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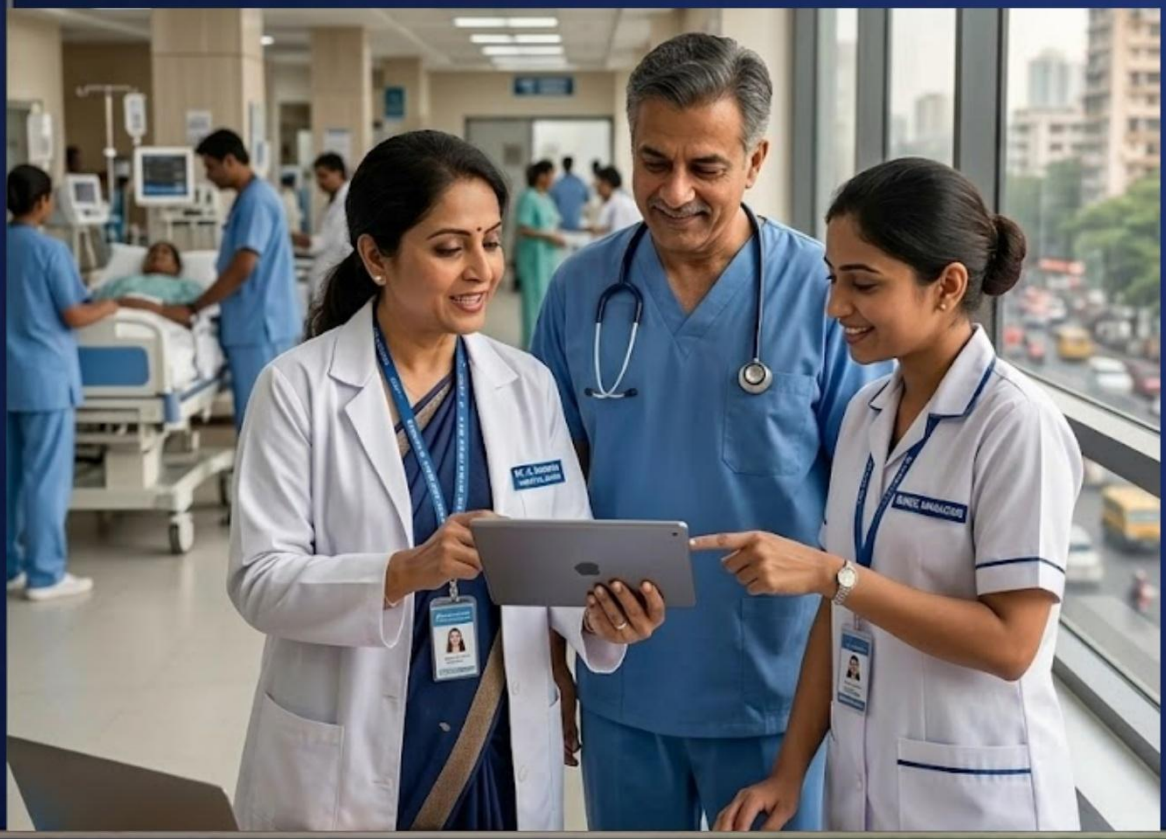
HEALTHCARE MANAGEMENT IN THE INDIAN CONTEXT

Challenges and Innovations

Editors:
Dr. Dhananjay Mankar
Prof. M. Mariappan
Prof. Sandeep Bhanot



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Healthcare Management in the Indian Context: Challenges and Innovations

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PREFACE

Healthcare is one of the most critical pillars of national development and human well-being. As India advances toward becoming a global economic and technological leader, its healthcare system is simultaneously undergoing an unprecedented transformation. Rapid urbanization, demographic transition, changing disease patterns, technological advancements, growing patient expectations, and evolving public health priorities have fundamentally reshaped the healthcare landscape. Alongside these opportunities, the country continues to face persistent challenges such as unequal access to healthcare, workforce shortages, rising healthcare costs, quality and patient safety concerns, fragmented healthcare delivery, digital transformation barriers, and the increasing burden of both communicable and non-communicable diseases. These realities necessitate innovative, evidence-based, and context-specific approaches to healthcare management.

The edited volume, Healthcare Management in the Indian Context: Challenges and Innovations, has been conceived with the objective of presenting a comprehensive understanding of India's unique healthcare ecosystem and the managerial approaches required to strengthen it. Unlike many international texts that discuss healthcare management from a generalized perspective, this book specifically focuses on the complexities, diversity, and realities of the Indian healthcare system. It highlights the interrelationship between policy, governance, administration, technology, finance, public health, quality management, legal frameworks, ethics, leadership, and innovation within the Indian context.

Healthcare management today extends far beyond hospital administration. Modern healthcare managers are expected to lead multidisciplinary teams, optimize limited resources, ensure patient safety, maintain quality standards, implement digital health solutions, comply with regulatory requirements, respond to public health emergencies, and foster organizational resilience. The emergence of Artificial Intelligence, Health Information Systems, telemedicine, digital health records, predictive analytics, precision medicine, and value-based healthcare has further expanded the scope of healthcare management. At the same time, India's commitment to Universal Health Coverage, Ayushman Bharat, National Health Mission, Digital Health Mission, and Sustainable Development Goals has created new opportunities for strengthening health systems through effective governance and innovative management practices.

This book brings together scholarly contributions from distinguished academicians, researchers, healthcare administrators, clinicians, public health professionals, policymakers, and industry experts from diverse institutions across India. Each chapter has been carefully selected to provide readers with theoretical foundations, contemporary evidence, practical experiences, case studies, and innovative solutions addressing the challenges faced by healthcare organizations in India. The contributors have examined healthcare management from multiple perspectives, offering balanced discussions on policy, operational excellence, healthcare financing, quality improvement, accreditation, hospital information systems, healthcare leadership, legal and ethical dimensions, supply chain management, human resource management, disaster preparedness, patient-centred care, digital transformation, and emerging trends shaping the future of healthcare.

One of the distinctive strengths of this volume lies in its emphasis on contextual relevance. India's healthcare delivery system is characterized by immense diversity, ranging from advanced tertiary care hospitals equipped with cutting-edge technologies to resource-constrained primary healthcare facilities serving remote rural and tribal populations. The coexistence of public and private healthcare providers, traditional systems of medicine alongside modern medicine, varied socio-economic determinants of health, and cultural diversity makes healthcare management in India uniquely complex. This book acknowledges these realities and presents practical approaches that are adaptable to Indian healthcare institutions across different settings.

Innovation has become an indispensable driver of healthcare improvement. The COVID-19 pandemic demonstrated the importance of resilient health systems, digital healthcare delivery, integrated disease surveillance, emergency preparedness, and collaborative governance. Since then, innovations in telehealth, artificial intelligence, electronic health records, wearable technologies, healthcare analytics, robotics, and digital public health have accelerated significantly. This volume explores how such innovations can be effectively integrated into healthcare organizations while ensuring quality, equity, affordability, ethical governance, and patient-centred care.

The book is intended to serve as a valuable academic and professional resource for undergraduate and postgraduate students of Hospital Administration, Health Management, Public Health, Healthcare Quality Management, Health Informatics, Nursing Administration, Medical Administration, and Business

Administration with healthcare specialization. It will also benefit hospital administrators, healthcare executives, clinicians, policymakers, researchers, faculty members, healthcare consultants, and professionals involved in planning, managing, and evaluating healthcare services. The diverse themes covered in this volume make it equally useful for multidisciplinary teaching, research, policy formulation, and professional practice.

As editors, we firmly believe that healthcare management is not merely about managing hospitals or healthcare institutions; it is about strengthening health systems that improve people's lives. Effective healthcare management requires compassionate leadership, ethical decision-making, evidence-based policies, efficient utilization of resources, technological adaptability, and an unwavering commitment to quality and equity. Through this book, we hope to inspire future healthcare leaders to embrace innovation while remaining grounded in the principles of accessibility, accountability, inclusiveness, and social justice that are fundamental to India's healthcare vision.

We express our sincere gratitude to all the contributing authors for sharing their expertise and scholarly insights. Their commitment, intellectual rigor, and timely contributions have significantly enriched this volume. We also acknowledge the reviewers, editorial team, and publishing staff whose constructive suggestions and dedicated efforts have helped shape the manuscript into its present form. We are equally grateful to our colleagues, institutions, students, healthcare professionals, and researchers whose continuous engagement with healthcare challenges has inspired many of the themes discussed in this book.

We hope that Healthcare Management in the Indian Context: Challenges and Innovations stimulate critical thinking, promotes interdisciplinary collaboration, encourages evidence-based healthcare management, and contributes meaningfully to strengthening healthcare systems in India. It is our sincere aspiration that this volume will serve not only as an academic reference but also as a practical guide for healthcare professionals, educators, researchers, and policymakers committed to building a more equitable, efficient, innovative, and resilient healthcare system for the nation.

- Editors

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FLORENCE NIGHTINGALE:
A PIONEER OF INFECTION CONTROL AND QUALITY OF CARE

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Abstract

Florence Nightingale (1820–1910) is widely regarded as the founder of modern nursing and one of the earliest pioneers of infection control and healthcare quality. Her work during the Crimean War transformed the understanding of sanitation, hygiene, and patient care at a time when germ theory had not yet been established. Nightingale's reforms at Scutari Hospital, emphasizing cleanliness, handwashing, proper waste disposal, ventilation, and improved nutrition, reduced mortality dramatically from 42% to 2%. Beyond infection prevention, she championed dignity, compassion, and individualized care, laying the foundation for modern patient-centered healthcare. This review critically evaluates existing literature on Nightingale's contributions, identifies key findings and controversies, and highlights persisting knowledge gaps. It also examines the enduring relevance of her principles in contemporary global health, particularly in the context of hospital-acquired infections, antimicrobial resistance, and the COVID-19 pandemic. Furthermore, the paper explores her pioneering use of statistical data visualization as an early form of health informatics, demonstrating how empirical evidence can drive public health reform. It also discusses the global diffusion of her nursing education model and its influence on professionalization, gender equity, and ethical leadership in healthcare. Finally, by connecting Nightingale's environmental principles to modern sustainability and healthcare design, this study underscores her continued relevance as a model for integrating science, compassion, and social responsibility in 21st-century healthcare systems.

Keywords: Florence Nightingale, Infection Control, Sanitation, Nursing, Quality of Care, COVID-19, Hospital Reform.

Introduction

The mid-nineteenth century marked a defining era in the transformation of healthcare, profoundly influenced by industrialization, urbanization, and the social upheavals of war. Rapid urban growth and overcrowded living conditions created fertile ground for infectious diseases such as cholera, typhoid, dysentery, and tuberculosis. Hospitals, instead of being places of healing, often became epicenters of contagion. They were poorly ventilated, inadequately sanitized, and staffed by untrained attendants rather than professional nurses. Medical science at

the time lacked an understanding of microorganisms, and infection control practices were virtually non-existent. Consequently, preventable deaths were widespread, reflecting both scientific limitations and systemic neglect within healthcare institutions.

The Crimean War (1853-1856) brought these failures into sharp relief. British soldiers were not only wounded on the battlefield but also subjected to appalling sanitary conditions that led to catastrophic mortality rates. The war, fought in harsh climates and remote territories, revealed the unpreparedness of the British military medical system, where logistical inefficiency and unhygienic hospitals proved deadlier than combat itself. Against this backdrop, Florence Nightingale emerged as a reformer whose work redefined the foundations of modern healthcare.

In 1854, Nightingale was appointed by the British War Office to lead a team of nurses to the Barrack Hospital at Scutari, located in present-day Istanbul. Upon arrival, she found chaotic and deplorable conditions, wards overcrowded with wounded soldiers, water contaminated by sewage, and vermin infesting bedding and food supplies. Administrative disarray compounded the crisis, with minimal record-keeping and inadequate medical supplies. Undeterred, Nightingale applied a systematic and empirical approach to restoring order. She implemented rigorous sanitary reforms: ensuring proper ventilation, waste removal, clean bedding, handwashing, and nutritious diets. Her collaboration with the Sanitary Commission to improve drainage and water supply further enhanced living conditions. Within months, mortality rates dropped dramatically from approximately 42% to just 2%, offering one of the earliest and most compelling demonstrations of environmental determinants of health long before the advent of germ theory.

Nightingale's influence extended far beyond the immediate improvements at Scutari. Her meticulous collection of data, coupled with her pioneering use of statistical visualization, introduced a new paradigm of evidence-based healthcare. Through her innovative "coxcomb" or polar area diagrams, she translated complex mortality statistics into visually persuasive narratives that communicated the magnitude of preventable deaths to policymakers and the public alike. This empirical rigor lent credibility to her advocacy and directly contributed to the formation of the Royal Commission on the Health of the Army (1857)**.** The Commission's recommendations led to sweeping reforms in sanitation, nutrition, and hospital design, permanently altering the standards of military and public health administration.

Moreover, Nightingale's intellectual legacy transcended the confines of war medicine. Her seminal works, Notes on Nursing (1859) and Notes on Hospitals (1863), articulated a holistic philosophy of care that emphasized the interplay between environment, mind, and body. She argued that recovery depended not only on medical treatment but also on the cleanliness, ventilation, light, diet, and emotional well-being of patients. This integration of environmental

science with moral and psychological dimensions of care reflected an advanced understanding of health as a multidimensional phenomenon.

Equally transformative was her contribution to professional nursing education. Through the establishment of the Nightingale Training School for Nurses at St. Thomas' Hospital in 1860, she institutionalized structured nursing curricula that combined theoretical instruction with practical bedside experience. Her emphasis on discipline, ethics, and observation redefined nursing as a respected, skilled profession rather than domestic service. Graduates from her program went on to establish nursing schools and hospitals worldwide, disseminating her principles across Europe, North America, and the British colonies.

Ultimately, Florence Nightingale's work bridged the humanitarian compassion of caregiving with the emerging scientific rationality of public health. By linking cleanliness, statistical reasoning, and patient-centered ethics, she laid the intellectual and institutional foundations of modern healthcare systems. Her reforms not only reduced mortality but also transformed the moral and professional identity of nursing, making it both a science and an art. The legacy of her work continues to inform contemporary approaches to infection prevention, quality assurance, and healthcare management, reaffirming her status as a visionary whose insights remain relevant to the challenges of global health in the twenty-first century.

The Crimean War: A Catalyst for Reform

The Crimean War (1853-1856) was not only a defining geopolitical conflict between the Russian Empire and an alliance of Britain, France, and the Ottoman Empire but also a watershed moment in the history of healthcare reform. Beyond its military outcomes, the war exposed the severe deficiencies of nineteenth-century medical services and catalyzed transformative changes in public health, hospital management, and nursing practice. British field hospitals were characterized by overcrowding, inadequate ventilation, contaminated water supplies, and poor sanitation. The absence of systematic nursing care and minimal medical oversight created conditions in which infectious diseases, particularly cholera, typhus, dysentery, and typhoid fever, spread unchecked. As a result, mortality rates among British soldiers soared, with far more deaths occurring from preventable infections than from battle wounds.

Amid this crisis, Florence Nightingale emerged as a pioneering reformer whose interventions at Scutari (modern-day Üsküdar, Istanbul) became a turning point in both military and civilian healthcare. Appointed in 1854 by the British War Office to supervise nursing care for wounded soldiers at the Barrack Hospital, Nightingale and her team of 38 volunteer nurses encountered appalling conditions upon arrival. The hospital, a converted military barracks, was built directly over a cesspool that contaminated the water supply. The wards were overcrowded, dark, and poorly ventilated; sewage and refuse accumulated beneath the floors; bedding was rarely

washed; and patients were often left in filth and neglect. Medical staff were overwhelmed, supplies were insufficient, and record-keeping was nearly non-existent.

Confronted with this humanitarian catastrophe, Nightingale's approach combined moral conviction, organizational skill, and a deep understanding of environmental health. She and her team immediately introduced basic hygiene measures, washing patients, cleaning wards, laundering linens, and ensuring proper ventilation. She insisted that hospital corridors be cleared of waste, that fresh air circulate freely, and that contaminated bedding be replaced regularly. Recognizing the structural causes of illness, Nightingale collaborated closely with the Sanitary Commission, which was dispatched to Scutari in 1855. Together, they undertook large-scale engineering works to repair the hospital's drainage system, improve water supply, and eliminate sources of contamination.

The results were dramatic. Within months of these reforms, mortality rates dropped sharply, from approximately 42% to around 2%. Although later historians have noted that some of this decline coincided with seasonal changes and logistical improvements, the impact of Nightingale's environmental interventions remains undeniable. She transformed Scutari from a site of despair and disease into a model of disciplined, compassionate, and effective medical care. More importantly, she demonstrated, decades before the discovery of germ theory, that the hospital environment itself was a determinant of health outcomes.

Nightingale's achievements during the Crimean War extended beyond immediate clinical improvements. She meticulously collected and analyzed data on mortality, sanitation, and disease, recognizing that effective reform required empirical evidence. Her statistical reports, later synthesized into striking visual representations such as the "coxcomb" diagrams, revealed that preventable diseases were responsible for the majority of deaths. These visualizations not only made the data accessible but also powerful in influencing political and public opinion. Her findings, presented to the British government after the war, provided irrefutable proof that poor sanitation and inadequate hospital design were lethal, thereby galvanizing large-scale reform.

In 1857, her evidence informed the establishment of the Royal Commission on the Health of the Army**,** which led to sweeping changes in military healthcare policy. The Commission's recommendations, grounded in Nightingale's data, included the introduction of improved drainage, ventilation, nutrition, and hygiene standards across all British military hospitals. These reforms extended to barracks and civilian institutions, laying the groundwork for modern public health and sanitary engineering in Britain.

The Crimean War thus served as both a crucible and a catalyst for Nightingale's lifelong mission. Her wartime experiences forged her conviction that healthcare reform must be systemic, data-driven, and rooted in prevention rather than reaction. The lessons of Scutari became the foundation for her later writings, including Notes on Matters Affecting the Health, Efficiency,

and Hospital Administration of the British Army (1857) and Notes on Hospitals (1863), where she articulated the principles of environmental hygiene and hospital design that would shape global healthcare for generations.

Ultimately, the Crimean War transformed Nightingale from a compassionate nurse into a pioneering architect of modern healthcare systems. It demonstrated that effective nursing extended beyond bedside care to encompass the organization of environments, the management of institutions, and the collection and interpretation of data for policy reform. The war not only exposed the failings of nineteenth-century medicine but also illuminated the transformative power of informed, humane, and scientifically grounded care, a legacy that continues to inform public health and hospital practice today.

Table 1: Excerpt from Nightingale's Crimean War Death-Rate Data (Oct 1854–Apr 1855)

Regiment	Admitted to Hospital (a)	Died in Crimea (b)	Sent to Scutari (c)	Died at Scutari (d)	Percent (c/a)	Died at Scutari [%] (d/c)
30th	934	108	308	93	33%	30%
55th	1,462	61	265	96	18%	36%

These figures illustrate the high disease burden and the transformative impact of Nightingale's reforms on hospital mortality.

Selimiye Barracks Hospital and the Theoretical Foundations of Nursing

During the Crimean War, the Selimiye Barracks in Üsküdar (Scutari) were converted into a British military hospital. When Nightingale and her team arrived in November 1854, they encountered overcrowded wards, contaminated water, sewage flowing beneath beds, and rampant vermin infestation. Mortality from disease was extreme.

Nightingale implemented a series of crucial environmental and organizational reforms, including handwashing, regular ward cleaning, improved ventilation, systematic nursing rounds, and better nutrition. Under her leadership, the hospital environment was transformed into one that prioritized hygiene, structure, and comfort.

These practical interventions became the foundation for her later theoretical framework. After returning to England, Nightingale published Notes on Matters Affecting the Health, Efficiency and Hospital Administration of the British Army (1857) and Notes on Nursing: What It Is and What It Is Not (1859). Drawing upon her wartime experience, these texts outlined a coherent nursing theory centered on sanitation, environmental control, trained nursing, systematic observation, and hospital design.

Her work at Selimiye Barracks symbolized the transition from unstructured, emergency nursing to a formal discipline grounded in science, ethics, and management, illustrating that nursing

involves organizing environments, training professionals, collecting and interpreting data, and designing care systems.

Florence Nightingale and the Foundations of Infection Control

Nightingale's Environmental Theory emphasized that "pure air, pure water, efficient drainage, cleanliness, and light" are essential for recovery. Without knowledge of germ theory, she intuitively recognized the role of environmental conditions and personal hygiene in disease prevention.

At Scutari, she implemented strict hygiene protocols, handwashing, ward reorganization, and waste management, while ensuring access to clean water, fresh air, and nutritious food. These practices reduced mortality from 42% to as low as 2%.

Equally revolutionary was her application of statistical analysis. Her polar area (coxcomb) diagrams visually demonstrated that preventable diseases killed far more soldiers than battle injuries. This evidence-based advocacy influenced policymakers and the public, promoting investment in sanitation and health infrastructure.

Although later historians acknowledged additional factors such as seasonal variations and engineering improvements, Nightingale's systematic application of environmental health principles was the key driver of change. Her work bridged humanitarian care with scientific reasoning, laying the foundation for modern infection control and public health nursing.

Evidence-Based Nursing and Nightingale's Legacy

Nightingale's work prefigured modern Evidence-Based Nursing (EBN). As defined by Scott and McSherry (2009), EBN integrates research evidence, clinical expertise, patient values, and contextual understanding to enhance care quality. This aligns closely with Nightingale's philosophy that nursing decisions should derive from observation, analysis, and measurable outcomes rather than intuition.

