

NARRATIVE/SYSTEMATIC REVIEWS/META-ANALYSIS

A Glimpse Into the Deployment of Digital Health in India

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Abstract

The well-being of any country depends on the health of its citizens. As India is the most populated country and an emerging economy, a solution for India might also be a model for the rest of the world. Over the last eight years, India has taken significant steps to incorporate Digital Health (DH) at the core of its healthcare delivery system. Challenges, importance, fallout, specific applications, and growth of DH in the Indian setting are discussed in this report.

Plain Language Summary

Digital Health (DH) is a significant component of healthcare in the new Digital India. Technology is being used to achieve the bold objective of providing universal health coverage, initially to 500 million economically challenged citizens. This report traces the initiatives of the Government of India to meet this challenge, including the formation of the National Digital Health Authority, Ayushman Bharat Digital Health Mission, and Ayushman Bharat Health Account. In addition, showcased, as a specific illustration of the use of DH, is the *The TB Free India* campaign—a plan to eliminate tuberculosis by 2025. This report contains many agency names and programs. The Appendix at the end of this article defines each.

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Since 2015, India's digital transformation has been based on innovation and a commitment to rapid implementation. Conviction, coordination, and collaboration among stakeholders have resulted in technology-based solutions, making a significant difference.

Today, the 850 million internet users in India benefit from access to the most inexpensive data worldwide. Monthly, 10 billion transactions take place, accounting for 45% of global real-time payments using the Unified Payments Interface system.¹

A workforce with digital skills is a fundamental prerequisite in today's digital economy.² Addressing infrastructure, affordability, and digital literacy challenges is crucial to realizing a Digital India. The 107 unicorns, valued at \$340.79 billion and 1.3 billion digital identities, testify to the radical transformation of India's digital economy, which is growing 2.4 times faster than India's non-

digital economy. Today, India is poised to lead a technology revolution, digital public infrastructure, and other digital solutions.³

Introduction to Digital Health in India

Digital Health is a multi-disciplinary domain encompassing every component of healthcare where digital technology is primarily used.⁴ The World Health Organization defines DH as "a broad umbrella term encompassing eHealth, as well as emerging areas, such as using advanced computing sciences in 'big data,' genomics, and artificial intelligence."⁵ Virtual Reality, genomics, business analytics, blockchain, and other emerging technologies are included. DH also includes telemedicine, wearable devices, mobile health applications, and remotely accessible electronic health records.

Innovative biomedical materials and digitally enabled medical devices are used clinically in the medical devices sector. Computer-aided drug design, modeling for predictive toxicology, and big data analytics are deployed in clinical trials.⁶ DH is slowly becoming an integral part of the healthcare delivery system in India.⁷ Furthermore, DH makes healthcare more efficient, cost-effective, and universally accessible. Ensuring privacy and security is challenging. To this end, digital technology enables collecting, analyzing, storing, and sharing health data, resulting in better healthcare. Digital requirements for a healthcare organization must be customized, considering how, when, where, and what to do and how to measure success. The primary objective is deploying risk management and execution strategies.⁸

Government Initiatives and Policy Support

The flagship program, the Digital India campaign, was launched in 2015 by the Government of India. It included digital public health initiatives for healthcare services in rural areas. The National Health Policy in 2017 envisioned a fully digitized healthcare system. The National Health Authority (NHA), a statutory body responsible for promoting and adopting e-health standards, privacy, security storage, and exchanging all electronic health data, was initiated on January 2, 2019. The NHA has published a Health Data Management Policy to be adhered to. Details regarding notice and consent, right to access and erase records, limitations on collection use, and storage of personal data have been defined. An electronic consent management architecture collects and maintains verifiable records of user consent.

Similar initiatives include the National Medical College Network, the Digital Medical Library Network, the National Cancer Network, and the National Rural Telemedicine Network.⁹ In addition, the National Digital Health Blueprint was launched in 2019. The National Digital Health Mission (NDHM) was created on August 15, 2020 and renamed the Ayushman Bharat Digital Mission (ABDM) in September 2021.¹⁰ Its mission was to make accessible, affordable, and acceptable quality healthcare available to anyone, anytime, anywhere. The resulting unified DH infrastructure served as the backbone for an integrated, effective, and inclusive digital healthcare system, connecting stakeholders through digital highways. Seamless access to healthcare services facilitated the exchange of health information. This enabled individuals to have greater control over their health data. Interoperable frameworks and open protocols enabled citizens, public and private healthcare providers, and all stakeholders to unite. The Ayushman Bharat Digital Health Mission introduced transparency and reliability by integrating digital identity services. This enabled the verification of patient identities.

