lifestyle and behavioral interventions at the micro level (27). This recommendation may not address the immediate, individual-level challenges faced by diabetic patients, such as adherence to treatment plans, diet, and exercise routines. The partnership approach tends to focus more on upstream determinants, which, while essential, may overlook the nuanced, downstream determinants of health that directly impact patients' daily lives.

To overcome these limitations, a more focused approach is necessary, one that integrates AI applications with community-based health strategies. By combining AI's predictive and personalized capabilities with on-the-ground public health interventions tailored to specific communities, India can more effectively address the growing diabetes epidemic. For instance, community health workers can use AI tools to monitor patient adherence to diabetes management plans in real-time, offering immediate support and adjustments as needed (27). This approach not only bridges the gap between high-level AI applications and individual patient needs but also ensures that the solutions are sustainable and culturally appropriate.

Table 1 provides a comprehensive overview of the challenges associated with the use of AI in public health management in India. While these challenges are not unique to India, the table highlights the need for a localized strategy that integrates AI with existing public health infrastructure and cultural practices. Addressing these challenges requires concerted efforts from policymakers, healthcare professionals, researchers, and stakeholders to ensure the responsible, equitable, and effective integration of AI technologies into public health systems.

Comparison examples from other LMICs and continents

In comparison, other Low- and Middle-Income Countries (LMICs) like Brazil and Kenya have also leveraged AI to improve healthcare, albeit in different ways. In Brazil, AI has been utilized in telemedicine to extend healthcare services to remote areas (28), similar to India's approach. However, Brazil has also focused on AI in mental health, developing chatbots that provide psychological support in underserved communities (29). Kenya, on the other hand, has implemented AI-driven mobile health platforms to combat malaria and maternal health issues (30), demonstrating AI's versatility in addressing diverse health challenges. These examples illustrate that while the challenges of implementing AI in healthcare are global, the solutions must be tailored to the specific needs and contexts of each country.

In the United States, AI applications in healthcare have encountered challenges such as data privacy concerns, interoperability issues, and algorithmic biases (31, 32), similar to those in India. However, the U.S. has also seen successes, particularly in the use of AI for personalized medicine and precision health, where AI is used to tailor healthcare treatments to individual genetic profiles. While this is a promising area, it also underscores the importance of data security and the ethical use of AI. In contrast, China's extensive use of AI in public health has demonstrated success in predictive analysis and disease outbreak management (33). China's AI strategies often involve large-scale data collection and government-led initiatives, which have proven effective in managing public health emergencies, such as the COVID-19 pandemic. However, this approach has also faced scrutiny over data privacy and ethical concerns, highlighting the trade-offs between public health benefits and individual privacy rights.

In Europe, countries like Germany have made strides in integrating AI into their healthcare systems, yet they too grapple with regulatory and standardization challenges (34). Germany's approach emphasizes the importance of patient data protection and the need for robust ethical frameworks, which can serve as a model for other countries looking to balance innovation with privacy concerns. These international examples highlight that while AI offers promising solutions, the associated challenges are global and necessitate tailored approaches to address specific regional and cultural contexts. For India, this means developing AI strategies that not only harness the technology's potential but also respect and integrate the country's diverse cultural and socio-economic landscape.

Road ahead and way forward for AI applications in public health in India

The journey toward harnessing the full potential of artificial intelligence (AI) in public health in India requires a strategic and collaborative approach, encompassing various stakeholders, innovative solutions, and sustained efforts. Several key considerations and action points emerge to maximize the impact of AI applications in addressing public health challenges in India:

Firstly, establishing robust data infrastructure and governance frameworks is essential. This involves creating interoperable health information systems, ensuring data quality and standardization, and adhering to stringent data privacy regulations. By fostering partnerships for data sharing while safeguarding patient confidentiality, India can unlock the full potential of AI-driven public health initiatives.

Investing in capacity building and workforce development is critical. Equipping healthcare professionals, data scientists, and policymakers with the necessary skills and knowledge is essential for the effective utilization of AI technologies in public health. Through collaborative efforts and interdisciplinary training programs, India can cultivate a skilled workforce adept at harnessing AI for improved healthcare outcomes.

Promoting innovation and fostering collaboration should be guiding principles along this path. Encouraging entrepreneurship,

TABLE 1 Challenges and strategic approaches for AI integration in public health management in India.

Challenges	Description	Strategic approaches
Data accessibility and quality	Limited access to high-quality healthcare data, particularly in rural areas, impedes the development and effectiveness of AI algorithms	Develop a national digital health infrastructure with standardized data collection protocols and invest in expanding digital access in rural areas
Infrastructure and connectivity	Inadequate infrastructure and connectivity in remote regions restrict the implementation of AI-driven healthcare solutions	Enhance digital infrastructure with a focus on last-mile connectivity and incentivize public-private partnerships to improve technology access
Cultural and linguistic diversity	India's diverse cultural and linguistic landscape presents challenges for AI systems in processing local languages and providing culturally sensitive care	Develop AI models that are trained on multilingual datasets and incorporate cultural nuances to ensure broader accessibility and acceptance
Healthcare workforce skills	Shortage of professionals skilled in AI technologies within the healthcare sector limits the adoption and utilization of AI solutions	Implement interdisciplinary training programs for healthcare workers and data scientists, and promote AI literacy through continuous education
Regulatory framework and compliance	Lack of comprehensive regulations governing AI in healthcare raises concerns about data privacy, security, and the ethical use of AI technologies	Establish a robust regulatory framework that addresses data privacy, security, and ethical considerations, including algorithmic transparency and accountability
Financial resources and funding	Limited financial resources allocated for AI research and development pose barriers to scaling up AI-driven public health initiatives	Increase funding for AI in healthcare through government grants, international collaborations, and private sector investments, with a focus on scalable solutions
Equity and access	Ensuring equitable access to AI-driven healthcare solutions across socio-economic and geographical divides remains a challenge, exacerbating healthcare disparities	Design AI applications that are affordable and accessible, with targeted interventions for underprivileged communities, and ensure equitable distribution of resources
Trust and acceptance	Building trust and acceptance among healthcare professionals and the public toward AI technologies requires transparency, education, and evidence-based outcomes	Engage in community outreach and education campaigns to demystify AI technologies, involve local stakeholders in AI deployment, and ensure AI solutions are evidence-based and user-friendly

supporting start-ups, and facilitating cross-sector collaborations are pivotal in accelerating the development and deployment of scalable AI-driven healthcare solutions. By nurturing partnerships between academia, industry, government, and non-profit organizations, India can co-create and implement AI-enabled public health programs tailored to its unique context, driving progress toward Health for All.

Establishing a clear regulatory framework and ethical guidelines is imperative to ensure the responsible and equitable utilization of AI in public health. Policymakers must address issues related to data privacy, security, and algorithmic bias through comprehensive legislation and regulatory oversight. Engaging stakeholders in the development of ethical guidelines fosters transparency, trust, and acceptance of AI-driven interventions, paving the way for sustainable impact in India's public health landscape.

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