EBN follows a cyclical process: identifying problems, evaluating evidence, applying interventions, and assessing results, an approach parallel to Nightingale's wartime methodology at Scutari. Her evidence-driven reforms anticipated today's clinical governance practices, where data and audit are central to patient safety and quality improvement.

Nightingale viewed nursing as both empirical and humanistic. Like Scott and McSherry's argument, she balanced empirical rigor with compassion, recognizing qualitative evidence such as patient experience as vital. Modern frameworks like the PARIHS model (Promoting Action on Research Implementation in Health Services) similarly stress the interplay of evidence, context, and facilitation, concepts Nightingale intuitively applied.

Thus, Nightingale can be regarded as the intellectual precursor to the evidence-based movement. Her insistence on data collection, evaluation, and patient-centered reasoning established the foundation for EBN and continues to guide nursing education and practice.

Contribution to Quality of Care and Nursing Professionalization

Florence Nightingale extended her impact beyond infection control, redefining hospitals as centers of healing grounded in compassion, dignity, and holistic care. She recognized the emotional and psychological dimensions of recovery, emphasizing observation, hygiene, nutrition, and individualized attention in her seminal work Notes on Nursing (1859).

In 1860, she founded the Nightingale Training School for Nurses at St. Thomas' Hospital in London. Combining classroom instruction with clinical practice, the school professionalized nursing, elevating it to a respected, science-based vocation. Graduates disseminated her teachings worldwide, embedding her principles of hygiene, accountability, and patient dignity across healthcare systems.

Her publication Notes on Hospitals (1863) expanded her influence to hospital architecture and management, advocating designs emphasizing natural light, ventilation, and sanitation, principles that shaped modern hospital construction. Through these efforts, Nightingale demonstrated that infection control, environmental health, and compassionate care are inseparable elements of healthcare quality.

Legacy, Critiques, and Contemporary Relevance

Florence Nightingale's legacy continues to shape modern healthcare, public health policy, and nursing education. Her data-driven approach laid the groundwork for modern epidemiology, infection surveillance, and health informatics. She linked healthcare outcomes with social determinants such as housing, sanitation, and nutrition, concepts foundational to today's global health frameworks.

However, critical perspectives offer nuance. Feminist and postcolonial scholars argue that Nightingale's legacy sometimes overshadows the contributions of local and indigenous caregivers. Others point out that her environmentalist approach, rooted in miasma theory, initially resisted germ theory, revealing the tension between her practical success and incomplete scientific basis.

Despite these debates, her principles remain profoundly relevant. During the COVID-19 pandemic, her emphasis on hand hygiene, ventilation, and infection surveillance proved timeless. Her holistic, patient-centered philosophy resonates with modern healthcare initiatives such as Brazil's National Humanization Policy (2003), which prioritizes dignity, empathy, and quality of care.

Her preventive focus also informs contemporary challenges such as antimicrobial resistance and hospital-acquired infections, emphasizing sanitation and stewardship. Additionally, Nightingale's advocacy for natural light, green spaces, and ventilation continues to influence sustainable hospital design. Her interdisciplinary approach, bridging medicine, environment, and

social justice, remains a guiding model for integrated global health strategies that unite disease prevention with human well-being.

Discussion

A critical evaluation of the literature reveals that Florence Nightingale's reforms represent one of the earliest and most compelling examples of evidence-based healthcare improvement. Her systematic integration of infection control practices with compassionate, patient-centered care established a holistic model that continues to inspire health systems today. Equally significant is her pioneering use of statistical visualization, her "coxcomb" diagrams, which marked the beginning of health informatics by transforming complex mortality data into persuasive tools for policy advocacy and public understanding.

Despite these strengths, the literature also presents notable limitations. Much of the existing scholarship relies heavily on Nightingale's own reports, with limited quantitative reanalysis of primary hospital records from the Crimean War. Comparative institutional studies are scarce, and historiography often swings between excessive glorification and overly critical revisionism, leaving room for a more balanced and interdisciplinary understanding of her legacy. Furthermore, the contributions of lesser-known contemporaries, including local nurses and auxiliaries, remain underexplored, particularly within colonial and postcolonial contexts.

Another critical gap lies in the underdeveloped connection between Nightingale's environmental principles and contemporary sustainability or healthcare architecture, a field of growing global relevance. Modern health systems increasingly recognize the importance of environmental design for infection control, yet few studies systematically trace this lineage back to Nightingale's foundational ideas.

Future scholarship can bridge these gaps by applying modern epidemiological tools to re-examine her mortality data, exploring how her nursing model diffused globally beyond Europe, and assessing the measurable, long-term effects of her curricula on patient outcomes. Interdisciplinary research that combines historical, statistical, and sociological analysis will provide deeper insight into her enduring influence. Comparative studies that situate her theories within the framework of contemporary infection control policies, digital health tools, and global equity initiatives could also contextualize her philosophy within the dynamic landscape of 21st-century healthcare.

Conclusion

Florence Nightingale was a transformative figure who revolutionized infection control and redefined the quality of care during the nineteenth century and beyond. Her interventions at Scutari demonstrated how sanitation, nutrition, and organized nursing could drastically reduce preventable deaths, proving that environmental reform and systematic care were essential to survival. By professionalizing nursing and embedding compassion, accountability, and evidence-

based practice into healthcare, she elevated nursing from a domestic task to a respected and scientific discipline.

Her influence extended beyond hospital wards to public health reform, healthcare design, and global nursing education. While debates persist regarding the precise attribution of mortality reductions and the scientific completeness of her theories, her overarching impact remains indisputable. Nightingale's principles continue to underpin modern infection prevention, quality-of-care standards, and global pandemic response strategies.

Crucially, her legacy reminds us that infection control and compassionate care are not separate domains but complementary elements of effective healthcare. In confronting modern challenges such as antimicrobial resistance, emerging pandemics, and resource scarcity, her emphasis on hygiene, environmental design, patient dignity, and data-driven reform remains profoundly relevant.

Her advocacy for data transparency and accountability laid the foundation for public health reporting and outcome monitoring, reinforcing the ethical duty to measure and act upon preventable harm. Furthermore, her integrative approach, uniting clinicians, administrators, and policymakers, anticipated the collaborative frameworks that define contemporary healthcare governance. Above all, her philosophy offers a vital counterbalance to technological medicine, underscoring that empathy, ethics, and social justice are as essential to healing as scientific innovation.

In essence, Florence Nightingale's vision bridges the past and future of healthcare. Her enduring principles of cleanliness, compassion, and evidence continue to guide modern practice, ensuring that her work remains a living blueprint for safer, fairer, and more humane healthcare systems worldwide.

Future Directions

The enduring relevance of Nightingale's philosophy calls for its renewed application to contemporary global health challenges. In an era defined by emerging infectious diseases, rapid technological change, and environmental degradation, integrating her principles with modern science is crucial for advancing infection control and quality care.

First, digital health innovations, such as artificial intelligence, predictive modeling, and real-time infection surveillance, can extend Nightingale's vision of evidence-based practice. These tools allow for continuous monitoring, rapid response, and informed decision-making, reflecting her pioneering belief in the power of data to improve public health outcomes.

Second, environmental sustainability has re-emerged as a cornerstone of infection prevention. Climate change, pollution, and urban crowding exacerbate disease transmission, reaffirming the importance of clean air, water, and sanitation. Healthcare infrastructure must therefore integrate

green architecture, effective ventilation, and waste management systems to ensure safe and sustainable care environments, a modern embodiment of Nightingale's environmental ideals.

Third, nursing education and leadership must continue evolving in response to global health demands. Updated curricula should emphasize infection prevention, epidemiology, ethics, and leadership to prepare nurses as agents of policy change and system resilience, continuing Nightingale's professional and humanitarian mission.

Finally, equity and cultural sensitivity must anchor future infection control strategies. Community-based and collaborative approaches are vital for ensuring that Nightingale's principles of compassion, dignity, and inclusivity are upheld in diverse settings worldwide.

In conclusion, applying Nightingale's philosophy today means blending compassion with technology, sustainability, and global equity. Her timeless assertion that "the very first requirement in a hospital is that it should do the sick no harm" continues to serve as a moral and practical compass for 21st-century healthcare systems, reminding us that the pursuit of safety, empathy, and justice remains the heart of healing.

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EMBEDDING ESG IN INDIAN HOSPITALS: PATHWAYS TO SUSTAINABLE AND RESILIENT HEALTHCARE

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Abstract

The Indian healthcare industry is at that juncture where hospitals need to harmonize clinical excellence with environmental stewardship, social obligation, and good governance. With hospitals among the most resource-consuming institutions, their operation accounts for considerable carbon footprint, biomedical and plastic waste generation, and water and energy consumption. Integration of ESG principles into the system allows for a formal way in which hospitals can meet such demands and work toward increasing resilience and accountability. Most of the aspects of ESG frameworks applied in Indian hospitals are discussed in this chapter in relation to the promotion of sustainability. Green building planning, green energy generation, water conservation, biomedical waste management, and circular economy measures are the major areas of the environmental aspect discussed in this chapter. The social element focuses on the fair accessibility of care, well-being of workers, patient protection, and involvement of the community as integral elements of long-term delivery of care. The governance element lays immense emphasis on moral leadership, transparency, adherence to the national acts like Bio-Medical Waste Management Rules, and the accrediting standards such as JCI and NABH. The chapter reviews the advantages and disadvantages of adopting ESG in healthcare through policy models, Indian practices, and global best practices. It enumerates the new finance system, digitalization, and leadership commitment as major drivers toward transitioning to green hospitals. Long-standing concerns include lack of awareness, funding gaps, and disparities in execution between rural and urban areas. The chapter performs an exceptional job of aligning key benefits resulting from ESG implementation with overall public health. Reducing environmental footprints and upholding ethical and patient-focused practices can be accomplished to enhance health equity, strengthen public confidence in the sector, and make communities more climate resilient. This chapter positions ESG as a strategic path to the future of Indian healthcare through convergence among hospital administration, policy drivers, and public health considerations. To ensure that Indian hospitals do not only provide for the care of the patient but also take care of the environment and society, it concludes with a roadmap for the administrator, legislator, and practitioner to implement ESG at the hospital strategy level.

Keywords: ESG, Green Hospitals, Sustainability, Environmental Health, Governance, Public Health in India, And ESG in Healthcare.

Introduction

Healthcare systems worldwide face increasing demands to provide high-quality, equal access to care, while minimizing environmental impact and assuring sustainability. Hospitals are inherently contradictions to health; while they exist to safeguard and restore health, their operations often negatively impact the environment through energy use, water usage, and biomedical waste produced. The health sector is responsible for approximately 4–5% of most greenhouse gas emissions worldwide, and India, given its extensive network of both public and private hospitals, has a substantial contribution to that share [5].

While the country is rapidly moving toward Universal Health Coverage through programs such as "Ayushman Bharat", the question no longer remains if sustainability principles should be adopted in healthcare, but rather how quickly and effectively these can be embedded into policy and practice.

The ESG framework offers a formal and strategic approach for this integration. While it has been created for corporate finance and investment decisions, the ESG principles have entered the health sector as an indispensable tool for the advancement of institutional responsibility. This framework moves beyond short-term approaches to compliance or philanthropic CSR, embedding sustainability within the core governance, operations, and culture of health organizations. ESG enables hospitals to examine not only their environmental efficiency but also their social responsibility and ethical integrity-thus defining "health performance" in a multidimensional way.

In India, perhaps nowhere is the relevance of ESG more pressing than in healthcare. The country's rapid population growth, urbanization, and rising health demands are driving unprecedented growth in hospital infrastructure. But this brings with it escalating resource use, waste, and inequity. The Indian healthcare system produces over 700 tons of biomedical waste daily [6], and faces critical challenges in segregation, treatment, and safe disposal. At the same time, hospitals must address staff wellbeing, patient safety, and equitable access-all central to the ESG agenda.

Embedding ESG principles in Indian hospitals offers a transformational opportunity whereby healthcare growth is aligned to climate action, social justice, and ethical governance. This chapter reflects on how ESG might redefine hospital sustainability in the Indian context, focusing on the environmental, social, and governance dimensions; relevant policy frameworks; implementation barriers; and future pathways for creating hospitals as vehicles not only of healing but also of planetary and social wellbeing.

Understanding ESG in Healthcare

The ESG framework offers the management of sustainability, accountability, and the creation of value in the long term in a structured manner to hospitals. ESG moved from investor guidance

into mainstream organizational strategy during the early 2000s and accelerated after the 2008 financial crisis. Its relevance in healthcare crystallized further during the COVID-19 pandemic, when supply-chain fragility, workforce stress, and governance lapses highlighted systemic risk [12, 16, 19]. Unlike traditional Corporate Social Responsibility (CSR) approaches that focus on philanthropy, ESG integrates environmental performance, social responsibility, and governance integrity into the core operations and strategic decision-making of the hospital [12].

The environmental component of ESG largely encompasses direct operational impacts like energy, water, waste, and procurement issues for hospitals, while the social pillar includes patient safety, staff well-being, equitable access, and community engagement. Governance covers the areas of ethical leadership, transparency, regulatory compliance, and risk management [7, 9, 18]. These dimensions put together create a holistic performance lens with which clinical objectives align with planetary and social goals, placing long-term resilience at the center of institutional strategy.

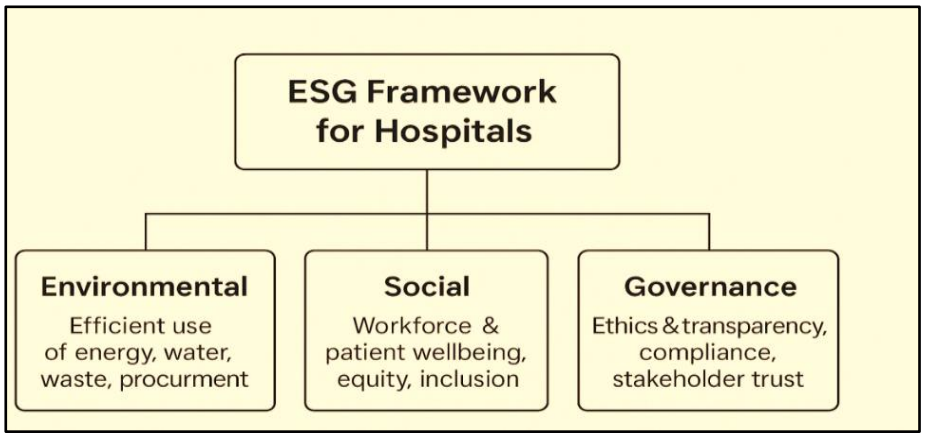
Measuring ESG in a hospital setting requires pragmatic, sector-specific indicators. International frameworks such as the Global Reporting Initiative (GRI), the Sustainability Accounting Standards Board (SASB), and the Task Force on Climate-related Financial Disclosures (TCFD) provide useful templates [12]. In India, SEBI's Business Responsibility and Sustainability Report (BRSR) offers a national disclosure baseline that large healthcare groups have started to adopt on a voluntary basis [3]. Practical hospital KPIs include energy and water intensity per occupied bed, biomedical waste generated per case mix, staff turnover and safety incidents, patient satisfaction indices, and governance indicators such as audit outcomes and frequency of ethics-committee reviews [4, 7, 18].

Digital tools and integration with HIS make measurement feasible. IoT sensors, building-management systems, and ESG dashboards enable near-real-time tracking of consumption patterns and incident reporting. Standardized data collection supports benchmarking across facilities and enables access to green financing, banks and multilateral lenders increasingly require evidence of ESG performance for concessional loans or sustainability-linked finance products [11, 15].

Operationalizing ESG also requires cultural change. Leadership commitment, cross-departmental ownership, and capacity building are paramount. Each hospital should have a dedicated sustainability or compliance officer who can translate strategic targets into operational plans with continuous improvement. Training programs must integrate infection control, waste segregation, occupational health, and resilience planning with sustainability objectives.

In all, ESG redefines hospital performance beyond narrow clinical metrics to include environmental limits, social equity, and governance quality. The translation of global frameworks into local, measurable actions and the fostering of organizational culture change

allow Indian hospitals to enhance their resilience, improve patient trust, attract sustainable finance, and provide care that is ethically and environmentally responsible [5, 7, 9, 10].



The Environmental Dimension – Greening Indian Hospitals

Hospitals are among the most energy and resource-intensive facilities in the built environment, continuously consuming electricity for lighting, ventilation, sterilization, and digital systems. Besides this, they generate huge amounts of biomedical and plastic waste daily. The Central Pollution Control Board estimates that India generates over 700 tons of biomedical waste daily, while tertiary hospitals use around 350–450 liters of water per bed per day. As the healthcare sector grows under "Ayushman Bharat", this footprint is bound to increase sharply unless sustainability is made a design and operational priority.

The environmental pillar of ESG concerns the management of energy, water, waste, and procurement responsibly to reduce this ecological footprint. Energy efficiency is the most immediate intervention. Many hospitals, such as AIIMS Delhi and Apollo Chennai, have adopted solar rooftops, LED retrofits, and high-efficiency HVAC systems that reduce electricity use by 15–25% [1, 9]. Incorporating daylight, reflective roofing, and automated sensors further lowers demand. The use of renewable energy along with options for Energy Service Company financing models enables hospitals to invest without heavy upfront costs [15].

Water conservation is another priority. With the help of low-flow fixtures, rainwater harvesting, and on-site sewage treatment plants, substantial savings are possible [4, 17]. A few hospitals in Gujarat and Karnataka have already established zero-liquid-discharge systems, reusing treated water for landscaping and cooling. Wastewater management directly enhances the health of the community through decreasing contamination of local water bodies a very important link between environmental and public health outcomes [8,17,21].

Management of biomedical and plastic waste remains a perpetual problem. Although the regulations are clear under the Bio-Medical Waste Management Rules, 2016 as amended in 2022 [7], compliance with segregation and treatment remains erratic [6, 20]. Color-coded bins, bar-coding systems, and partnerships with the CBWTFs are now mandatory under the realm of good

practice. Advanced technologies like autoclaving, plasma pyrolysis, and microwave disinfection present safer and low-emission alternatives to incineration [6, 20].

Green building design forms the very foundation of long-term sustainability. The Indian Green Building Council and GRIHA certification basically encourage efficient architecture, natural ventilation, and the use of sustainable materials for hospitals. For instance, Fortis Gurgaon and AIIMS Jodhpur are resource-efficient hospital designs that reduce energy demand and enhance indoor air quality [1, 4, 9]. Healthcare organizations must establish baseline data and monitor energy and water usage, waste production, procurement of sustainable materials, and emissions [23].

The environmental aspect of ESG, then, is much more than about compliance. It establishes a culture of efficiency and stewardship that reduces operating costs, mitigates climate risks, and protects community health. Greening hospitals is not peripheral-it is core to building a resilient healthcare system that heals without harming the planet [5, 11, 16, 18].

The Social Dimension – Equity, Wellbeing, and Community Engagement

The "S" in ESG addresses the people who sustain and are served by healthcare institutions. Hospitals are social ecosystems are employers, caregivers, educators, and community partners. For India, where healthcare access and workforce conditions vary widely, embedding social sustainability is vital to achieving equitable and resilient healthcare delivery [9, 10]**.**

Workforce wellbeing is the cornerstone of the social dimension. Healthcare workers operate in stressful environments with exposure to infection and emotional fatigue. Hospitals implementing structured occupational health and safety (OHS) programs, regular training, and mental-health counseling report higher retention and morale [9, 18, 19]**.** For example, AIIMS Delhi and CMC Vellore introduced stress-management cells during the COVID-19 pandemic, reducing absenteeism and burnout [9, 19]**.** Equal opportunity and fair pay must complement safety efforts. Women form roughly 80% of India's healthcare workforce yet remain underrepresented in

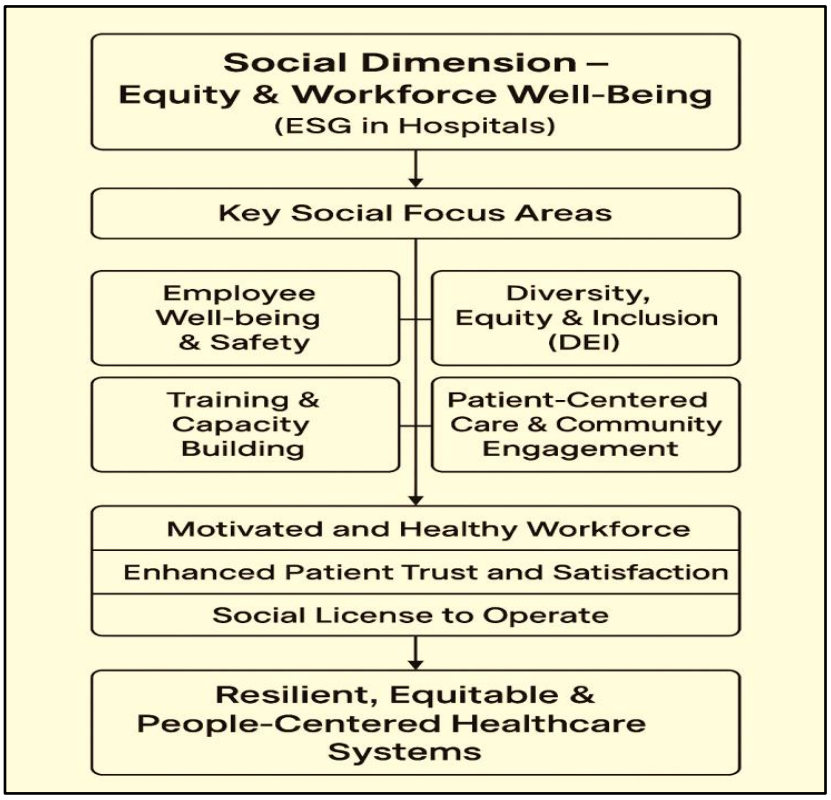
leadership roles; ESG frameworks push institutions to monitor gender ratios and leadership diversity [9, 18].