Indian citizens receive a unique identifier called the Ayushman Bharat Health Account (ABHA). Individuals securely store and share their medical information with doctors, hospitals, and laboratories through this personalized account. Data are shared only with the patient's explicit consent. The ABHA number is the primary building block contributing to the transformation of India's DH infrastructure. This 14-digit randomly generated unique identification number (Figure 1) is voluntarily generated to standardize an individual's identification process between healthcare providers and facilities.¹¹ The ABHA number will help link Electronic Health Record (EHR), public or private. In August 2023, there were 468 million ABHA accounts, and 230,000 doctors had been registered along with 220,000 healthcare facilities (Figure 2).¹²

The ABHA offers convenient, hassle-free digital access to health records. The health ID can be linked to one's national ID number (Aadhaar) or mobile phone number. One can receive lab reports, prescriptions, and diagnoses digitally from verified doctors and health service providers. The Healthcare Professionals Registry of the ABDM verifies the credentials of all healthcare providers. Health records are part of a mobile application system. In January 2022, the NHA launched the Unified Health Interface—a digital healthcare service platform under the ABDM.¹³ Digi-Doctor is a voluntary digital registry with details of medical practitioners practicing modern and traditional medicine. Participants use available digital infrastructure, facilitating seamless access to professional information.

CoWIN

The COVID Vaccine Intelligence Network (CoWIN) system was the technological backbone of India's Covid-19 vaccination program drive,^{14,15} which led to over 2 billion vaccinations. CoWIN enabled citizens to book vaccination appointments. It facilitated vaccine stock management and generated digital vaccination certificates.



Fig. 1. A sample National Health Authority E Card showing a citizen's unique 14-digit ID number called ABHA (Ayushman Bharat Health Account).

Aarogya Setu is the world's most used App for Covid-19. It has a real-time dashboard for contact tracing. As of October 11th 2023, 218.2 million people had enrolled.¹⁶ Aarogya Setu uses contact tracing to record details of all those with whom a registrant may have come in contact. Subsequently, if any test positive for COVID-19, the original registrant is informed immediately.

Illustrations of Applications of Digital Health in India

Point-of-care diagnostics, m-health, medical virtual assistants, robot-assisted surgery, self-monitoring healthcare devices, health service aggregation, big data and blockchain in healthcare, e-pharmacies, e-learning, and metaverse are examples of DH applications in India. Telehealth, the single largest component of DH, has experienced an astronomical growth rate. Teleconsultations allow patients to receive medical advice and treatment in their homes, reducing travel and waiting times and minimizing face-to-face consultations and hospital visits. Remote monitoring



Fig. 2. In August 2023, 468 million ABHA (Ayushman Bharat Health Account) accounts, 230,000 doctors, and 220,000 healthcare facilities had been registered.

solutions reduce out-of-pocket expenses. Electronic medical records (EMRs) enable remote access to a patient's clinical history. Many tertiary centers now deploy digital pathology. Computational pathology and artificial intelligence (AI) integrate information from multiple slides and ancillary investigations, correlating clinical and radiological data.¹⁷ DH is also playing a major role in facilitating quick settlement of insurance e Claims.

Regulatory and Legal Concerns

Massive deployment of DH necessitates additional attention to regulatory and legal concerns. The robust software should ensure data protection, privacy, and security and be user-friendly. Compliance and adherence require collaboration among healthcare providers, technology developers, policymakers, and regulatory bodies. Laws and regulations relevant to the deployment of DH in India are listed in Table 1.

Advantages of Digital Health in the Indian Setting

The advantages of DH include equity and inclusion, enhanced patient engagement, and streamlined healthcare delivery. These and other benefits of DH are outlined in Table 2.

Illustrations of Some Specific Government Initiatives in Digital Health²⁰

Initiatives instituted by the Government of India include Tele-MANAS, Nikshay 2.0 Portal, Assessment (HTA), and the Sanjeevani app. Each is described in Table 3.