Patient-centered care defines social accountability to service users. NABH accreditation requires respect for patient rights, transparent consent, data privacy, and grievance management systems [18]. Hospitals like Max Healthcare and Apollo have installed digital feedback kiosks and online grievance dashboards to enhance transparency [1, 2]. Accessibility ramps, tactile flooring, and signage in local languages ensure dignity for people with disabilities and linguistic minorities [18].

Community engagement extends a hospital's role beyond its physical walls. ESG-oriented hospitals collaborate with local governments and NGOs on immunization drives, maternal health, and lifestyle-disease prevention [8, 9]. Such partnerships strengthen trust and directly contribute to India's Universal Health Coverage (UHC) goals [9, 10]. Healthcare organizations should ensure workforce wellbeing, equitable employment practices, occupational health and safety, and staff training in sustainability and climate resilience [23].

Hospitals can quantify social performance using indicators such as staff turnover, patient satisfaction, diversity ratios, training hours, and community beneficiaries [2, 9]. Integrating these metrics into sustainability reports links hospital success to broader social wellbeing [12,15].

The social dimension thus transforms hospitals into trust-based institutions that care for people, uphold dignity, and strengthen community resilience are foundations as vital as clinical excellence [9, 18, 19].



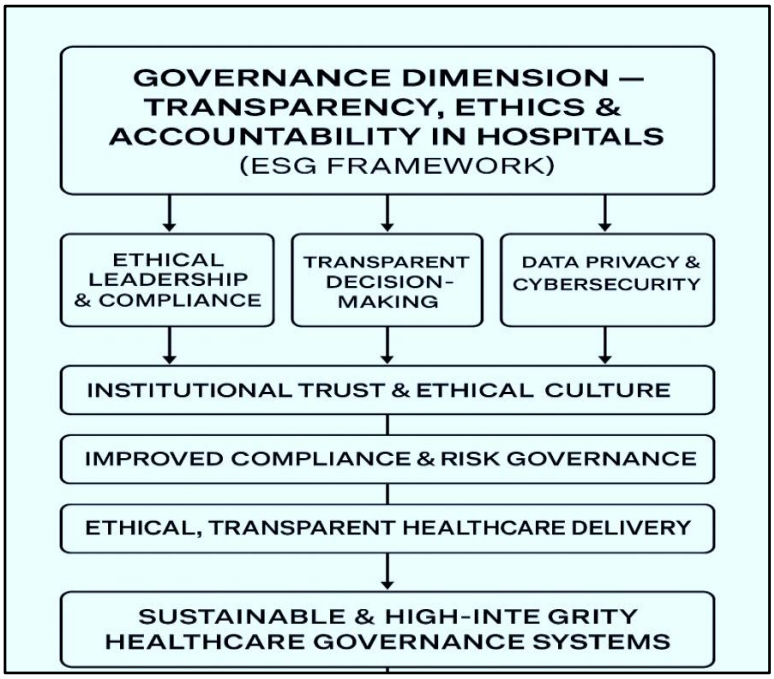
The Governance Dimension – Ethics, Accountability, and Leadership

Governance forms the structural and ethical backbone of ESG. In hospitals, it ensures that sustainability commitments are institutionalized, not just aspirational. Good governance determines how hospitals are led, how decisions are made, and how accountability is maintained to patients, staff, and society. In India's diverse healthcare landscape ranging from large corporate chains to charitable and government hospitals with strong governance differentiates transparent, responsible institutions from those driven by short-term or profit-centric goals [9, 18].

Governance in hospitals encompasses ethical leadership, regulatory compliance, and risk management. It includes oversight of financial integrity, patient rights, environmental performance, and data privacy. The Clinical Establishments Act (2010), NABH standards, and Companies Act (CSR provisions) already integrate elements of governance, but ESG reframes them into a cohesive strategy of accountability and trust [7, 9, 18].

Ethical leadership supported by codes of conduct, ethics committees, and whistleblower policies ensures that decision-making prioritizes patient safety, staff wellbeing, and compliance with national and global health norms [9, 12, 19].

Transparency is another hallmark of governance. Hospitals increasingly use ESG or sustainability reports to disclose their performance in energy use, workforce diversity, and community initiatives [1, 2]. The Securities and Exchange Board of India (SEBI) encourages such disclosures through its Business Responsibility and Sustainability Reporting (BRSR) framework [3]. Even though healthcare isn't yet mandated, major networks such as Apollo and Max Healthcare voluntarily publish sustainability reports aligned with the Global Reporting Initiative (GRI) [1, 2, 12].



Effective governance also requires inclusive leadership. Board-level ESG committees or sustainability officers ensure institutional ownership of sustainability goals [9, 23]**.** Governance for climate-resilient healthcare involves leadership commitment, establishment of sustainability/ESG committees, organizational policy integration for sustainability, and linking ESG goals to institutional KPIs [23]**.** Linking executive Key Performance Indicators (KPIs) to ESG targets such as waste reduction, workforce safety, or community engagement fosters accountability and continuous improvement [2, 9, 15]**.**

Strong governance transforms ESG from a reporting exercise into an organizational culture. It embeds integrity into decision-making, aligns hospitals with public interest, and ensures sustainability remains central to healthcare management in India [9, 18, 19].

Policy Ecosystem for ESG in Indian Healthcare

India's policy and regulatory environment provide a strong foundation for ESG adoption in hospitals, even if the term "ESG" is not explicitly mentioned in existing health or environmental laws. Over the past decade, government initiatives have progressively emphasized sustainability, equity, and accountability the three pillars of the ESG framework. However, these initiatives often operate in silos, lacking an integrated approach specific to healthcare [7, 9, 10, 11]**.**

The National Health Policy (2017) sets the overall vision for quality, accountability, and equity in service delivery. It calls for strengthening hospital governance, promoting environmental health, and aligning healthcare with sustainable development principles [9, 10]**.** Complementing this, the National Program on Climate Change and Human Health (NPCCHH) integrates climate adaptation into the health sector, encouraging hospitals to assess and reduce their environmental footprint [8, 9, 18]**.**

From a regulatory standpoint, the Bio-Medical Waste Management Rules (2016, amended 2022) have introduced stricter standards for waste segregation, tracking, and emissions, directly supporting the environmental pillar of ESG [6, 7]**.** Meanwhile, the Clinical Establishments Act (2010) enforces minimum standards for infrastructure, human resources, and data reporting — essential for governance [9, 18]**.** Financial transparency and social accountability are further reinforced by the Companies Act (2013)**,** which mandates corporate hospitals meeting certain thresholds to spend 2% of profits on CSR initiatives [6]**.**

Emerging frameworks such as the Business Responsibility and Sustainability Report (BRSR) mandated by SEBI for top listed companies are shaping ESG disclosure culture in India [3]**.** Large private hospital chains are voluntarily publishing ESG reports aligned with the Global Reporting Initiative (GRI) and SASB Healthcare Sector Standards, signaling an evolving maturity in sustainability governance [1, 2, 12]**.**

While India has the building blocks for a robust healthcare ESG ecosystem, the next step is policy convergence, a unified framework that integrates environmental, social, and governance

goals [9, 10, 11, 12]**.** This will ensure hospitals operate not only as treatment centers but as accountable institutions that advance public health and sustainability simultaneously [5, 7, 9, 15, 18].

Barriers and Enablers for ESG Integration in Hospitals

Embedding ESG principles into hospital operations is a transformative process that demands systemic change across management, culture, finance, and technology. In India, while awareness of sustainability has grown, many healthcare facilities particularly smaller or mid-tier ones still treat ESG as an external compliance burden rather than an operational priority. The challenges are multidimensional, but so are the opportunities [9, 10, 11].

The foremost barrier is financial constraint. Many hospitals operate on thin margins, focusing on immediate delivery needs rather than long-term sustainability investments. Renewable energy systems, wastewater recycling, and digital monitoring infrastructure often require upfront capital, which can deter adoption [11, 15]. Green financing mechanisms, such as ESG-linked loans and Energy Service Company (ESCO) models, can mitigate this by linking repayment to savings generated through efficiency gains [11, 15].

A second challenge is limited ESG literacy. Most administrators and clinicians lack formal training in sustainability management. Capacity building through short certification programs, inclusion of ESG modules in hospital management curricula, and cross-sector workshops can bridge this gap [9, 18, 19, 23].

Data fragmentation also impedes ESG implementation. Hospitals rarely maintain consolidated records of energy consumption, waste generation, or staff diversity. Integrating environmental and social indicators into existing Hospital Information Systems (HIS) can resolve this, enabling real-time tracking and evidence-based decision-making [12, 15].

Cultural resistance is another obstacle. Without visible leadership commitment, staff may perceive sustainability as peripheral. Hospitals that establish ESG committees chaired by senior executives or medical directors are more successful in mainstreaming sustainability goals [9, 23]. Recognizing and rewarding staff for green initiatives further reinforces participation [18, 19].

Addressing these barriers requires coordinated effort. Policy incentives, institutional leadership, and transparent reporting can transform ESG from a compliance exercise into a strategic driver of efficiency, reputation, and resilience in Indian hospitals [9, 11, 15, 18, 23].

ESG and Public Health Linkages

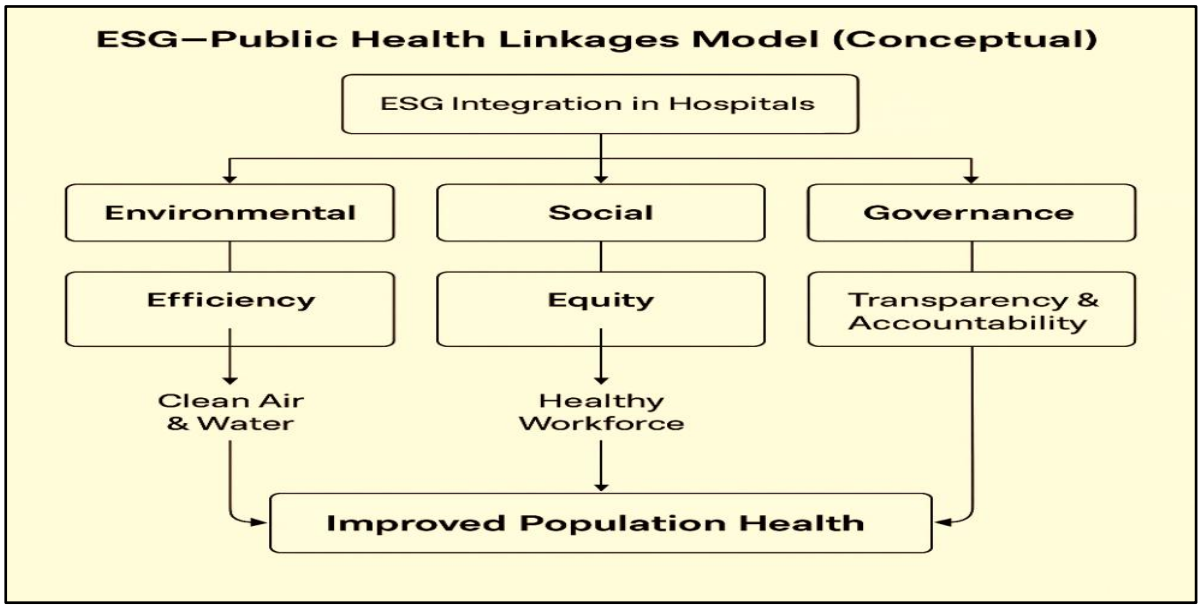
The health of people and the health of the planet are inseparably connected. Hospitals that embrace Environmental, Social, and Governance (ESG) principles contribute not only to institutional sustainability but also to broader public health outcomes. Every improvement in waste management, air quality, water use, or worker wellbeing ultimately enhances the health of

the surrounding population. Thus, ESG in healthcare is not simply an internal management tool, it is a public health intervention in itself [8, 9, 16, 18].

The environmental dimension directly affects disease patterns and community health. Poorly managed hospital emissions, biomedical waste, and contaminated water sources contribute to respiratory illness, antimicrobial resistance, and vector-borne diseases [6, 7, 17, 20]. Conversely, green hospitals with efficient waste treatment, renewable energy use, and clean air circulation reduce local pollution and improve community hygiene. For example, studies from the World Health Organization (2021) show that hospitals implementing green infrastructure experience measurable reductions in staff respiratory illness and community exposure to toxins [8, 18, 21].

The social dimension reinforces public health equity. Hospitals with fair employment practices, inclusive access, and strong community engagement act as hubs of social resilience [9, 10, 18]. Outreach programs on maternal health, nutrition, vaccination, and non-communicable disease prevention directly reduce disease burden and promote healthier lifestyles. The National Health Mission (NHM) and Ayushman Bharat have already demonstrated that partnerships between hospitals and local health systems can extend preventive care deep into underserved regions [9, 10].

Governance links these environmental and social benefits by ensuring transparency, accountability, and ethical stewardship [1, 2, 3, 12]. Hospitals that disclose ESG performance and adhere to ethical procurement not only build trust but also contribute to systemic efficiency and public confidence in healthcare institutions [1, 2, 3, 12].



By aligning ESG principles with India's public health goals such as those in the National Program on Climate Change and Human Health (NPCCHH) and the Sustainable Development Goals (SDGs) hospitals can evolve from treatment centers into health-promoting institutions that protect both lives and livelihoods [8, 9, 14, 18].

Future Pathways – Vision 2030 for Sustainable Healthcare

The coming decade presents a defining opportunity for India to position itself as a leader in sustainable and resilient healthcare. To achieve this, hospitals must transition from isolated "green" projects toward fully integrated ESG systems embedded in governance, financing, and clinical practice. The vision for healthcare 2030 is one where hospitals serve not only as centers of care but also as agents of environmental stewardship, social equity, and ethical governance [9, 11, 18, 23].

At the policy level, a National ESG Framework for Healthcare should be developed jointly by the Ministry of Health and Family Welfare (MoHFW) and the Ministry of Environment, Forest and Climate Change (MoEFCC). This framework could define benchmarks for energy use, waste generation, staff welfare, and governance transparency, aligning hospitals with India's Nationally Determined Contributions (NDCs) under the Paris Agreement [6, 7, 9, 14].

Financing innovation will be critical. Hospitals can leverage green bonds, sustainability-linked loans, and public–private partnerships (PPPs) to fund infrastructure retrofits, renewable energy systems, and community outreach programs [11, 15]. These mechanisms not only reduce financial burden but also attract ESG-conscious investors [11, 12, 15].

Digital transformation is another enabler. Hospitals can use ESG dashboards and AI-driven analytics to track real-time performance on carbon footprint, waste management, and patient safety. Integration with the Ayushman Bharat Digital Mission (ABDM) can ensure standardized, transparent reporting across the health ecosystem [8, 9, 10, 23].

Education and capacity building remain foundational. Introducing ESG and sustainability modules in medical and hospital administration programs can create a new generation of "green healthcare leaders." Collaborative research centers focusing on climate-resilient healthcare can further strengthen this agenda [9, 18, 19, 23].

By 2030, India can establish hospitals that are net-zero, socially inclusive, digitally transparent, and ethically governed a healthcare model that heals people and the planet alike [5, 9, 11, 14, 18, 23].

Conclusion

India's healthcare sector stands at a pivotal juncture where the ambition to achieve Universal Health Coverage (UHC) must be harmonized with the global imperative for sustainability, equity, and ethical governance. Hospitals, as the operational and moral centers of the health system, are uniquely positioned to drive this transformation. Embedding Environmental, Social, and Governance (ESG) principles into their operations offers a structured and measurable pathway to deliver healthcare that is both resilient and responsible [9, 10, 18, 23].

The evidence across this chapter demonstrates that ESG is not merely a reporting mechanism but a strategic framework that redefines how hospitals operate, engage, and sustain. The

environmental dimension ensures that hospitals minimize their ecological footprint through efficient resource management and green infrastructure [4, 6, 7, 9]. The social pillar emphasizes equity, workforce wellbeing, and community engagement, aligning with India's commitment to "Health for All" [8, 9, 18, 19]. Finally, governance acts as the anchor that guarantees ethical leadership, transparency, and accountability in every aspect of healthcare delivery [1, 2, 3, 12, 18].

India's policy environment through initiatives such as the National Health Policy (2017), Bio-Medical Waste Management Rules (2016/2022), and the Business Responsibility and Sustainability Reporting (BRSR) framework already provides the scaffolding for ESG integration [3, 6, 7, 9]. What remain essential are coherence, collaboration, and capacity. Hospitals must institutionalize ESG governance through dedicated committees, transparent disclosure, and leadership accountability, ensuring sustainability becomes a core management function rather than a peripheral project [9, 15, 23].

The path forward demands collective action:

- Policymakers should create enabling frameworks and fiscal incentives [9, 10, 11].
- Hospital leaders must commit to measurable ESG goals [9, 18, 23].
- Academia and training institutions should develop sustainability curricula [9, 19, 23].
- Communities and civil society must hold institutions accountable for social and environmental impact [8, 9, 18].

When these efforts converge, Indian hospitals can evolve into healing ecosystems, institutions that safeguard not just patients but the planet itself [5, 9, 11, 16, 18]. The transition toward ESG-driven healthcare is not a luxury; it is a moral and operational necessity.

Ultimately, a truly sustainable hospital is one that heals without harming, serving as a beacon of ethical care, resilience, and stewardship for generations to come [9, 18, 23].

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ARTIFICIAL INTELLIGENCE IN MEDICAL IMAGING AND DIAGNOSTICS

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Abstract
Artificial intelligence (AI) is rapidly transforming medical imaging from a purely interpretive discipline into an integrated computational decision-support system. The exponential growth of imaging data combined with a global shortage of radiology specialists has created a diagnostic bottleneck, motivating the adoption of automated analysis tools. This paper reviews recent advances in AI across radiological and non-radiological imaging domains, including CT, MRI, digital pathology, and ophthalmology. It analyzes modern architectures such as 3D convolutional neural networks, vision transformers, and multimodal foundation models, highlighting their roles in detection, reconstruction, and workflow optimization. The study also examines critical engineering challenges limiting clinical deployment, including explainability, domain generalization, and data privacy. Finally, it discusses emerging research directions such as real-time inference systems, human–AI collaboration frameworks, and patient-specific digital twins. The findings indicate that the future of medical imaging lies in integrated, multimodal clinical intelligence systems that augment rather than replace physician expertise.
Keywords: Medical Imaging, Artificial Intelligence, Deep Learning, Radiology, Pathology, Multimodal Models.

Introduction

Medical imaging has become one of the most information-rich components of modern healthcare, enabling clinicians to visualize anatomy, physiology, and pathology with increasing precision. Modalities such as Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Ultrasound, and digital pathology scanning generate enormous volumes of diagnostic data daily. However, the rate at which imaging data is produced significantly exceeds the growth of trained specialists capable of interpreting it. Workforce analyses in radiology indicate rising imaging demand alongside persistent shortages of radiologists, contributing to reporting delays and workflow strain (Afshari Mirak *et al.,* 2025).

The evolution of medical imaging can be understood through three technological eras. The first era began with X-ray radiography in 1895, introducing the concept of noninvasive internal visualization. The second era emerged in the late 20th century with cross-sectional imaging technologies such as CT and MRI, enabling volumetric anatomical analysis and dramatically improving diagnostic accuracy. The third and current era is defined by computational imaging, in which artificial intelligence algorithms assist or augment interpretation. Unlike earlier modalities

that focused on data acquisition, this era focuses on data understanding, transforming imaging devices from visualization tools into intelligent analytical systems.

Recent advances reflect a shift from narrow, task-specific algorithms toward large-scale multimodal models capable of integrating images, clinical notes, and structured patient data. Evaluation studies of multimodal medical AI demonstrate that combining imaging with contextual clinical information improves diagnostic reasoning consistency compared with single-input systems (Ruan *et al.,* 2024). This transition represents a fundamental architectural change: from isolated prediction tools to integrated diagnostic platforms.

Despite these developments, translating AI from research prototypes into clinical practice remains challenging. Systems that perform well on controlled datasets may degrade when exposed to real hospital variability, including differences in scanner manufacturers, imaging protocols, and patient populations. Furthermore, deep learning models are often difficult to interpret, limiting clinical trust and regulatory approval. Consequently, modern medical imaging AI must be assessed not only for accuracy but also for reliability, explainability, and privacy compliance.

This paper surveys recent progress across radiological and non-radiological imaging domains, analyzes engineering barriers to deployment, and outlines future clinical integration architectures likely to shape next-generation diagnostic systems.

AI in Radiological Imaging (Macro-Level Diagnostics)

Radiology represents the most mature clinical application area for artificial intelligence, largely because of standardized acquisition protocols and large annotated datasets accumulated over decades. From a systems engineering perspective, radiological AI applications fall into two operational categories: interpretative systems that perform automated detection or segmentation, and non-interpretative systems that optimize acquisition, reconstruction, and workflow.

Interpretative AI Architectures

The fundamental computational challenge in radiological AI is extracting meaningful patterns from high-dimensional volumetric data. CT and MRI scans contain three-dimensional spatial information in which clinically relevant abnormalities may be subtle or spatially distributed. Modern systems therefore employ 3D Convolutional Neural Networks (3D-CNNs) that analyze entire volumetric tensors rather than individual image slices. This architecture preserves spatial continuity across scans. As illustrated in Fig. 1, transformer-based architectures capture long-range spatial dependencies more effectively than traditional convolutional networks.

Large clinical screening studies have demonstrated the importance of reliable detection systems in real-world workflows, particularly for lung cancer screening programs that analyze thousands of patient scans (DeSimone *et al.,* 2025). Automated segmentation tools can also compute tumor

burden measurements that previously required time-consuming manual delineation by radiologists, improving efficiency and reproducibility.

In recent years, Vision Transformers (ViTs) have emerged as powerful alternatives or complements to convolutional models. Transformer architectures use self-attention mechanisms to model long-range dependencies across an image, enabling detection of diffuse pathologies whose patterns extend across multiple regions. A comprehensive survey of transformers in medical imaging documents their successful application across classification, segmentation, reconstruction, and multimodal reasoning tasks (Azad *et al.,* 2024). MRI segmentation workflows commonly rely on U-Net-style encoder–decoder architectures, which preserve spatial detail through skip connections while learning hierarchical semantic features. These models are widely used for brain lesion segmentation and neurodegenerative biomarker detection. One major constraint in MRI analysis is the scarcity of annotated datasets, since high-quality labels require expert clinicians. Transfer learning and self-supervised pretraining therefore play a crucial role in improving model generalization when labeled data are limited (Azad *et al.,* 2024).

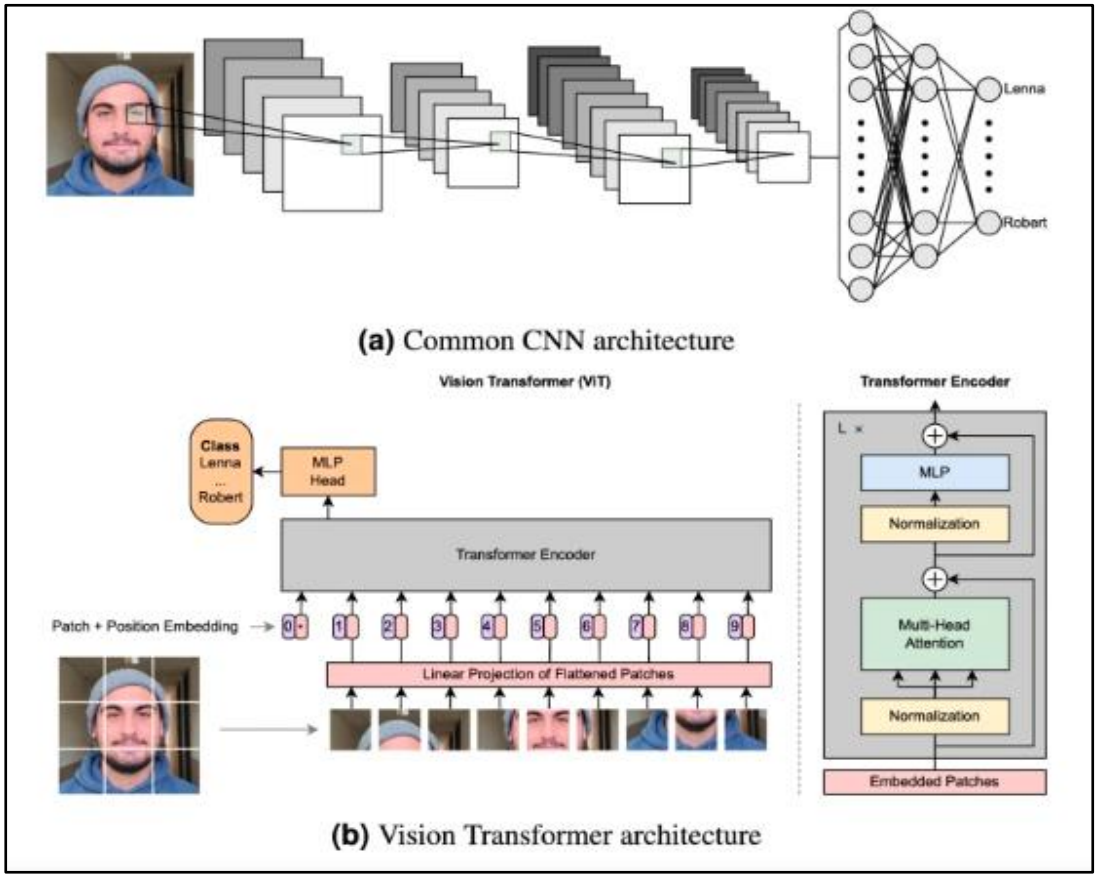

Figure 1: Architectural comparison between Convolutional Neural Networks (CNN) and Vision Transformers (ViT), illustrating differences in spatial feature extraction mechanisms.

Note. Adapted from Azad, R., *et al.* (2024). Advances in medical image analysis with vision transformers: A comprehensive review. Medical Image Analysis, 86, 102762.

Non-Interpretative AI in Radiology

While diagnostic automation often attracts the most attention, non-interpretative AI systems frequently provide faster clinical impact because they optimize imaging pipelines rather than replacing physician judgment.

One major innovation is Deep Learning Reconstruction (DLR). Imaging physics imposes trade-offs between scan speed, radiation dose, and image quality. For example, faster MRI scans often introduce undersampling artifacts, and lower CT radiation doses increase noise. DLR methods replace classical iterative reconstruction algorithms with learned priors that can reconstruct high-quality images from low-dose or undersampled data. Technical reviews of DLR show its potential to improve image quality while reducing acquisition time or radiation exposure (Koetzier *et al.,* 2023). This reconstruction improvement is demonstrated visually in Fig. 2.

Another important development is AI-driven triage systems integrated into radiology workflow platforms. These systems analyze incoming scans and automatically prioritize urgent cases, such as suspected intracranial hemorrhage. By reordering worklists, triage models reduce time-to-diagnosis without altering physician authority, effectively improving throughput and patient safety.

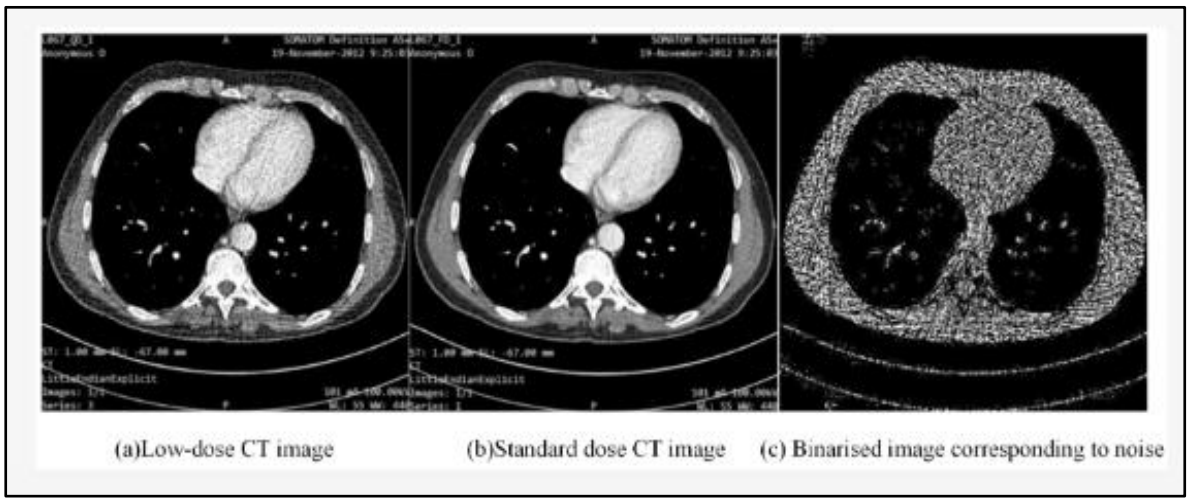

Figure 2: Comparison between low-dose CT reconstruction and deep learning-based reconstruction methods.

Note. Adapted from Koetzier, L. R., *et al.* (2023). Deep learning image reconstruction for CT: Technical principles and clinical prospects. Radiology, 307(1), e221257.

AI in Non-Radiological Imaging (Micro-Level Diagnostics):

Whereas radiology analyzes organs and tissues at macroscopic scale, non-radiological imaging modalities such as digital pathology and ophthalmology operate at microscopic resolution. Here, the central engineering challenge is not merely detection but resolution integration—connecting pixel-level cellular features with patient-level clinical interpretation.

Digital Pathology and Whole Slide Imaging

Digital pathology relies on Whole Slide Images (WSIs) that may exceed gigapixel resolution. The computational workflow used to address this challenge is shown in Fig. 3. A widely adopted solution is patch-based processing, where slides are divided into thousands of smaller tiles that are processed independently and then aggregated into slide-level predictions. A comprehensive review of WSI deep learning techniques explains how patch-based pipelines make large-scale pathology analysis feasible on modern hardware (Dimitriou *et al.,* 2019).

Multi-resolution architectures further enhance performance by combining global tissue context with fine cellular detail. This design mirrors the workflow of human pathologists, who first examine tissue at low magnification and then zoom into suspicious regions. Such multi-scale modeling has shown improved performance in tasks such as tumor microenvironment analysis and prognostic prediction (Dimitriou *et al.,* 2019).

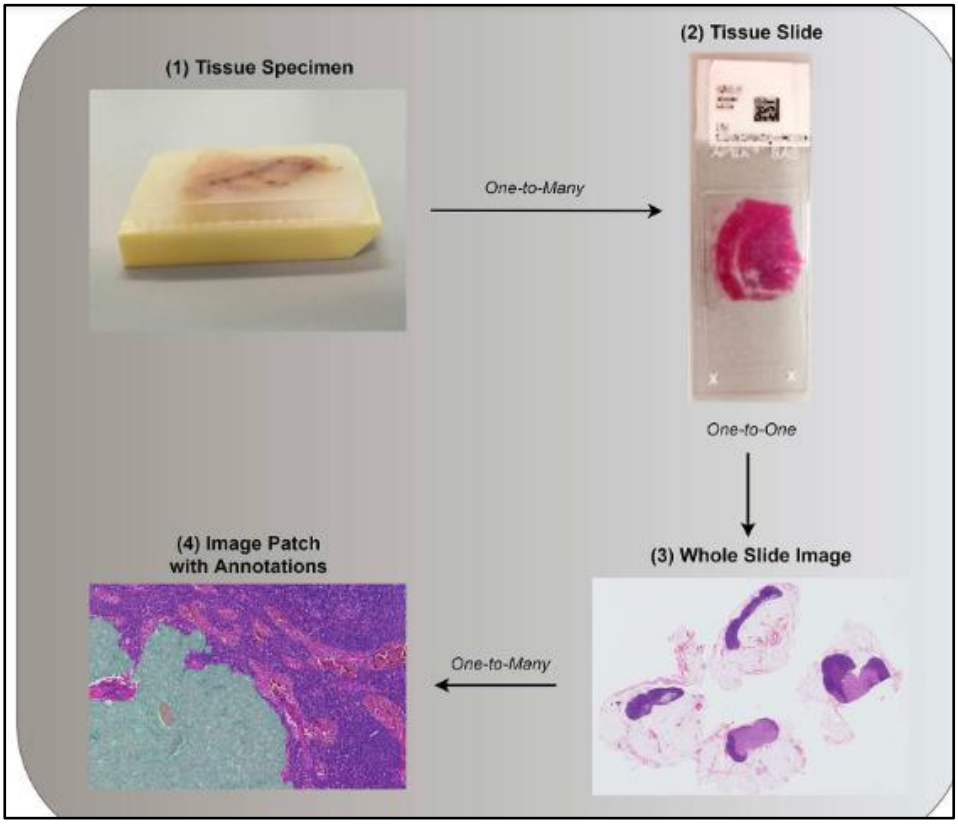

Figure 3: Workflow of digital pathology analysis showing the transformation from tissue specimen to whole slide image (WSI) and patch-based processing for deep learning.

Note. Adapted from Dimitriou, N., Arandjelović, O., & Caie, P. (2019). Deep learning for whole slide image analysis: An overview. Frontiers in Medicine, 6, 264.

Ophthalmology Screening Systems

Retinal imaging represents one of the most successful real-world deployments of AI diagnostics because it enables population-scale screening without requiring specialist presence. Modern diabetic retinopathy screening systems often combine convolutional layers with attention

mechanisms to detect both local lesions and global vascular patterns. Reviews of transformer-based medical imaging approaches describe how such hybrid architectures balance local sensitivity and global reasoning (Azad *et al.,* 2024).

A major engineering advantage of ophthalmology AI is deployability. Model compression and distillation techniques allow high-accuracy models to run on lightweight devices, enabling screening in rural or low-resource environments. In system design terms, these solutions function as edge-AI diagnostic pipelines that perform immediate triage and refer only high-risk cases to specialists.

Cross-Scale Multimodal Integration

An emerging research direction is cross-scale fusion, which combines radiological and pathological features into unified predictive models. Multimodal evaluation frameworks show that integrating imaging with structured clinical information improves diagnostic reasoning consistency and reduces uncertainty compared with single-modality systems (Ruan *et al.,* 2024). From an engineering perspective, multimodal fusion increases robustness because different data sources capture complementary biological signals.

Engineering Challenges: Reliability and Trust:

Although AI models can achieve expert-level performance on controlled datasets, clinical deployment requires additional reliability guarantees.

i. Explainability

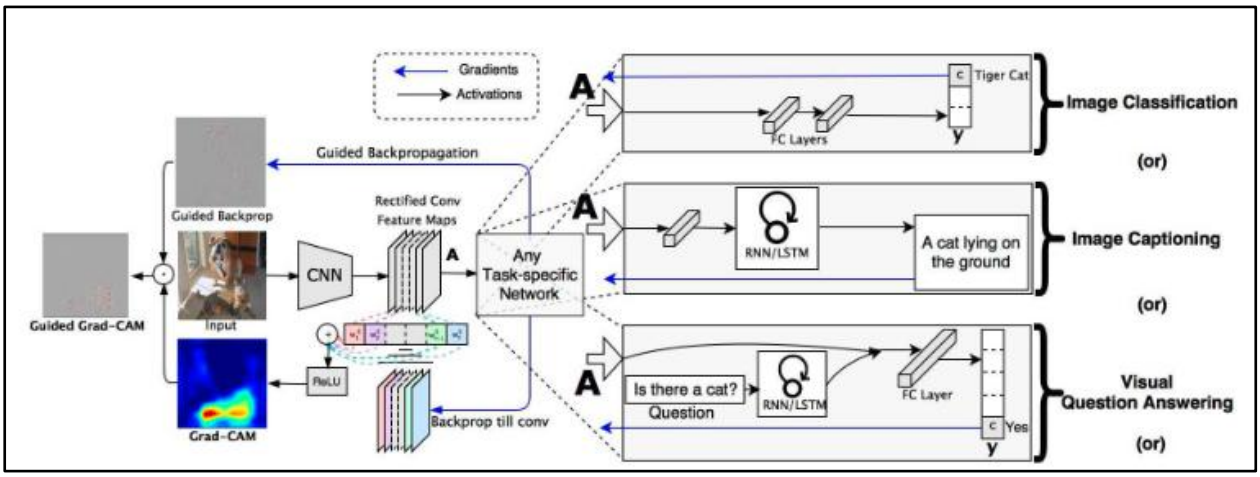

Figure 4: Guided Grad-CAM visualization combining Grad-CAM and guided backpropagation to produce high-resolution class-discriminative visual explanations across multiple vision tasks.

Note. Adapted from Selvaraju, R. R., Cogswell, M., Das, A., Vedantam, R., Parikh, D., & Batra, D. (2017). Grad-CAM: Visual explanations from deep networks via gradient-based localization. Proceedings of the IEEE International Conference on Computer Vision (ICCV), 618–626

Deep neural networks often operate as opaque systems whose decision processes are difficult to interpret. Explainable AI techniques such as Grad-CAM generate saliency maps highlighting image regions that influenced a prediction. The original Grad-CAM paper demonstrates how gradient-based localization can visually explain network decisions and improve user trust (Selvaraju *et al.,* 2017).

ii. Domain Shift

Models trained on one dataset may perform poorly when deployed in a different hospital because of differences in scanners, acquisition parameters, or patient populations. Experimental studies confirm that scanner-related domain shift can significantly degrade performance across institutions (Guo *et al.,* 2024). Domain adaptation methods aim to address this by learning invariant feature representations that generalize across environments.

iii. Privacy

As illustrated in Fig. 5, federated learning (FL) enables institutions to train AI models collaboratively while keeping patient data local. Healthcare data sharing is tightly restricted by privacy regulations such as HIPAA and GDPR. In FL, each site trains on its own data and sends only model updates — not raw records — to a central aggregator. A foundational review of federated learning in healthcare highlights its potential for privacy-preserving collaboration across hospitals (Rieke *et al.,* 2020).

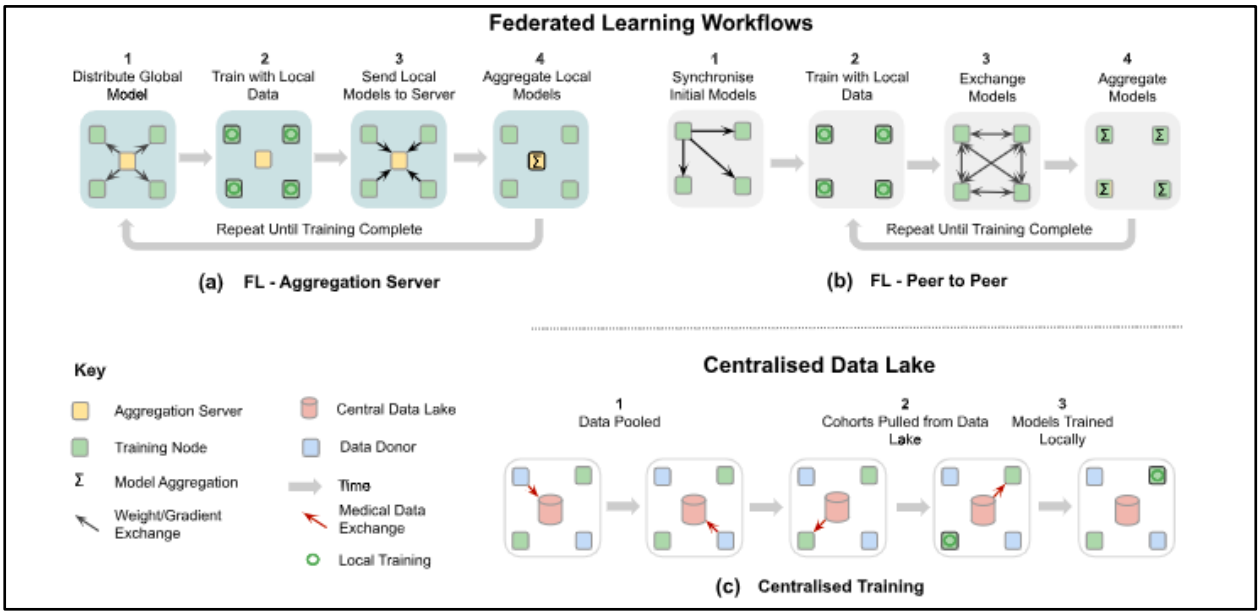

Figure 5: Federated learning workflows illustrating local model training at participating institutions and encrypted parameter aggregation at a central server, enabling collaborative AI development without transferring patient data.

Note. Adapted from Rieke, N., *et al.* (2020). The future of digital health with federated learning. Digital Medicine, 3(1), 1–7. https://doi.org/10.1038/s41746-020-00323-1

Future Directions: Toward Integrated Clinical Intelligence

The next generation of medical imaging AI will likely focus on system integration rather than isolated algorithmic improvements. Real-time inference pipelines may allow AI models to analyze imaging data during acquisition, enabling adaptive scanning protocols and immediate anomaly detection. Such systems would transform imaging from a batch process into a streaming decision pipeline.

Human–AI collaboration is expected to remain the dominant paradigm. Rather than replacing clinicians, AI systems function as high-speed analytical assistants that automate pattern detection and quantitative measurement while physicians retain interpretive authority. This collaborative architecture parallels control systems engineering, where automated subsystems operate under human supervision.

Long-term research envisions patient-specific digital twins—dynamic computational models that integrate imaging, clinical history, and physiological data to simulate disease progression and treatment outcomes. While still largely conceptual, such systems represent a logical extension of multimodal foundation-model approaches (Ruan *et al.,* 2024).

Conclusion

Artificial intelligence is transforming medical imaging from a purely interpretive discipline into a computationally augmented diagnostic ecosystem. Advances in radiological imaging have improved both detection performance and imaging efficiency, while developments in pathology and ophthalmology demonstrate how AI can operate effectively at cellular resolution and population scale. At the same time, challenges related to explainability, domain generalization, and privacy remain critical barriers to widespread clinical adoption.