Eradicating Tb from India—An Illustration of Digital Health Deployment

The ambitious proposal of the National Strategic Plan (2017–2025) for tuberculosis elimination has major DH components. These include computer-aided diagnosis, teleradiology-enabled digital X-ray machines, and

Table 1. Laws in India Related to Digital Health¹⁸

No	Name of the ACT
1	The Information Technology Act, 2000
2	The Information Technology (Reasonable Security Practices and Procedures and Sensitive Personal Data or Information) Rules, 2011
3	The Information Technology (Intermediary Guidelines and Digital Media Ethics Code) Rules, 2021
4	The Clinical Establishments (Registration and Regulation) Act, 2010 Clinical Establishments Rules, 2012, and Electronic Health Record Standards, 2016
5	Draft Digital Personal Data Protection Bill, 2022
6	Health Data Management Policy, 2020
7	Data Security Council of India Privacy Guide for Healthcare, 2021
8	Digital Personal Data Protection (DPDP) Bill 2023

Table 2. Advantages of Digital Healthcare

Features in Digital Health	Benefits
Equity and Inclusion in Healthcare	Digital Health interventions have improved access to healthcare services, particularly in underserved areas. Providing multilingual platforms helps cater to diverse populations.
Enhanced patient engagement and empowerment	Digital Health solutions empower patients by providing them access to their health information and tools for management. Health apps and wearable devices enable tracking of vital signs, monitoring progress, and making informed decisions.
Efficient and streamlined healthcare delivery	Adoption of digital tools has led to increased efficiency and streamlining of processes. EMR and health informatics platforms enable providers to access and share patient information seamlessly, reducing paperwork and eliminating manual errors.
Cost Savings for Patients and Healthcare Systems	Digital Health interventions reduce healthcare costs. Digital health technologies improve operational efficiency and resource allocation.
Enhanced quality of care and outcomes	Digital Health interventions are facilitating personalized and evidence-based care. Access to real-time patient data, health analytics, and decision support tools ensure informed clinical decisions. This leads to improved treatment outcomes and patient safety.
Advancements in Medical Research and Innovation	Digital Health platforms and data analytics help collect and analyze large-scale health data. The data-driven approach supports evidence-based decision-making, clinical trials, and the development of new treatments and interventions.
Preventive Medicine	Preventive Medicine will play a crucial role in healthcare of the future. Regular screenings, health check-ups, health education, vaccination, and improved sanitation can make a significant difference in the prevention/early detection of non-communicable diseases.
Personalized and Precision Medicine	Personalized and precision medicine is becoming a reality due to the translation of advances in genetic and molecular research. Digital Health enables targeted screening, lifestyle modifications, and early interventions based on one's genetic profile.
Public Health Policies and Initiatives	Policy interventions target risk factors, including tobacco use, air pollution, and sanitation. This requires close interaction among healthcare providers, policymakers, and communities. ¹⁹

EMR: Electronic medical records.

Table 3. eHealth initiatives in India

Initiative	Contribution to eHealth
Tele-MANAS	Telemental Health Assistance and Networking Across States (Tele-MANAS) enable video consultations with mental health specialists. It offers counseling, medical interventions, follow-up services, and linkages to in-person care, particularly for vulnerable populations and in remote areas.
Nikshay 2.0 Portal	A digital platform that supports community involvement in the care of patients with TB. It enables the registration of these patients, which facilitates additional support from donors, including diagnostic services, nutritional aid, and vocational support. The platform enhances the management and monitoring of needs of patients with TB.
Health Technology Assessment (HTA):	<i>Health Technology Assessment in India (HTAI)</i> is an institutional arrangement for evidence-based decision-making in health. HTAI evaluates clinical and cost-effectiveness of health technologies, medicines, and programs. It supports the formulation of health policies and efficient allocation of resources.
Sanjeevani app	This is a telemedicine and teleconsultation government platform, widely used, especially during the Covid-19 pandemic. The app enables remote consultations. It has expanded the reach of healthcare, ensuring timely medical support, particularly in rural and hard-to-reach areas.

barcoding/QR coding of all TB drugs. Digital verification ensures that all prescriptions comply with TB care standards.

After six continuous drug refills, the treatment outcome is generated as "Treatment Completed." Failure of a drug refill generates an alert. Then, digitally trained health workers reestablish contact to promote the resumption of treatment. An Aadhaar (1.3 unique billion cards are already operational)-linked TB smart card ensures direct benefits in addition to medication. A Geographic Information System (GIS) mapping of patients helps identify hot spots—crucial for a quick and adequate response.²¹ Digital technologies improve compliance and tracking, diagnostic accuracy, and screening. Laboratory Information Management System (LIMS) provides results, tracks samples, and tests workflows inside the lab. Data analytics, HR availability, training, equipment maintenance, sample storage, and bio-medical waste management are all addressed. Digitally enabled call centers ensure the resolution of issues. An AI solution is being developed to screen and detect TB from cough sounds so frontline staff can triage patients. AI algorithms also predict loss to follow-up. A chatbot provides information on most aspects of TB.²²