The trajectory of research suggests that the future of medical imaging lies not in individual algorithms but in integrated platforms that combine multimodal data, real-time analysis, and human oversight. In this framework, AI serves not as a replacement for clinicians but as a precision engineering instrument that enhances diagnostic accuracy, efficiency, and accessibility. As these systems mature, they have the potential to reshape healthcare into a more predictive, personalized, and data-driven discipline. Despite promising results, limitations remain in dataset bias, real-world validation, and clinical integration.

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LEGISLATIONS AFFECTING HOSPITALS IN INDIA: NAVIGATING THE LEGAL LANDSCAPE OF HOSPITAL ADMINISTRATION

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Abstract
Hospitals in India operate within a complex framework of legislations that govern their establishment, administration, clinical practices, and interactions with patients, employees, and society. Compliance with these legal provisions is critical not only to ensure patient safety and quality care but also to safeguard institutions and healthcare professionals from medicolegal liabilities. This chapter provides a comprehensive overview of the major laws impacting hospitals in India, categorized into those affecting management and employee relations, doctors, nursing and paramedical staff, patient care, and hospital infrastructure. Key Acts such as the Clinical Establishments Act, Transplantation of Human Organs and Tissues Act, PCPNDT Act, MTP Act, Consumer Protection Act, and Biomedical Waste Rules are discussed with their salient features, amendments, and implications for hospital administrators. In addition, the chapter highlights mandatory licenses required for operating hospitals and nursing homes. By integrating legal obligations with operational realities, this chapter serves as a practical guide for hospital administrators, medical professionals, and policymakers to navigate the evolving medicolegal landscape and promote ethical, safe, and sustainable healthcare delivery.

Keywords: Legislations, Medico-legal, Hospital, Acts, Licences, Healthcare.

Introduction

"Hospitals function at the intersection of science, ethics, and law; legislation provides the guardrails that protect both patients and practitioners."

Law and legislation are fundamental to the governance of hospitals, providing a structured framework that ensures the delivery of healthcare is safe, ethical, and accountable. As institutions entrusted with human lives, hospitals must operate within well-defined legal boundaries to protect patient rights, uphold professional standards, and maintain public trust. Legislative provisions regulate critical domains such as licensing, clinical protocols, infection control, biomedical waste management, data confidentiality, and ethical medical practice. They also serve to safeguard healthcare providers and institutions from legal liabilities by prescribing clear standards for documentation, dispute resolution, and risk management. Furthermore, compliance with statutory requirements facilitates access to accreditation, insurance reimbursements, and government health programs, thereby strengthening institutional credibility. Ultimately, law and legislation are not mere regulatory impositions but essential safeguards that

balance patient welfare with professional accountability, enabling hospitals to function responsibly and sustainably. India's Constitution has listed health as a state subject. This means the states or the subnational governments are the primary actors in providing healthcare services. Thus, the Seventh Schedule of the Constitution which allocates powers and functions between the Centre and states makes it explicitly clear that on issues of public health and sanitation; hospital and dispensaries and their management, states are supreme.

Hospitals in India need to follow various laws and have to have a number of licences which need renewal from time to time. It is important for every Hospital Administrator to be aware of these laws and licences and ensure compliance. In addition to the above laws, an Administrator needs to comply with requirements of several other organizations like the NABH, JCI etc.

The various legislations affecting Hospitals in India can be listed as follows-

1. Legislations affecting management & employee relations in hospitals

- The four Labour Codes (Central) — Code on Wages (2019); Industrial Relations Code (2020); Code on Social Security (2020); Occupational Safety, Health & Working Conditions Code (2020). Consolidate and modernise labour law; affect wages, employment contracts, social security, occupational safety and industrial relations for hospital employers.
- Employees' State Insurance Act (ESI), 1948 — social security, medical care and cash benefits for employees (applicability depends on workforce size/state rules).
- Employees' Provident Funds & Miscellaneous Provisions Act (EPF) — provident fund, pension and related employer contributions for eligible staff. (Admin: EPFO.)
- Payment of Gratuity Act, 1972 — terminal benefits for qualifying employees.
- Maternity Benefit Act, 1961 and Sexual Harassment of Women at Workplace (Prevention, Prohibition and Redressal) Act, 2013 — leave, protections, workplace policies.
- Shops & Establishments Acts (State level) — working hours, leave, record-keeping — many hospitals additionally follow the state Shops & Establishment or separate State Health Establishment rules.
- Contract Labour (Regulation & Abolition) Act / rules & other outsourcing compliance — affects use of contract staff, cleaners, security, etc.
- Statutory registrations for the corporate form — Societies Registration Act, Companies Act, Trust Acts — determine governance and reporting requirements.

2. Legislations affecting Doctors

- National Medical Commission (NMC) Act, 2019 — primary regulator of medical education, standards, registration (replacement of the Indian Medical Council Act); affects doctors' registration, disciplinary procedures, ethics and medical education.

- Clinical Establishments (Registration & Regulation) Act, 2010 (Central / State adoption) Very important for hospital licensing and minimum standards.
- Drugs & Cosmetics Act, 1940 and Rule.
- Transplantation of Human Organs and Tissues Act, 1994 (amended)
- Medical Termination of Pregnancy (MTP) Act & Rules — legal framework for termination services and approvals.
- Clinical Trials Rules / New Drugs & Clinical Trials Rules (as notified) — regulation of clinical trials and responsibilities of investigator sites (hospitals involved in research).
- The PCPNDT Act (Pre-Conception & Pre-Natal Diagnostic Techniques Act), 1994
- The Consumer Protection Act, 2019

3. Legislations affecting Nursing & Paramedical staff-

- Indian Nursing Council Act, 1947 — registration, education standards and code of conduct for nurses; state nursing councils implement registration and renewals.
- The National Commission for Allied and Healthcare Professions (NCAHP) Act, 2021 — statutory framework to regulate education, practice standards and registration for allied and paramedical professions (physiotherapy, lab techs, radiography, etc.).
- State Paramedical Council / State Acts and Rules — many states have complementary rules for paramedics and technicians.
- Code of conduct & statutory licensing for pharmacists (Pharmacy Act, 1948) — affects pharmacy staff and hospital pharmacy operations.

4. Legislations affecting patient care in hospitals-

- Clinical Establishments Act, 2010
- Mental Healthcare Act, 2017 — patient rights, capacity, informed consent, duties of mental health establishments and psychiatrists; statutory requirements for admission, advance directives and boards.
- Right to Information Act (RTI) — public hospitals and some records may be subject to RTI requests (limits re: patient confidentiality).
- Digital Personal Data Protection Act / IT Act & rules (data privacy & electronic records) -important for telemedicine and hospital IT.
- Bio-Medical Waste Management Rules, 2016 (and amendments)
- Infection control & epidemic laws — Epidemic Diseases Act, 1897 (used for public health emergencies), Disaster Management Act, and various national/state infection control guidelines (critical for outbreak response).

Table 1: General Licences required for Hospitals in India

Sr. No.	Registration / License / Certificate	Issuing Authority / Applicable Act
1	Registration under the Clinical Establishments Act, 2010 (or respective State Nursing Home Act)	State Health Department / Clinical Establishments Act, 2010
2	Shops and Establishments Act Registration	State Labour Department
3	Biomedical Waste Management Authorization	State Pollution Control Board
4	Biomedical Equipment Calibration and Safety Certification	NABL-accredited Testing and Calibration Agencies
5	Fire No Objection Certificate (Fire NOC)	Fire Department
6	Building Completion / Occupancy Certificate	Municipal or Local Authority
7	Pharmacy License	Drugs and Cosmetics Act, 1940; State Drug Control Department
8	Blood Bank License (if applicable)	Central/State Drug Licensing Authority
9	AERB License for X-ray, CT, MRI, and Radiotherapy Units	Atomic Energy Regulatory Board (AERB)
10	Lift License (if applicable)	State Electrical Inspectorate / Lift Inspectorate
11	Food Safety License (FSSAI) for Hospital Canteens/Cafeterias	Food Safety and Standards Authority of India (FSSAI)
12	Society, Trust, or Company Registration	Registrar of Societies / Charity Commissioner / Registrar of Companies
13	Laboratory Registration (NABL accreditation optional)	State Health Authority / National Accreditation Board for Testing and Calibration Laboratories (NABL)
14	Registration under the Pre-Conception and Pre-Natal Diagnostic Techniques (PCPNDT) Act	Appropriate Authority under the PCPNDT Act
15	Organ Transplant License (if applicable)	Authorization Committee under the Transplantation of Human Organs and Tissues Act (THOTA)
16	Wastewater / Drainage Consent	State Pollution Control Board
17	Trade License (where applicable)	Municipal Corporation / Local Authority

5. Legislations affecting construction of hospitals (infrastructure, safety & environment)

- National Building Code of India (NBC) — technical building standards, structural, fire-safety and services guidance used by states/municipalities for approvals (hospital design, M&E, HVAC).
- Local Municipal/State Building Byelaws & Development Control Regulations — land use/zoning approvals and occupancy certificates — essential for hospital construction and licensing.
- Fire Safety Rules / Fire NOC & Fire Prevention Acts (State fire services) — fire audits, NOC, escape routes, sprinklers — mandatory for hospital occupancy.
- Environment (Protection) Act, 1986 & EIA/Govt notifications — where applicable for large projects; also pollution control consents from State Pollution Control Boards.
- Electricity Act / Regulations & statutory clearances — power backup, medical gas systems; compliance with electrical safety codes.
- Building & Other Construction Workers (Regulation of Employment & Conditions of Service) Act, 1996 — protections for construction workers during hospital construction (labour safety).

In this Chapter, we shall discuss the salient features of a few of the important legislations from the above list.

1. Clinical Establishments (Registration and Regulation) Act, 2010

The Clinical Establishments (Registration and Regulation) Act, 2010 (CEA) is a central legislation enacted to bring all clinical establishments—hospitals, maternity homes, nursing homes, dispensaries, clinics, laboratories, imaging centres—under a uniform regulatory framework. It mandates compulsory registration of both government and private establishments, with the exception of those run by the armed forces.

The Act requires establishments to conform to minimum standards of facilities and services, maintain proper records, provide transparent billing, display services and charges, and follow ethical practices. It also empowers the authorities to prescribe standard treatment guidelines (STGs) to promote rational and cost-effective care.

Purpose of the Act is to ensure uniform regulation and minimum quality standards across all clinical establishments. To promote transparency and accountability in hospital administration, including display of charges and services. To improve patient safety and rights, through ethical practice and rational care. To create a national registry of clinical establishments for health planning and research.

Registration is two-tiered: provisional (on application with basic documents) and permanent (after fulfilling minimum standards). State and district registering authorities have powers to

inspect, suspend, or cancel registration. The Act provides penalties for non-compliance, including fines and closure.

The Act applies automatically to Union Territories and to those States that adopt it by passing a resolution in their legislature (Concurrent List subject). This has resulted in a mixed adoption landscape.

Amendments to Clinical Establishments Rules, 2012 Amendment framed under the Act, clarified application procedures, fees, forms, and record maintenance. 2016 Amendment & later state rules had several states issuing specific guidelines on minimum standards, record-keeping formats, and infrastructure norms. No major central amendment has yet overhauled the parent Act, though policy proposals exist to strengthen enforcement and integrate it with digital health initiatives.

Exceptions- Armed Forces Medical Establishments are expressly excluded. Establishments already registered under any other law may be deemed compliant until expiry of that registration (saving clause). States not adopting the Act continue under their own state-level health establishment laws (e.g., Delhi Nursing Homes Act, Maharashtra Nursing Homes Registration Act).

2. Consumer Protection Act, 2019

This Act has replaced the Consumer Protection Act, 1986 to modernize consumer rights in line with digital age practices. Purpose of the Act is to safeguard consumer rights against exploitation and ensure accountability of service providers, including healthcare. To offer a simple, accessible, and speedy mechanism for dispute redressal. To enhance trust in services and curb malpractices, including in the hospital sector.

The Act defines a consumer as any person who buys goods or avails services for consideration (excludes resale or commercial purposes). The Act recognizes healthcare services (except free services) under the ambit of "services," bringing hospitals, doctors, and diagnostic centers under scrutiny. It establishes Consumer Dispute Redressal Commissions at district, state, and national levels with enhanced pecuniary jurisdiction. Introduces mediation cells for faster resolution. Recognizes product liability, holding manufacturers, sellers, and service providers accountable for defective goods or deficient services. Prohibits unfair trade practices, misleading advertisements, and deficiency in service.

The 2019 Act itself is the amendment over 1986 law, with wider scope like the inclusion of e-commerce transactions. Power to initiate class action suits. Authority to impose penalties on false/misleading advertisements (₹10–50 lakh fines, imprisonment up to 2 years for endorsers).

Higher compensation limits: District Commission: up to ₹1 crore. State Commission: up to ₹10 crore. National Commission: >₹10 crore. 3.

Exceptions- Healthcare services rendered free of charge (e.g., government hospitals, charitable hospitals) are usually outside CPA's scope. Emergency care given in good faith is often protected against harsh liability. Professional autonomy of doctors is not overridden, provided due care and standard protocols followed. Parallel remedies under other legislations (e.g., tort, Indian Penal Code, MCI/NMC ethics regulations) remain available.

3. Transplantation of Human Organs and Tissues Act, 1994 (Amended 2011)

The Transplantation of Human Organs and Tissues Act, 1994 (THOTA) was enacted to regulate the removal, storage, and transplantation of human organs for therapeutic purposes, and to curb organ trade. It makes commercial dealings in human organs a punishable offence.

Purpose of the Act is to regulate transplantation and prevent exploitation through organ trade. To legally recognize brain death, promoting cadaveric donation. To establish a transparent framework for authorization and allocation of organs. To balance the demand–supply gap in organ transplantation by encouraging ethical donation.

The Act permits organ donation by:

Living donors: primarily "near relatives" (spouse, parents, children, siblings, grandparents, grandchildren). Unrelated donors: allowed only with approval of an Authorisation Committee, ensuring no financial inducement. *Deceased donors*: donation permitted after certification of brain death by a medical board.

Hospitals conducting transplants must be registered, maintain detailed records, and comply with strict standards. Authorization Committees are set up at state and hospital levels to scrutinize non-related donations.

The Act also covers tissues (skin, cornea, bones) after its amendment. Offences include organ trafficking, false certification, and illegal advertisement. Penalties include imprisonment and heavy fines.

By defining brain death legally, the Act paved the way for cadaveric organ donation in India.

Amendments -2011 Amendment (in force from 2014): Expanded scope to tissues along with organs. Recognized swap transplantation (between two donor–recipient pairs). Broadened "near relative" definition to include grandparents and grandchildren. Provided for National and State Organ and Tissue Transplant Organizations (NOTTO, SOTTO, ROTTO) to streamline allocation. Enhanced penalties for organ trade and illegal transplants. Rules, 2014 & 2016: Detailed procedures for registration, certification of brain death, and functioning of transplant coordination bodies.

Exceptions - Living near-relative donations can proceed with less bureaucracy (only hospital committee approval). Unrelated altruistic donation is permitted if approved by the Authorisation Committee after scrutiny. Certain institutions (armed forces medical establishments) have specific procedural relaxations. Consent requirements: if a person has given prior consent (e.g.,

donor card), it remains valid unless the family objects (family consent often still considered in practice)

4. Medical Termination of Pregnancy Act, 1971

This Act was enacted to regulate termination of certain pregnancies under medical supervision, balancing maternal health and social considerations. Purpose of the Act was to reduce maternal morbidity and mortality from unsafe abortions. To provide a legal, safe, and accessible framework for abortion while ensuring ethical safeguards. To protect doctors performing abortions in good faith from prosecution under IPC Sections 312–316. It allows termination by a registered medical practitioner (RMP) in approved facilities.

Permissible grounds as per the original Act were:

- Risk to life of the pregnant woman.
- Grave injury to physical/mental health.
- Substantial risk of child being born with serious abnormalities.
- Pregnancies arising out of rape or contraceptive failure (in married women).

Gestational limits were initially up to 12 weeks with one doctor's opinion, 12–20 weeks with two doctors' opinions. However, the 2002 Amendment, decentralized approval of abortion facilities to state/UT governments; streamlined RMP requirements. 2021 Amendment was landmark as it extended upper limit for termination to 24 weeks for certain categories (survivors of rape, minors, differently-abled, etc.) and removed marital status restriction — unmarried women included for contraceptive failure grounds. Only one doctor's opinion needed up to 20 weeks; two doctors required 20–24 weeks.

Special category: termination beyond 24 weeks in cases of substantial foetal abnormalities (approval by state-level medical board). It strengthened confidentiality — revealing identity of the woman is now punishable.

Emergency clause: termination at any stage permitted if immediately necessary to save the woman's life. It has resulted in protection of RMPs as actions in "good faith" are protected. Woman's consent mandatory (if ≥18 years or not mentally ill); in minors/mentally ill, guardian's consent required.

Despite amendments, access remains inequitable, especially in rural India due to shortage of approved facilities. Requirement of medical board opinion beyond 24 weeks may cause delays. Ambiguity persists around interpretation of "grave injury to mental health." Does not cover self-managed abortions with newer medical technologies, leading to grey areas. Stigma and fear of legal repercussions still discourage many doctors from offering MTP services.

5. Pre-Conception and Pre-Natal Diagnostic Techniques (PCPNDT) Act, 1994 (Amended 2003)

It was enacted to curb female feticide and misuse of diagnostic techniques for sex selection. Prohibits use of pre-natal diagnostic techniques except for specific medical purposes (e.g., detecting genetic/metabolic disorders, chromosomal abnormalities, congenital malformations). Regulates use of ultrasound and genetic counselling/diagnostic centers. Mandates registration of all such facilities. Bans advertisement relating to pre-conception or pre-natal sex determination. Provides for maintenance of detailed records by diagnostic centers; non-maintenance itself is an offence.

Strict penalties: imprisonment up to 5 years and fine up to ₹1 lakh for violations. The 2003 Amendment expanded scope to cover pre-conception techniques (e.g., sperm sorting, IVF-based sex selection). It also brought ultrasound clinics explicitly under regulation. Empowered appropriate authorities with powers of search, seizure, and sealing of equipment. Introduced stricter punishments and provisions for suspension/cancellation of medical practitioners' registration.

Subsequent amendments and rules ensured mandatory reporting through Form F, restrictions on sale of ultrasound machines, introduction of online monitoring systems in many states.

The Act permits use of diagnostic techniques only for medical reasons such as: Detection of genetic/chromosomal abnormalities. Risk of physical/mental handicaps. Sex-linked disorders. Allows procedures only with written consent of the pregnant woman. Protection for doctors acting in good faith for lawful indications.

6. Protection of Children from Sexual Offences (POCSO) Act, 2012

It is a comprehensive law to protect children (<18 years) from sexual assault, harassment, and pornography. Purpose of the Act To provide a robust legal framework for protection of children against sexual exploitation and abuse. To ensure justice through speedy trial and child-sensitive procedures. To make reporting of child sexual offences mandatory, thereby ensuring accountability of institutions, including hospitals

It is a gender-neutral act — it protects both boys and girls. Defines various offences with clarity: penetrative sexual assault, aggravated penetrative assault, sexual harassment, use of children in pornography. Mandates child-friendly procedures like recording statement at residence/hospital in presence of parents or trusted persons. Medical examination is done preferably by female doctor. Child is not to be detained in police station overnight. Special Courts established for speedy trial. Burden of proof shifted: presumption of guilt against accused once prosecution establishes prima facie case.

The 2019 Amendment: Introduced death penalty for aggravated penetrative sexual assault. Enhanced punishments for all offences. Criminalized possession/distribution of child

pornography more stringently. Included punishment for using children for pornographic purposes, with aggravated penalties if penetration involved.

Mandatory reporting: Doctors, teachers, or any person aware of child sexual abuse must report to authorities (failure is punishable). Protection of doctors/hospitals: good-faith reporting cannot be penalized. Proceedings to be conducted in-camera and confidentiality of victim's identity preserved (Sec 23). Emergency medical care must be provided without waiting for legal formalities.

7. Narcotic Drugs and Psychotropic Substances (NDPS) Act, 1985

It is a comprehensive legislation controlling cultivation, production, possession, sale, transport, and consumption of narcotic drugs and psychotropic substances. Purpose of the Act is to curb drug abuse and trafficking while ensuring medical availability of narcotics for palliative care, anaesthesia, and psychiatry. To comply with India's obligations under international drug control treaties. To balance enforcement with healthcare needs.

The Act establishes stringent penalties: even small quantities attract imprisonment; commercial quantities can lead to rigorous imprisonment up to 20 years. Grants power to Central & State Governments to regulate and control narcotics. Provides for NDPS Courts for speedy trials. Recognizes medical and scientific use of narcotics (e.g., morphine for cancer pain, psychotropic medicines in psychiatry). Hospitals and doctors must obtain licenses/authorizations for procurement, storage, and use of controlled drugs.

The 1988 Amendment has strengthened enforcement; property derived from drug trafficking liable to forfeiture. The 2001 Amendment, rationalized sentencing — as penalties are now proportional to quantity (small, intermediate, commercial). The 2014 Amendment recognized essential narcotic drugs (ENDs) like morphine, fentanyl, oxycodone; centralized their regulation under Central Government. Simplified licensing as hospitals now need single license for possession/use of ENDs instead of multiple approvals. Boosted access for palliative care patients.

Exceptions: Medical and scientific use permitted under licensing/authorization. Emergency possession/use by registered medical practitioners allowed within notified limits. Protection for doctors/hospitals acting in good faith under license conditions.

8. Biomedical Waste Management Rules, 2016 (BMW Rules)

This Act was issued under the Environment Protection Act, 1986 to regulate biomedical waste (BMW) from hospitals, nursing homes, labs, research centers, and blood banks. 3. Purpose of the Act is to ensure safe handling, segregation, transport, treatment, and disposal of biomedical waste. To minimize adverse impact on human health and the environment. To create accountability among hospitals and waste disposal facilities.

The Act consolidated categories of BMW into 4 classes (yellow, red, white, blue) for simpler segregation. Mandatory segregation at source in color-coded containers. It prohibits storage of BMW for >48 hours without permission from pollution control board. Requires authorization from State Pollution Control Board (SPCB) for handling BMW. The Act emphasizes occupier's responsibility (hospital authority) for safe disposal. Record-keeping, barcoding, and annual reporting is mandated. It stipulates training of healthcare workers and safety for staff handling BMW.

The 2018 Amendment ordered the Phase-out of chlorinated plastic bags and gloves. It revised standards for incinerators and deep burial. Introduction of barcoding for tracking BMW. The 2019 Amendment, increased reporting requirements, stricter compliance deadlines. State boards empowered to levy environmental compensation for violations. The 2023 Amendment laid greater stress on single-use plastics reduction. Provisions for pre-treatment of lab waste, liquid waste standards.

Small healthcare facilities (<10 beds) can utilize common biomedical waste treatment facilities (CBWTFs) instead of setting up their own. Deep burial permitted only in remote/rural areas where CBWTF is not available. Protection for healthcare workers acting in good faith under the rule.

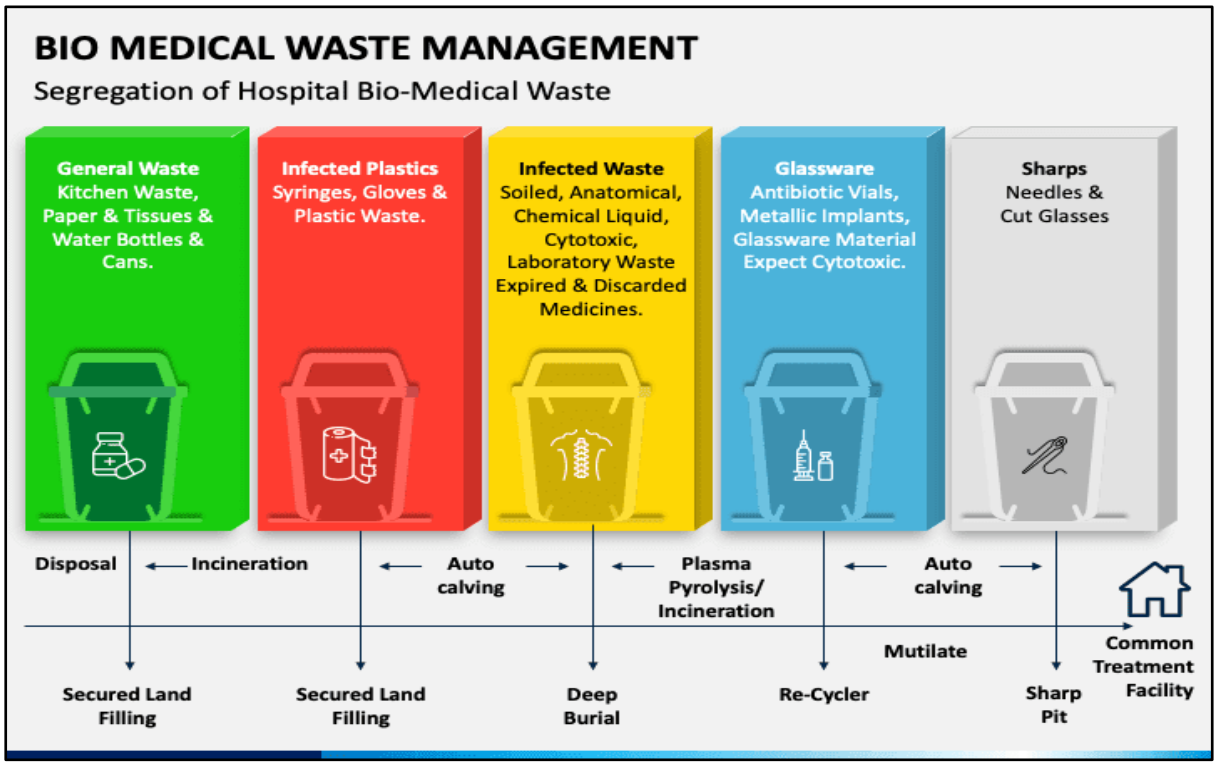

Figure 1: Segregation of Hospital Bio-Medical Waste

9. Digital Personal Data Protection Act, 2023 & IT Act, 2000 (with Rules) : [9,10]

DPDP Act, 2023, governs processing of digital personal data in India. Purpose of the Act is to protect patient confidentiality and privacy in the digital era. To create a legal framework for

handling health data in electronic health records (EHRs), telemedicine, cloud storage, and hospital management systems. To prevent data misuse, identity theft, and unauthorized sharing with insurers or pharma companies

The Act applies to hospitals, clinics, labs, insurers, and telemedicine platforms handling patient data. It introduces principles of consent-based processing, purpose limitation, data minimization, and lawful usage. It requires explicit consent from patients before collecting/processing health records, except in emergencies or for legal obligations. The Act recognizes rights of individuals: access, correction, erasure, grievance redressal, and nomination.

Data Fiduciaries (e.g., hospitals) must maintain safeguards; Significant Data Fiduciaries (large hospitals/health chains) require DPO appointments and audits. IT Act, 2000 & Rules (SPDI Rules, 2011): Treats medical records as sensitive personal data. Mandates reasonable security practices, privacy policies, and breach reporting.

IT Amendment Act, 2008: Strengthened provisions for cybercrime, data security, and electronic signatures. DPDP Act, 2023 replaces fragmented data rules, aligning closer with global standards (like GDPR), but tailored to Indian context.

Exemptions for processing without consent in case of medical emergencies. Compliance with court orders, laws, or public health emergencies. And for research or statistical purposes (with anonymization). Government retains powers for data access in interest of national security, public order, or prevention of offences. Hospitals acting in good faith under medical/public health duties protected.

Conclusion

Hospitals operate at the intersection of healthcare and law, where compliance with legislations is not only a statutory duty but also an ethical imperative. The diverse Acts and rules governing management, medical staff, patient care, infrastructure, and waste management collectively safeguard patient rights, ensure staff welfare, and uphold institutional accountability. City-specific requirements further emphasize the need for administrators to remain vigilant and well-informed. By understanding and adhering to these legal frameworks, hospitals can reduce risks, build public trust, and provide safe, equitable, and sustainable care. Ultimately, legislation serves as both a guiding framework and a protective shield for the healthcare system, ensuring that hospitals remain reliable pillars of society.

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HEALTHCARE QUALITY MANAGEMENT IN GOVERNMENT HOSPITALS IN INDIA: AN OVERVIEW

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Abstract

Healthcare is seen among the largest expanding businesses in the Indian industry, experiencing spectacular increases in revenue as well as employment opportunities. Despite this growth, a critical question arises, is this expansion leading to better patient outcomes and improved healthcare quality? In response to this concern, the government started the National Health Policy (NHP) 2017, imagined as a fundamental document for policy makers with the aim of fulfilling India's national objectives and international obligations. In addition, it is important to increase the quality of healthcare for achieving health-related goals established by the Sustainable Development Goals (SDG). Though there is a continuous annual increase in government expenditure on healthcare. However, the current literature on healthcare quality management studies is mostly focused on private hospitals. Even today, government sector employees are equipped with high salaries, flexible work hours, and secure employment until retirement, which contrasts the performance-driven employment structure in the private sector. Additionally, patient satisfaction is indirectly influenced by the quality of clinical staff and physicians, which is mindfully prioritized in the private sector, but the government healthcare sector generally focuses on the core quality services, considering the cost of treatment and the mass population catered. Our study tends to recognize the current gap in quality management between government and private hospitals by identifying the major challenges and recommending industry-based practices and scope of improvement.

Keywords: Healthcare Quality Management, Government Hospitals, Physicians, Clinical Staff, Patient Satisfaction.

Introduction

In government health, the term quality in medicine is relatively recent. The "medical audit" was first used in the United States in the early 1900s, and it was the beginning of the call for high-quality care[1]. This project in 1918 also expanded into the "Hospital Standardization Program" and later the establishment of "Quality Assurance Activities" to improve the standards of effective medical care. These standards were set by the "Joint Commission on Accreditation of

Hospitals" in 1960[1]. Since 1946, the year it was established, the International Organization for Standardization (ISO) has also attracted significant interest from all over the world regarding its respective standards[1]. To develop and oversee an accreditation program for healthcare facilities, the Quality Council of India (QCI) established the National Accreditation Board for Hospitals and Healthcare Providers (NABH)[1]. Ensuring quality in healthcare implies that patients receive exceptional treatment, have access to qualified and skilled medical personnel, and are part of a patient-centered establishment. Patients have the right to clear information and education about their treatment, and their satisfaction should be evaluated regularly[1].

Moreover, the system seeks to empower patients to make informed health choices and to standardize healthcare practices. It emphasizes patient safety, addresses the needs of vulnerable populations, ensures secure transportation, and maintains continuity of care, all of which are essential for providing high-quality healthcare[1]. In India, the healthcare system is categorized into government and private/corporate sectors. Private and corporate hospitals, motivated by their objectives, promote a culture centered around quality and consistently pursue certifications for various accreditation standards. Recently, the relevance of these hospitals has grown considerably due to a marked increase in both their numbers and the quality of services they deliver[1].

Nonetheless, the government healthcare framework, which includes district hospitals, community health centers, primary health centers, and sub-centers, remains the backbone of healthcare nationwide[1]. Through the National Rural Health Mission (NRHM), and with accredited social health activists in place, a notable surge in the demand for health services is anticipated, necessitating that the system is adequately prepared to meet this challenge. Along with improving the healthcare system to meet the increasing patient load, quality enhancement should be the top priority in an effort to increase patient satisfaction levels[1].

In a bid to enhance patient outcomes, ensure safety, and optimize the utilization of available resources, healthcare quality management embraces various friendly techniques, systems, and procedures. India's government hospitals play an essential role in the delivery of healthcare services to a considerable percentage of the population. Sadly, barriers such as institutional inefficiencies, infrastructure issues, and resource shortages can complicate the delivery of the high levels of care that the patients need.

Health Services Categories.

Health services include a wide range of activities. Some of these activities can be categorized under various alternatives, while others are required to be provided by the government sector. We can classify governmentally provided health services into two main groups[2]:

(1) Classical government health, further categorized into the following:

a. Government health interventions based on populations: These efforts include extensive initiatives related to water supply, city sanitation, and vector (pest) control, such as draining wetlands and using insect repellent. A key activity in this area is the systematic collection and sharing of information about the health status of the population. This involves regularly gathering data on health conditions, conducting research on their causes, and engaging in rapid-response monitoring activities[2].
b. Preventive and government health promotion interventions. These services involve repetitive tasks such as immunizations, monitoring child nutrition, and conducting person-to-person Information, Education, and Communication (IEC) activities[2]. Paramedics, nurses, specialist health educators, and other relevant professionals typically perform these services[2].

(2) Curative services, which fall under the following other categories:

a. Ambulatory care: A large, albeit variable in quality, private sector as well as low-cost, routine services. TB detection is one such "secondary prevention" activity[2].
b. Hospital care: For "catastrophic" (cost) illnesses[2].

Concept of Quality in Healthcare

The hospital's quality concept involves a number of important dimensions, such as safety and timeliness. These include the delivery of evidence-based care, the use of available resources, equal access to care, and meeting the needs of the patient while preventing harm and making care timely[3]. For healthcare services, quality management strategies are defined as ‘quality control,’ ‘total quality management,’ and ‘quality assurance[3].

For hospitals, the most vital factors are the elimination of mortality, satisfaction of people using the hospital's services, and quality and promptness of treatment [[3]]. There should preferably be monitoring and evaluation of processes to ensure the greatest results. By following and understanding these principles, hospitals can improve their services, which in turn enables good health results and patient confidence. With most concepts and strategies of quality provided, achieving the high standards of quality in healthcare becomes immensely relevant[3].

India's Healthcare Growth and Structure

The healthcare sector in India is experiencing substantial development and is anticipated to reach a value of US$280 billion by 2020 (World Health Organization, 2006). The country has a comprehensive universal healthcare system, which is mainly administered by the various states and union territories[4]. Additionally, some of the nation's leading hospitals are directly operated by the federal government[4]. This initiative began during the period of independence as part of the effort to nationalize essential services. Patients receive treatments including consultations with doctors, laboratory services, and medications at no cost[4]. Nevertheless, in recent years, many government hospitals have adopted a multitier system that allows patients who are willing to pay

for enhanced services, such as air-conditioned and multimedia-equipped rooms (Bhat, 1993)[4]. India's healthcare system is managed by the Ministry of Health and Family Welfare. The Department of Health, the Department of Family Welfare, and the Department of Ayush, which focuses on complementary and alternative medicine like Ayurveda, homeopathy, and Siddha, are the three primary divisions that make up this ministry[4].

Our top goal is your health, and we are committed to ensuring that everyone receives high-quality treatment. Everyone should be able to use necessary medical care without any difficulty. Because of this, it provides free or inexpensive healthcare through a vast network of basic, secondary, and tertiary care institutions run by the state of India. In addition, there is a large private healthcare industry that includes various types of establishments, such as regular hospitals, special clinics, and private medical offices run by individual doctors[5].

Quality Challenges in India's Government Hospitals

India's government healthcare, while mostly free, suffers from many challenges, which negatively impact the quality of the offering. Lack of qualified medical professionals, insufficient infrastructure, and differences in health care between urban and rural areas are the main reasons for anxiety[6]. Rural communities face a serious problem with insufficient health services, often caused by incorrect diagnosis, misunderstanding of the personnel, and administration of incorrect drugs. These problems are extended from corruption, especially when medical workers take unauthorized leave. In addition, disease transmission is made smooth by the abundance of congested clinics, lack of beds, and inadequate employees[2].

Progress in India's Government Hospitals

In recent years, the Indian healthcare system has made remarkable progress in enhancing health outcomes and expanding access to healthcare services, despite the numerous challenges it faces. Thanks to various government initiatives, programs, and regulations, all Indians now benefit from improved access to high-quality healthcare[6]. Due to these initiatives and changes, India's healthcare system is constantly changing. Even though many obstacles are still being overcome, such as the high prevalence of diseases and inequalities in access to the healthcare system, continuous investment and development in the region are optimistic for the next phase of India's healthcare system. To ensure that the benefits of these programs get to their targeted groups and lead to long-lasting reforms in health results, it is necessary that committed work and money continue[6].

Key Health Expenditure Estimates for India (2021-2022)

In India, health accounts expand the flow of finance and medical expenditure for a given financial year[7]. Current Health Expenditure (CHE) and its specifics (1) are explained in terms of the money received from the healthcare finance scheme, which is made up of organizations that supply funds for the purchase of medical supplies and services within the healthcare system; (2)

Healthcare Financing Scheme: these are organizations that receive and oversee funds from funding sources to purchase or pay for medical goods and services; (3) Healthcare Provider: these organizations receive funding to manufacture or offer medical goods and services; and (4) Healthcare Function: this defines how money is distributed among various healthcare services[7].

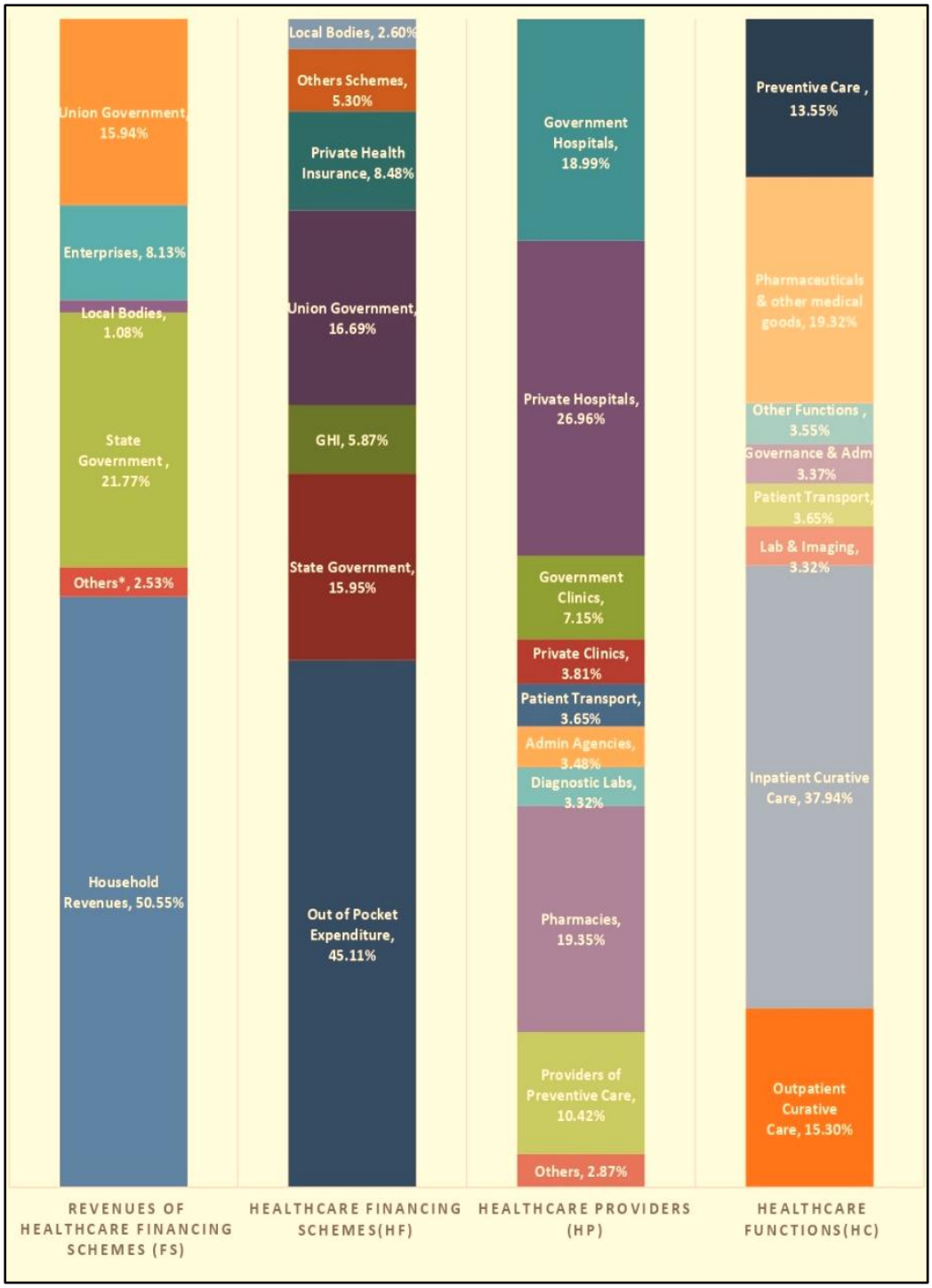

Figure 1: Current Health Spending Distribution by Healthcare Financing Schemes, Healthcare Financing Scheme Revenues, Healthcare Providers, and Healthcare Functions (%) for year (2021–2022)[7]

The quality of services in government hospitals is obtained from Figure 1, which reflects the distribution of current health expenditure in India for 2021-2022. In particular, private hospitals earn a higher percentage of expenses (26.96%) of healthcare providers than government hospitals, which get only 18.99%. This discrepancy may suggest that government hospitals have been reduced, which may have an impact on the standard of treatment, that they are able to introduce due to lack of funds for staffing, infrastructure, and equipment. Additionally, out-of-pocket expenses account for the biggest stake of healthcare funding schemes (45.11%), indicating that people bear a significant financial burden that may discourage them from receiving necessary care, especially if quality perception is poor in government facilities. In terms of healthcare functions, medicines and other medical products (19.32%) and input curative treatment (37.94%) get a larger share than preventive care (13.55%). Increased funds for preventive services in government hospitals can increase overall health results, as this allocation may suggest a reactive rather than an active approach to healthcare.

Table 1: Key metrics for health funding in a few states: NHA projected for year 2021-22[7].