Advances in Deep Learning for TB Screening using Chest X-rays offer the possibility of earlier diagnosis.²³ Studies in India confirm that handheld, battery-operated,

lightweight X-ray machines are easy to use, can be carried to the remotest areas, and produce X-ray images comparable to digital X-ray machines.²⁴ Integrating WhatsApp messenger application for communication among health-care providers and researchers significantly increased follow-up in TB patients.²⁵ Development and evolution of a mobile health tool for capacity building of India's health workforce resulted in better management of TB patients. eNikshay SETU is a novel digital capacity-building platform for enhancing human resource skills to eliminate TB (<https://nikshay.gov.in>). Demographic details, mobile number, and bank account number are registered. A unique alpha-numeric Beneficiary ID enables access to all services anywhere. Diagnostic reports and monthly prescriptions are updated in the Management Information System, which evaluates how people use technology to manage information. It includes hardware and software used to store, process, and retrieve information.²⁶ Available to government and private facilities, planned future enhancements include adherence support, logistics management, and direct data transfers. It would also include Interactive Voice Response, Short Message Service (SMS) reminders, specially designed electronic pillboxes or strips, a mobile app to report treatment compliance using video, audio, or text messages, and innovatively designed information and communication technologies (ICT)-enabled smart cards.²⁷

The Truenat MTB-RIF Dx assay is a novel battery-operated, hand-held point-of-care device. The DNA of the TB bacillus is extracted in 20 min and loaded onto the chip-based Truelab micro-PCR (polymerase chain reaction) device. The PCR results have 100% specificity and are available in 40 min. This Made in India product approved by the World Health Organization (WHO) is a classical demonstration of the practical applications of DH.^{28–30} Mobile applications are also used to help rural healthcare providers identify and refer possible TB patients to the nearest microscopy center.³¹ The author is the Principal Investigator of a pilot study in two remote districts in the state of Gujarat for technologically enabled TB screening using handheld X-ray machines and TrueNat on-site diagnostics.

Investment

The significant, intangible benefits of DH are impossible to quantify. The global DH market is expected to reach \$430.5 billion by 2028, growing at a compound annual growth rate (CAGR) of 17%. Post-pandemic, DH has created a monumental surge for telemedicine, AI-driven chatbots, smart wearables, and e-pharmacies.³² The Digital healthcare market in India is expected to grow at a CAGR of 28.50% between 2022 and 2027, reaching \$31 billion.³³ As no restrictions are imposed for DH Services, foreign direct investment up to 100% is permitted without government approval.

Conclusion and Future Possibilities

This communication demonstrates that pilot projects and proof of concept validations are giving way to DH implementation in India's healthcare delivery system. The author is optimistic that DH will eventually be the primary mode of providing healthcare services.

Within a decade, ePharmacies could deliver medication within hours of online ordering, using drones when required. Digital tools and platforms could expand geographic reach, increase capacity, and extend service hours. Predictive, Personalized, Participatory, and Preventive (P4) medicine could be a reality.

With 75,000 genetic tests available and 10 new such tests added daily, pharmacogenomics and genome sequencing could also be available. While there is a long way to go, DH is gaining a solid foothold in India. India could eventually be the center stage of Digital healthcare globally.

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Appendix

Aadhaar: A 12-digit randomly generated individual identification number issued by the Unique Identification Authority of India on behalf of the Government of India. The number serves as proof of identity and address anywhere in India.

Aarogya Setu: An Indian COVID-19 “contact tracing, syndromic mapping and self-assessment” digital service, primarily a mobile app, developed by the National Informatics Centre under the Ministry of Electronics and Information Technology.

Ayushman Bharat Digital Health Mission (ABDM): Aims to develop the backbone necessary to support India’s integrated digital health infrastructure.

Ayushman Bharat Health Account (ABHA): The number that patients can seamlessly access and share their health records digitally 24 × 7, enabling interactions with health-care providers and allowing receipt of digital lab reports, prescriptions, and diagnoses.

Compound annual growth rate (CAGR): An investment’s mean annual growth rate over a period longer than 1 year.

COVID Vaccine Intelligence Network (CoWIN): An Indian government web portal for COVID-19 vaccination registration, owned and operated by India’s Ministry of Health and Family Welfare.

Deep learning: A method in AI that teaches computers to process data in a way inspired by the human brain. Deep learning models can recognize complex patterns in pictures, text, sounds, and other data to produce accurate insights and predictions.