S. No.	State	Total Health Expenditure (THE)			Government Health Expenditure (GHE)					Out of Pocket Expenditure (OOPE)					Popula-tion	GSDP	GGE
		In crores	% of GSDP	Per Capita Rs.	In crores	% of THE	% of GSDP	% of GGE	Per Capita Rs.	In crores	% of THE	% of GSDP	% of GGE	Per Capita Rs.	in Crores		
1	Assam	14,967	3.6	4,276	9,634	64.4	2.3	9.4	2,753	4,129	27.6	1.0	4.0	1,180	3.5	4,12,612	1,02,674
2	Andhra Pradesh	39,067	3.4	7,371	16,582	42.4	1.5	9.4	3,129	20,320	52.0	1.8	11.6	3,834	5.3	11,33,837	1,75,536
3	Bihar	29,543	4.5	2,383	16,374	55.4	2.5	9.0	1,320	12,205	41.3	1.9	6.7	984	12.4	6,50,302	1,82,898
4	Chhattisgarh	14,601	3.6	4,867	8,819	60.4	2.2	10.3	2,940	4,257	29.2	1.0	5.0	1,419	3	4,06,416	85,514
5	Gujarat	38,894	2.0	5,556	19,385	49.8	1.0	10.3	2,769	13,596	35.0	0.7	7.2	1,942	7	19,37,066	1,88,606
6	Haryana	21,161	2.4	7,054	9,710	45.9	1.1	8.9	3,237	7,941	37.5	0.9	7.3	2,647	3	8,70,665	1,09,471
7	Jammu and Kashmir	8,546	4.3	6,104	6,071	71.0	3.0	8.6	4,336	2,213	25.9	1.1	3.1	1,581	1.4	1,99,917	70,316
8	Jharkhand	18,430	5.1	4,726	9,056	49.1	2.5	12.6	2,322	8,749	47.5	2.4	12.1	2,243	3.9	3,58,863	72,155
9	Karnataka	50,956	2.6	7,605	21,837	42.9	1.1	8.5	3,259	12,954	25.4	0.7	5.0	1,933	6.7	19,62,725	2,57,302
10	Kerala	48,034	5.2	13,343	15,618	32.5	1.7	9.7	4,338	28,400	59.1	3.0	17.7	7,889	3.6	9,32,470	1,60,371
11	Madhya Pradesh	34,112	3.0	4,013	17,708	51.9	1.6	8.0	2,083	14,781	43.3	1.3	6.7	1,739	8.5	11,36,137	2,21,794
12	Maharashtra	1,04,518	3.4	8,361	35,895	34.3	1.2	9.1	2,872	39,796	38.1	1.3	10.0	3,184	12.5	31,08,022	3,96,356
13	Odisha	26,445	3.9	5,749	14,108	53.3	2.1	10.7	3,067	9,810	37.1	1.5	7.4	2,133	4.6	6,70,881	1,32,313
14	Punjab	19,249	3.1	6,416	6,900	35.8	1.1	6.6	2,300	11,005	57.2	1.8	10.5	3,668	3	6,14,227	1,04,646
15	Rajasthan	44,159	3.6	5,520	22,041	49.9	1.8	9.4	2,755	16,385	37.1	1.3	7.0	2,048	8	12,18,193	2,33,942
16	Tamil Nadu	50,779	2.5	6,595	26,257	51.7	1.3	9.0	3,410	17,554	34.6	0.8	6.0	2,280	7.7	20,71,286	2,91,041
17	Uttar Pradesh	1,09,811	5.6	4,733	34,720	31.6	1.8	8.5	1,497	69,932	63.7	3.5	17.1	3,014	23.2	19,74,532	4,09,024
18	Uttarakhand	6,391	2.3	5,810	4,341	67.9	1.6	9.3	3,946	1,716	26.9	0.6	3.7	1,560	1.1	2,72,159	46,462
19	West Bengal	67,361	4.9	6,874	24,051	35.7	1.8	10.6	2,454	39,295	58.3	2.9	17.3	4,010	9.8	13,63,926	2,27,644
20	Telangana	24,753	2.2	6,514	11,427	46.2	1.0	6.9	3,007	9,305	37.6	0.8	5.6	2,449	3.8	11,28,907	1,65,678
21	Himachal Pradesh	6,798	3.9	9,711	3,907	57.5	2.2	9.3	5,581	2,691	39.6	1.5	6.4	3,844	0.7	1,76,269	42,224

Figure 2 GDP reflects the total health expenditure in crores per state of Gross State Domestic Product (GSDP) and Out-Of-Packet Expenditure (OOPE). State-by-state variations in OOPE indicate the availability of government health services and variation in caliber. Some states show that people are turning to private hospitals for treatment because they believe government hospitals are inadequate. This can be challenging to provide necessary resources in states with infrastructure, maintain employee hospitals, and with low overall expenses (as the ratio of GDP), which can affect the quality of treatment. By comparing states, the best practices can be found; People with high health costs and lower OPH may have applied successful policies, which can be used to increase healthcare standards and reduce financial stress on individuals. The data

emphasizes the need for effective quality management systems in government hospitals, to upgrade infrastructure, better service distribution, and encourage patients to focus on happiness, promote confidence, and ensure better health results.

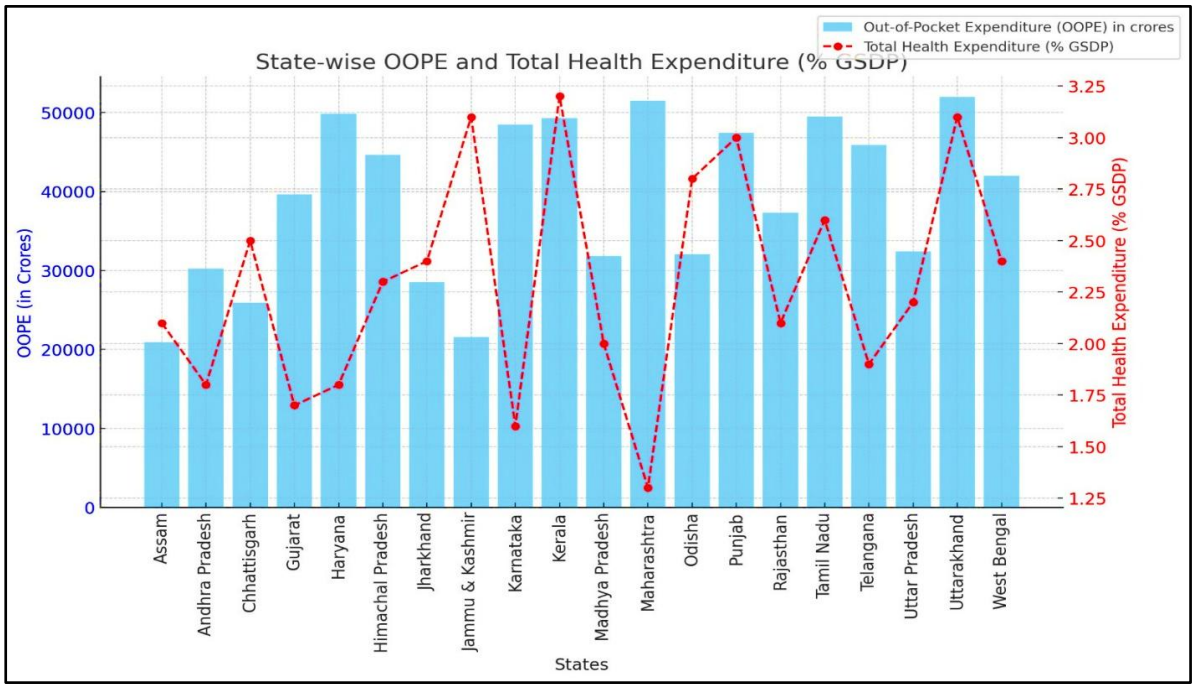

Figure 2: Key metrics for health funding in a few states: NHA projected for year 2021-22

Improvements in India's Government Hospitals

The National Urban Health Mission (NUHM) and the National Rural Health Mission (NRHM) are part of the National Health Mission (NHM), which was launched in 2013. NHM aims to improve primary healthcare by constructing and upgrading facilities, increasing access to medical supplies, and enhancing the health workforce through education and hiring in rural areas. It also emphasizes mother and child health-related services, including vaccination and prenatal care. To address both communicable and non-communicable diseases, NHM also runs a government health program. NHM received more than 290 billion Indian rupees for the financial year 2024[8].

Ayushman Bharat, which began in 2018, is a major healthcare initiative in India, including Pradhan Mantri Jan Arogya Yojana (PMJY) and Health and Wellness Center (HWC)[8]. The program aims to provide disadvantaged people with financial and medical safety[8]. More than 117,000 HWCs provide free clinical services, essential medicines, and telecommunications by December 2022. The PMJAY health insurance program provides coverage for secondary and tertiary hospitalization expenses up to INR 5 lakhs per family each year. This program supports around 500 million people from 100 million families facing economic challenges. Its goal is to lower out-of-pocket costs and improve access to high-quality healthcare services[6]. Additionally, over 217,000 government health facilities operated in India by fiscal year 2022, with outpatient departments delivering more than 1.4 billion services, a notable increase from the previous year[8].

Non-communicable diseases are increasing in India, due to which efforts have been made to prevent and treat them, promote health, and make special treatment attempts through campaigns. By the end of the financial year 2018, about 35 percent of Indian health insurance was covered by Indian health insurance, a small increase from 33% a year ago. By the financial year 2021, around 514 million Indians were covered under health insurance policies, with a premium for a total government-supported scheme of about 43 billion Indian rupees[8].

India has seen many examples of healthcare innovation in the spectrum, spread from new care models to budget-friendly medical devices. These measures save long-lasting costs in addition to the increased quality of care. The new standard of self-regulation that controls India's health services ensures the safety of the patient as well as encourages the best from doctors. Such improvements are to keep care cheap. These rules are the driving forces behind why new products are designed[9].

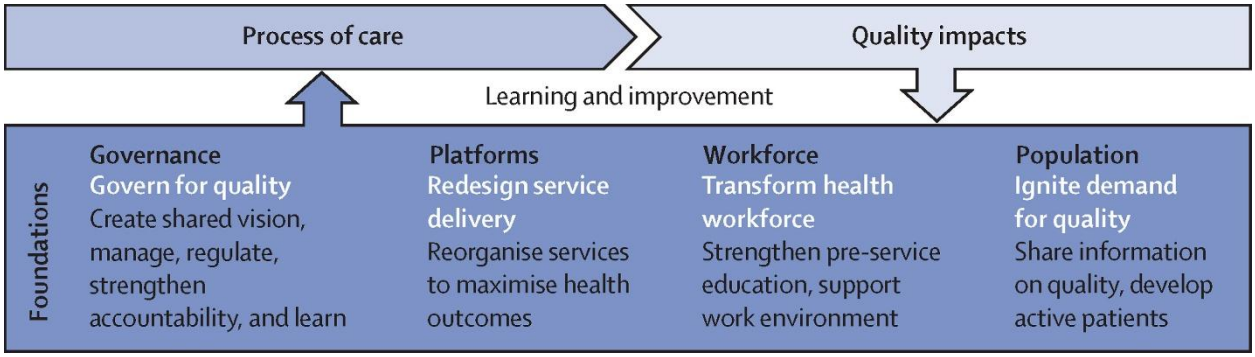

Figure 3: Universal actions for improving quality of care[10]

Indian Healthcare Evolution

The effectiveness, efficiency, and quality of healthcare organizations are evaluated through the internationally recognized recognition process. Certification has been established on the basis that the following evidence-based standards will increase health services in a rapidly safe environment. Additionally, it acts as a government acceptance that a health facility has achieved both international and national quality standards[11]. A comprehensive healthcare standard has been developed for hospitals and healthcare providers, such as India's Quality Council and institutions like hospitals and health service providers, for institutions such as the National Recognition Board. Hospitals are evaluated against over 600 criteria, which are divided into operational standards and patient-centric standards[12]. Accreditation is a government recognition of the achievement of a health organization that complies with the prescribed standards and has been detected through an independent external colleague review of its performance. The advantages of recognition are for all, but the biggest benefit is for patients. Ultimately, it promotes high-quality care and improves the patient's safety[11].

Quality Boost for Government Hospitals.

After many years of research into production and service delivery through the use of control charts and other statistical tools, quality specialists have recently begun to introduce a series of managerial principles designed to enhance quality. These principles include (1) the elimination of unnecessary variation; (2) a focus on processes as the key areas for improvement; (3) active and government support from both managerial and clinical leadership for the continuous development of quality; and (4) updated practices for managing personnel. The fundamental principle of quality improvement within healthcare organizations is that senior clinical and administrative leaders must explicitly and actively cultivate a culture of ongoing enhancement in the quality of care and services. Achieving this objective is fraught with significant challenges. Healthcare leaders are frequently compelled to prioritize pressing issues such as cost containment, nursing shortages, malpractice concerns, and various other factors, often resulting in temporary solutions that detract from a long-term commitment to quality improvement. This dilemma is especially evident within healthcare organizations confronting substantial financial constraints. Consequently, many chief executive officers exhibit hesitation in dedicating the necessary time and resources required to initiate and sustain effective quality improvement initiatives[13].

Quality professionals suggest that, alongside resource allocation, leadership should proactively manage the initiative by assessing its progress, implementing necessary adjustments, educating participants, and acknowledging their contributions. While quality management principles have been validated in many fields, they have yet to achieve the same experimental confirmation in the healthcare industry. As a result, healthcare organizations may need to adopt unconventional leadership strategies to run effective quality management. According to quality experts, the second fundamental principle of quality improvement is that individuals should emphasize procedures rather than individuals[13].

Conclusion

To effectively meet the requirements of a diverse and expanding population, it is imperative that India's government hospitals enhance their management of healthcare quality. While numerous challenges persist, the transformation of government healthcare is achievable through the implementation of innovative practices, robust legislation, and stable funding mechanisms. People's health can improve a lot and reduce their financial burden by implementing strong and successful evidence-based health enrichment programs. The plague of chronic diseases and injuries should be a top government priority, and if the UHC and SDG goals are to be met, then there should be a major issue in the conscience of the country. A concrete effort associated with communities, healthcare professionals, and government institutions is necessary for all citizens to ensure high-quality management and equal access to cheap healthcare.

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EMERGING AND FUTURE DIRECTIONS IN HEALTHCARE MANAGEMENT

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Abstract

As we navigate through 2026, healthcare management stands at the crossroads of unprecedented innovation and persistent challenges. Driven by rapid advancements in artificial intelligence (AI), digital health technologies, and shifting economic models, the industry is transforming to prioritize patient-centric, efficient, and equitable care. This chapter provides an in-depth exploration of key trends, including the scaling of AI and agentic systems, the evolution of value-based care, the rise of personalized medicine, workforce reinvention, and cross-sector collaborations. Drawing on insights from leading reports and analyses as of early 2026, it examines how these directions are reshaping operational strategies, enhancing outcomes, and addressing issues like rising costs, workforce shortages, and health disparities. Ethical considerations, regulatory landscapes, and future projections are woven throughout, offering healthcare leaders a comprehensive guide to fostering resilient, sustainable systems in a dynamic environment.

Keywords: Healthcare management, Artificial Intelligence, Tele-health, Blockchain and Value Based Care.

Introduction

Healthcare management in 2026 feels like steering a ship through foggy waters—exciting yet demanding careful navigation. The lessons from recent years, including the lingering impacts of global pandemics and economic pressures, have pushed the industry toward bold reinvention. Managers aren't just overseeing day-to-day operations; they're architects of systems that blend cutting-edge technology with human empathy to deliver better care at lower costs.

Recent outlooks highlight a mix of optimism and caution. For instance, payers and providers are grappling with headwinds like inflation and regulatory changes, but opportunities abound in areas like health services technology (HST), specialty pharmacy, and new care models. Executives surveyed in late 2025 anticipate that generative AI, care delivery transformation, and industry convergence will significantly influence strategies this year. This chapter dives deeper into these emerging and future directions, expanding on digital transformation, AI integration, value-based care, personalized therapies, workforce dynamics, ethical imperatives, and more. We'll explore real-world implications, potential pitfalls, and actionable insights in a way that's relatable and grounded in current realities.

Digital Transformation and Consumer-Centric Care

The digital revolution in healthcare isn't slowing down—it's accelerating, putting consumers firmly in the driver's seat. In 2026, organizations are prioritizing seamless digital experiences to empower patients, from intuitive apps for appointment scheduling to virtual reality tools for mental health support.

Telehealth and Hybrid Care Models

Telehealth, once a pandemic lifeline, is now embedded in everyday care. Hybrid models blending virtual and in-person visits are standard, allowing for flexible access that reduces wait times and travel burdens. For example, remote patient monitoring (RPM) via wearables tracks vital signs in real-time, alerting providers to issues before they escalate. This shift not only improves patient satisfaction but also cuts costs—studies show RPM can reduce hospital readmissions by up to 38% in chronic care cases. Looking ahead, expect further integration with smart home devices, creating "ambient" health monitoring where your environment passively supports wellness.

Digital Twins and Blockchain

Emerging technologies like digital twins—virtual replicas of patients, organs, or even entire hospitals—are enabling simulated treatments and predictive analytics. This could revolutionize surgical planning, minimizing risks and personalizing interventions. Blockchain is gaining traction for secure data sharing, ensuring interoperability across systems while protecting privacy. In management, this means streamlined operations, like automated claims processing that reduces administrative overhead.

Challenges and Future Outlook

However, digital transformation isn't without hurdles. Cybersecurity threats are rampant, with breaches emphasizing the need for robust protections. Managers must invest in scalable infrastructure and staff training to bridge the digital divide, ensuring rural and underserved populations aren't left behind. By 2030, experts predict a fully interconnected ecosystem where digital tools prevent 60% of chronic disease complications through proactive interventions.

Artificial Intelligence and Advanced Analytics

AI is the game-changer everyone's talking about, evolving from supportive tools to autonomous agents that reshape how decisions are made and care is delivered.

Generative and Agentic AI

Generative AI (gen AI) is scaling across functions, from drafting patient notes to analyzing imaging for faster diagnoses. Agentic AI takes it further—these systems observe, plan, and act independently, handling tasks like triage or workflow optimization with minimal oversight. In clinical settings, AI agents could manage chronic conditions by adjusting treatment plans in real-time based on data feeds. For managers, this means efficiency gains: AI in revenue cycle management automates billing, reducing errors and speeding reimbursements.

AI in Decision-Making and Operations

The shift in decision-making power is profound—from clinicians alone to a collaborative triad of patients, providers, and AI. In operations, AI-powered intelligence is evolving from basic analytics to trusted systems that predict staffing needs or optimize supply chains. Payers are under pressure to adopt AI admin stacks to keep pace with providers, driving widespread adoption.

Ethical Governance and Future Projections

Ethics are front and center: Bias in algorithms must be mitigated through diverse training data and transparent processes. By 2027, AI could add $150-260 billion in value to U.S. healthcare annually, but only if governance keeps up. Future directions include AI-driven drug discovery, slashing development times from years to months, and universal applications like predictive epidemiology for outbreak prevention.

Value-Based Care and Financial Strategies

Value-based care (VBC) is maturing, focusing on outcomes over volume, but it's facing a potential "thaw" after recent slowdowns.

Expansion of VBC Models

In 2026, VBC is an accountability standard, with reimbursements tied to quality metrics like patient satisfaction and readmission rates. This encourages preventive care, such as community programs addressing social determinants of health (SDOH). Managers are redesigning policies to integrate SDOH, promoting equity and long-term savings.

Financial Innovations and Cost Management

Rising expenses from inflation and emerging therapies are top concerns. Automation via AI is key for cost containment, enabling real-time payments and efficient spend management. Specialty pharmacy and HST are growth areas, with $1 trillion shifting toward scalable, tech-driven models by 2035.

Policy and Market Shifts

Policy changes, like new PBM rules, will test market access strategies. AI could revive VBC by providing tools for better risk management and outcomes tracking. Future outlook: Longer demonstration periods for VBC pilots to encourage participation.

Personalized Medicine and Emerging Therapies

Personalization is the future, tailoring treatments to individual genetics, lifestyles, and needs.

Next-Generation Treatments

GLP-1 medications are expanding beyond diabetes to tackle obesity and cardiovascular risks, ushering in longevity medicine. Cell and gene therapies are transforming cancer care, with mRNA vaccines and radiopharmaceuticals on the rise. Aging-in-place tech, like AI-assisted home care, supports seniors independently.

Integration with Digital Health

Digital health interventions (DHIs) are reducing hospitalizations through self-management apps, though adoption varies by demographics. Future: Universal cancer vaccines and AI-optimized therapies could redefine chronic disease management.

Workforce Reinvention and Operational Resilience

Healthcare's backbone—the workforce—is undergoing transformation to combat burnout and shortages.

Addressing Burnout and Skill Gaps

AI-assisted workflows are alleviating administrative burdens, allowing clinicians to focus on care. Labor reinvention includes upskilling for tech integration and flexible models like gig nursing.

Shifting Sites of Care

From hospitals to homes, care is decentralizing, driven by patient preference and cost savings. Managers must adapt operations for this, emphasizing real-time orchestration.

Health Equity and Ethical Considerations

Equity is non-negotiable. Trends like addressing SDOH and bias-free AI aim to close gaps. Ethical frameworks for AI include privacy safeguards and inclusive design.

Future of Medical Futures Studies

A new subfield, "Medical Futures Studies," uses foresight methods like scenario planning to anticipate challenges. This proactive approach could unlock untapped potential in policy and innovation.

Cross-Industry Collaborations and Convergence

Convergence—partnerships between tech, pharma, and providers—is key. Think Google Health teaming with hospitals for AI tools. Future: M&A in targeted regions to scale innovations.

Conclusion

In 2026, healthcare management is about intelligent reinvention—leveraging AI, digital tools, and collaborative models to create proactive, personalized systems. Challenges like costs and equity persist, but opportunities for growth are immense. By focusing on adaptability, ethics, and patient empowerment, leaders can build resilient futures. Looking to 2035, expect $1 trillion shifts toward automated, accessible care, redefining health as a lifelong journey rather than episodic treatment.