Digital Health (DH): Provides access to remote and advanced care. The DH innovations are designed to save time, boost accuracy and efficiency, and combine technologies in ways that are new to healthcare. One benefit of DH is telemedicine.

DigiDoctor: A service that offers citizens of India doctors specializing in modern and traditional medicine.

Digital Health India (DHI): A campaign launched by the Government of India to make its services available to citizens electronically through improved online infrastructure and by increasing internet connectivity. The initiative includes plans to connect rural areas with high-speed internet networks.

Digital India campaign: An initiative by the Government of India to make its services available to citizens electronically through improved online infrastructure.

eNikshay SETU: A novel digital capacity-building platform for enhancing human resource skills to eliminate TB (<https://nikshay.gov.in>).

Electronic medical records (EMR): Technology that provides access to patients’ clinical history.

Xpert MTB/RIF: A cartridge-based nucleic acid amplification test (NAAT) for simultaneous rapid tuberculosis diagnosis and rapid antibiotic sensitivity test. It is an automated diagnostic test that can identify *Mycobacterium tuberculosis* (MTB) DNA and resistance to rifampicin (RIF).

Geographic information system (GIS): Through mapping of patients helps identify hot spots, which is crucial for a quick and adequate response.

Healthcare Professionals Registry: An initiative by the Government of India as part of the Ayushman Bharat Mission to build an extensive repository of registered and certified medical professionals in India’s Digital Health Ecosystem.

Integrated Control Technology (ICT): One element of an integrated health information and communication technologies infrastructure.

Laboratory Information Management System (LIMS): Provides results, tracks samples, and tests workflows inside the lab.

Management Information Systems (MIS): The study of how people use technology to manage information. It includes the hardware and software used to store, process, and retrieve information.

mHealth (or m-health): The practice of medicine and healthcare over mobile devices, tablets, PDAs, and computers.

National Digital Health Authority (DIC): The objective is to create an integrated *healthcare* system linking practitioners with patients digitally by giving them access to real-time *health* records.

National Digital Health Blueprint: The Government of India initiated efforts for establishing a comprehensive, nationwide integrated Digital Health ecosystem through an architectural framework called the National Digital

Health Blueprint. This served to integrate various efforts in the ecosystem of digital health. This is essential for a holistic pursuit of the goals of the National Health Policy 2017 and the Sustainable Development Goals relating to health.

National Digital Health Mission (NDHM). The mission aims to create an integrated healthcare system linking practitioners with patients digitally by giving them access to real-time health records. This will promote prompt and structured healthcare across the country. Renamed as the Ayushman Bharat Digital Mission (ABDM), its mission is to make accessible, affordable, and acceptable quality healthcare available to anyone, anytime, anywhere.

National Health Authority (NHA): A statutory body responsible for the promotion and adoption of e-health standards, privacy, security storage, and exchange of all electronic health data. Responsible for implementing India's flagship public health insurance/assurance scheme. Has published a Health Data Management policy.

National Health Policy (NHP): Intended to digitize the entire healthcare ecosystem of India by creating digital health records and creating and maintaining registries for healthcare professionals and health facilities to ensure a smooth interoperable framework for the multiple partners associated with healthcare delivery to individuals in India.

National Medical College Network (NMCN): Established by the Ministry of Health and Family Welfare, the NMCN project includes 154 medical colleges across India focusing on e-education and ehealthcare delivery.

National Rural Telemedicine Network: The Ministry of Health & Family Welfare Government of India established the National Rural Telemedicine Network (NRTN).

A Grant-in-Aid of \$2.4 million in 2007–08 and 2008–09 was released to all the States/Union Territories to kick start the project. In 2012-13, \$3.1 million was allocated to seven states.

NI-KSHAY: The web-enabled patient management system for TB control under the National Tuberculosis Elimination Programme (NTEP). It is developed and maintained by the Central TB Division (CTD), Ministry of Health and Family Welfare, Government of India, in collaboration with the National Informatics Centre (NIC) and the World Health Organization Country Office for India.

TB Free India campaign: A plan to eliminate tuberculosis in India by 2025.

Telemental Health Assistance and Networking Across States (Tele-MANAS): Enables video consultations with mental health specialists.

The TB Free India campaign: A plan to eliminate tuberculosis by 2025.

Truenat MTB-RIF: A novel battery-operated, hand-held point-of-care diagnostic device.

Unicorns: Privately owned tech start-ups with a valuation exceeding US\$1bn.

Unified Payments Interface (UPI): An instant payment *system* developed in India by the National Payments Corporation of India (NPCI).

WhatsApp: End-to-end encryption that is more secure than texting and other messaging apps.