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STRENGTHENING PRIMARY HEALTHCARE QUALITY THROUGH NQAS: INSIGHTS FROM AYUSHMAN AROGYA MANDIR ASSESSMENTS ON IMMUNIZATION SERVICES PROVIDED

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Abstract

The National Quality Assurance Standards (NQAS) represent a structured framework by the MoHFW to institutionalize quality improvement in public healthcare facilities across India. Till June 2025, 30069 AAMs across India have been certified. We tried to assess the immunization components of NQAS. To assess the implementation and performance of immunization services under NQAS to identify key strengths, gaps, and opportunities for improving quality of immunization services. We analyzed findings from NQAS assessments for selected 5 Ayushman Arogya Mandirs on immunization services provided on six thematic areas: service provision, patient rights, inputs, support services, clinical care, and quality management. Data were reviewed from assessment checklists, facility records supplemented by interactions with ANMs. Data analyzed using MS Excel. A dedicated area for immunization in all AAM with 100% availability of all vaccines and logistics with ANM adhering to standard Immunization protocols noted. Outreach activities for immunization advocacy were satisfactory with a score of 4.5. However gaps remain in AEFI management, Performance Indicators generation with scope for follow up for Missed beneficiaries. NQAS implementation has contributed significantly to improving the quality of care in 5 assessed AAM. Sustained efforts in capacity building for immunization services, regular monitoring with follow up are essential to ensure long-term gains in form of 100% full immunization. Findings provide actionable insights for strengthening quality immunization service delivery to save lives from vaccine preventable diseases.

Keywords: NQAS (National Quality Assurance Standards), AAM (Ayushman Arogya Mandir), Immunization, Quality.

Introduction

The Primary healthcare sector is one of the most important foundation platforms to ensure an efficient, effective and equitable health care system. With the increase in research in healthcare, it is now seen in the global context that several countries have now recognized the importance of identifying that the achievement of universal health coverage lies in the strengthening of the primary health care system and not just focusing on the secondary and tertiary health services. Strengthening the health systems will also be a cornerstone in reducing the preventable mortality saving precious lives improving the population's health outcomes.

Indian health care delivery system has different dynamics. Its primary services play a critical role in delivering the priority public health intervention like maternal and child health along with communicable and noncommunicable diseases focusing on disease prevention through immunization, disease screening and health promotions. The grass root level workers, especially the ASHAs & ANMs, are the strong pillars providing the preventive services at field level.

India has seen success in the health in terms of achieving milestones while controlling, eliminating and eradication many diseases. Among these public health interventions bringing success to India, Immunization becomes one of the greatest impactful programs which has averted many precious lives preventing childhood mortality and morbidity. The list of achievements starts with eradication of smallpox, Wild polio type 2, Wild Polio type 3 and elimination of maternal and neonatal tetanus. Thus, proving that immunization is one of the best cost effective and feasible solutions saving millions of deaths and millions of dollars.

Immunization program in India was started in 1978 with BCG and DPT vaccine with a focus on urban areas. Later it was extended to all areas including rural areas with addition of Measles vaccine in 1985 and the name for the program was given as Universal Immunization program (UIP). Newer Vaccines were added from time to time based on the evidence generated through research and vaccination coverage. As on today there are 11 vaccines given through UIP for 12 diseases namely Tuberculosis, Polio, Hepatitis-B, Diphtheria, Pertussis, Tetanus, Hemophilus Influenzas, Pneumococcal Pneumonia, Rotavirus Diarrhea, Measles, Rubella and Japanese Encephalitis. The vaccine Japanese Encephalitis (JE) among the 11 vaccines is given in selected endemic areas. The immunization program of India is recognized as the largest immunization program globally.

With lot of achievement there are certain barriers and challenges which affect the service delivery and quality of the immunization program being ongoing on a routine basis. There are geographical issues related to access, vaccine acceptance, vaccine hesitancy issues raising a concern for demand generation in the community. Further the availability of trained health care workforce, insufficient monitoring systems and fluctuations in the adherence to the standard operating protocols, vaccine supply chain management along with use of technological assisted platforms have a bigger scope in improvement of the vaccination.

The immunization being a routine process cannot be stopped as the birth cohort is added every single minute, and every single newborn thus gets exposed to the harmful pathogens. The regular immunization coverage is very important to look at as there are ups and downs in the coverage based on the programmatic implementation strategies mostly requiring attention to the quality dynamics of immunization like beneficiary counselling, cold chain maintenance, safe injection practices, infection prevention measures, adverse events management and lastly reporting and documentation.

As there was a growing concern about the quality assurance in the health care and how it could be institutionalized the Ministry of health and family welfare introduced the National Quality Assurance standards (NQAS). The National Quality Assurance Standards (NQAS) were launched in 2013 with an aim to improve the Quality of Care in Public Health Facilities of India(1).Taking a base of the NHP 2017 which has its objective clearly advocating to Improve health status with a concentrated policy action in all sectors with a scope to expand all the services right from preventive, promotive, curative, palliative and rehabilitative services through government health facilities with emphasis on Quality NQAS framework was developed. The National Quality Assurance Standards are broadly arranged under 8 "Areas of Concern"– Service Provision, Patient Rights, Inputs, Support Services, Clinical Care, Infection Control, Quality Management and Outcome. These standards are ISQUA accredited and meets global benchmarks in terms of comprehensiveness, objectivity, evidence and rigor of development (2). Later with the launch of the Ayushman Bharat Scheme in 2018 there was a major shift noted wherein comprehensive primary health care services were given importance in India. Provision of these services would be provided through the Sub health centers which are now been upgraded to the Ayushman Arogya Mandir-AAM (Previously known as Health and Wellness Centers-HWCs). The concept of AAM revolved around provision of quality services close to the community breaking the barriers of accessibility and affordability providing the very basic health services of Maternal and child health services including non-communicable diseases, provision of essentials drugs, basic diagnostics, health promotion activities along with one of the most important preventive services the routine immunization through the Auxiliary Nurse Midwife (ANM) in joint teamwork with the Community health officer(CHO) and the frontline workers like ASHA and AWW.

It is noted that child immunization remains a critical component of primary healthcare and it is thus important to regularly assess the service for its quality under the NQAS framework. The NQAS assessments framework provides valuable opportunities to gauge the operational systems implemented at field level identifying the bottlenecks in the form of challenges, barriers so as to come with targeted interventions to ensure strengthening of the service delivery processes. These assessments thus provide evidence for program improvement and policy development.

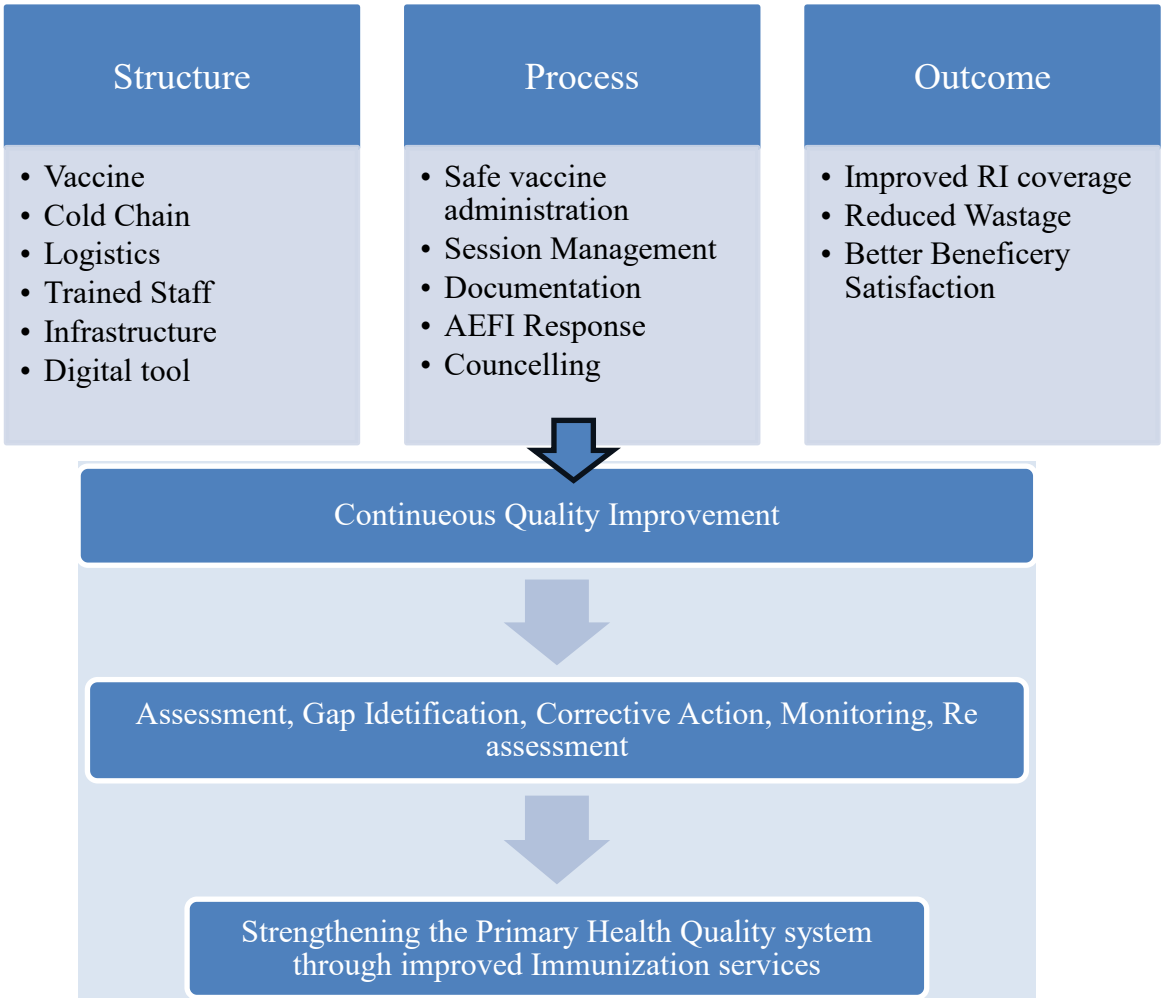
This chapter presents an analysis of immunization-related findings from NQAS assessments conducted in five selected Ayushman Arogya Mandirs between November 2025 and January 2026. The chapter explores key strengths, challenges, and opportunities for strengthening immunization quality within primary healthcare settings.

Theoretical Framework

The study is based on the Donabedian's Model of Quality of Care which basically takes the Structure–Process–Outcome into consideration. As per the model, the healthcare quality

outcomes are dependent on the adequacy of structural inputs and the effectiveness of service delivery processes.

The framework is further supplemented by the WHO Health System Building Blocks and Continuous Quality Improvement principles embedded within the National Quality Assurance Standards (NQAS). The framework when applied to the Ayushman Arogya Mandirs, enables the assessment of how quality assurance mechanisms influence the immunization service preparedness, the delivery practices and programmatic outcomes.



Review of Literature

A study by Swarnkar in 2016 on assessment of knowledge and practice about immunization had 144 respondents of which 96.5% were ANMs working at sub centers. The researcher found that the respondents have very good knowledge on the diseases preventable by the vaccination. The measurable outcome was more than 75% with respect to the knowledge. But when the knowledge was assessed on anaphylaxis it was found to be very poor with below 25% on measurable outcome. (3)

A 2021 study by Ernest SK on the knowledge and practice with respect to injection safety related to immunization services by health workers found that 58% thought only children receiving

immunization were at risk of a disease, 58.3% know that needle stick injury can also transmit the diseases. Reasons for existing unsafe injection practices revealed that 27% suggested inadequate provision, 18.3% suggested poverty, 17.7% ignorance about the needle stick injury and its consequences, 17.2% suggested improper disposal, 11.8% suggested lack of surveillance and health supervision for workers. Details on disposal of syringes and needles when explored revealed that 53.2% knew about waste burning only, 2.1% know about waste burying while 44.7% know both burning and burying methods. Very few with less than 9% knew that auto-disable syringes are used in immunization programs. The bundling approach used for vaccine supply at implementation site which is laid down jointly by WHO and UNICEF was known to 38.9% staff. 50% of respondents accepted of having limited facility for disposal of immunization waste at their health centers. 45.6% of the staff use apron like protective clothing during service delivery. For safe injection practice 33.7% suggested refresher training of health workers, 16.8% proposed planning, budgeting and purchasing of auto-disable syringes, 16.5% advocated for social mobilization and 11% proposed the provision of disposal facility at health center. The study concluded that awareness on safe injection practices was low among the health workers, and they are at greater risk of needle stick injuries, HIV and other infections due to this ignorance and risky practices. Training in safe injection practices was thus recommended (4)

According to a study by Usman M in 2021 who tried to assessed whether the continuity in utilizing maternal health care services affects the immunization of children. A total of 33,422 women between age group 15- 49 with 8246 children aged 12-23 months were included in the study. 19% of the women were conscious about their health and received complete continuum of care. Higher education and higher economic condition was directly associated with better maternal services along with an increase in the immunization level of their children. 76% of the children whose mothers had undergone complete continuum of care were found to be fully immunized (5)

N.C. Gupta, K.G Rathod L.R. Garg in their study on Assessment of knowledge of multipurpose health workers regarding adverse events following immunization in a rural block of Haryana in 2019 found that 56% of the health workers knew about the correct storage temperature of diluents and risk of its contamination. Only 30% has correct knowledge about proper reconstitution of the vaccine with proper diluent. 33% of health workers actually know that an AEFI form has to be filled while reporting an AEFI event. Further the result showed that 25 respondents who were MPWs which account 83.5% of the respondents had experienced an AEFI in during work but only 14 (46.6%) reported the AEFI event in 24 hours to higher officers. It was detected that level of correct knowledge was decreasing with increasing age of respondents. (6)

A KAP study done by Hiremath G in 2023 regarding reporting of Adverse Events Following Immunization (AEFI) among healthcare with 247 respondents having a 95% response rate

showed that 65% were proficient with AEFI knowledge, 88% showed a satisfactory attitude toward reporting AEFI practices. Significant factors linked with knowledge distinction were found to be age, gender, prior training and service duration of the health worker. Attitude variations were correlated with age, AEFI knowledge and prior capacity training. (7)

A cross-sectional study done by Pragya dixit in 2024 on AEFI among children below 2yrs post pentavalent vaccination had 209 mothers as respondent. 100% mothers were educated about occurrence of AEFI post vaccination. All mothers were found motivated to continue vaccinating their children for further doses. No serious or sever AEFI was noted except some minor one. Proper counselling on benefits of vaccines outweighed the AEFI observed and the mothers were willing to continue vaccinating their children even after the occurrence of AEFI (8)

Bhaskar and Solanki in a study to assess quality of outreach session through supervision and monitoring in 2020 interviewed 110 mothers, 20 ANMs coming to 50 outreach immunization sessions in Mumbai. Around 75.4% of mothers had better knowledge about the outreach services provided. The quality parameters for session implementation were found to be good by the assessors. The health workers acknowledged the increase of immunization coverage due to outreach session. The assessment also found full immunization of 89% for the eligible children checked (9)

A study on documentation of vaccine handling and service delivery at 136 outreach sessions across 27 districts from 3 states (Bihar-62, Gujarat-43 and Kerala-31) of India done in 2018 by M K Das et all showed that all necessary vaccines was available at 59.7% and logistics at 52.2% sessions. At the sessions sites beneficiary turnout was around 72.6%. The matching diluents for BCG, MR JE vaccine were available at 94.4% sessions. 4 Key message delivery was noted at 58.8% sessions while only 40% beneficiaries were advised to wait for 30 minutes post vaccination to observe any AEFI. Some session sites received vaccine vials with unusable vaccine vial monitors. The study further raised a concern on improvement in vaccine handling and logistics management to ensure optimal service delivery and better beneficiary experience. It also focused on the supportive supervision and monitoring strengthening activities on availability of updated due list, proper vaccine handling, counselling to beneficiaries and proper waste handling and disposal (10)

An Evaluation of session sites of routine immunization program in Damoh district of Madhya Pradesh by R K Gupta in 2018 assessing 36 session sites showed that the availability of Auto disable syringe of 0.1 ml and 0.5 ml was not adequate. Advancing a worry on safe injection it was seen that functional hub cutter was available at 30(83.3%) session sites. Due list of beneficiaries was available with 33 (91.6%) ANMs and 26 (72.2%) with ASHA workers. Availability of BCG noted at 20 (55.5%) and IPV at 27 (75%) sessions. Vaccine was not properly stored at 2 sessions sites. Reconstitution time on vial applicable for non-open vial

policy vaccines was written at 30 (83.3%) sites. Date and time of opening vial was written at 32 (88.8%) session sites. Immediate use of hub cutter after every syringe use was done at 28 (77.7%) sessions by ANM. Four key messages delivery seen at 16 (44.4%) sessions while advice to wait for 30min post vaccination was given at 22 (61.1%) sessions by ANM. The immunization sessions demonstrated satisfactory organization with adequate availability of logistics and proper cold chain maintenance. However, vaccination practices were found to be unsatisfactory (11)

Analysis

The NQAS for an AAM has 8 Areas of concern. In this study out of the 8 Areas of Concerns points pertaining to Immunization from 3 areas of concerns were taken into consideration for the assessment.

1. Services provision

From the first area of concern the services provision point related to provision of the immunization services being provided as a part of comprehensive primary health care services was considered.

2. Support Services

From the second area of concern the support services, points related to provision of outreach activities related to the immunization services along with the local committee involved and factors related to the supervision and monitoring of the services was known.

3. Clinical services

The third area of concern, the clinical services, was one of the major area to consider as the maximum points related to the actual operational and implementation of the point related to provision of the immunization services being provided as a part of comprehensive primary health care services was assessed.

Total 18 questions related to the immunization services were taken into consideration with one question from service provision area, two questions from support services area and rest fifteen points were taken from the clinical services area of the NQAS assessment module for an Ayushman Aarogya Mandir who at least provides 9 Health Package services from the center.

The same scoring pattern for the NQAS assessment was applied here also with a score of 2 for full compliance, 1 for partial compliance and 0 for no compliance. The standard method used was Record review, Staff Interview and Observations. The 18 points which were scored were called checkpoints. The score allotted to these checkpoints was based on the standard assessment methods laid down in the NQAS assessment protocol.

The actual names of the Ayushman Aarogya Mandir are not disclosed to keep confidentiality.

Table 1: The scoring of the Ayushman Aarogya Mandirs (AAM)

Sr. No.	Checkpoints	Method used	Score (2-fully compliance, 1-Partical Compliance, 0-No compliance)				
			AAM -1	AAM-2	AAM -3	AAM -4	AAM -5
1	Availability of Immunization services	RR/SI	2	2	2	2	2
2	Jas provides support for Health Promotion and Preventive services	RR/SI	2	2	2	2	2
3	Check CHO provides job mentoring & supervision for VHSND or campaign and household visits	RR	2	2	2	2	2
4	Vaccinator is aware about how to manage any immediate serious reaction/anaphylaxis	SI	1	1	0	1	0
5	Vaccinators are aware about how to prevent immunization error related reactions	SI	2	2	1	1	0
6	Process of reporting and route is communicated to all concerned	RR/SI	1	1	1	1	1
7	Reporting of AEFI cases is ensured by ANM	RR	2	2	2	2	2
8	Check person responsible for notifying & reporting of the AEFI is identified	RR/SI	2	2	1	1	1
9	ANM/CHW is aware segregation policy after completion of immunization session	OB/SI	1	1	1	1	1
10	Check Vaccinator is aware of different categories of AEFI	RR/SI	1	1	1	1	1
11	Ayushman Arogya Mandir -SC maintain tracking bag/ tickler box	RR/SI	1	1	0	0	1
12	Staff are aware of Open vial policy	OB/SI	2	1	2	2	1
13	Reconstituted vaccines are not used after recommended time	OB/SI	2	2	2	2	2

14	Staff is aware of how to calculate the number of beneficiaries, quantity of vaccines & syringes	RR/SI	1	1	1	1	1
15	Staff checks VVM level before using vaccines and identify discard point	SI	2	1	2	1	1
16	Check the availability of anaphylaxis kit with ANM at session site	OB	2	2	1	1	1
17	Check adrenaline is not expired in kit	OB	2	2	2	2	2
18	Staff is aware of the shelf life of Vit A once it is opened and ensures it is not given after shelf life	OB/SI	2	1	1	2	1

For the total five AAM assessed, it was noted that the provision of services and support services for immunization was found to be 100 %. It showed that all the immunization services are being provided as per the National Immunization schedule. The records were available for the reporting of the immunization services as well as availability of the AEFI registers have also been noted. The Jan Aarogya samiti has been meeting regularly at least once a month to discuss the activities and support required for strengthening the immunization activities. Also, proper minutes of meeting are noted at all the centers related to the VHNSC meeting with support and capacity building activities been undertaken by CHO for the health workers working under the AAM.

This shows that these health facilities are well performing especially with the availability of the immunization services with a robust reporting and documenting system in place.

One of the most important aspects for immunization to keep in mind is the Adverse events following immunization. Every beneficiary has been provided 4 key messages about the vaccine given, the expected side effects, measures to taken to combat the effects and are always asked to stay for 30 minutes post vaccination to manage and immediate side effect if happens especially the Anaphylaxis reaction. Following the assessment, it is seen that awareness about management of the AEFI is having gaps. The immunization waste segregation practices, vaccine handling knowledge while performing the vaccination activities and tracking of the beneficiaries is on a critical side and needs attention.

Immunization has many important implications on public health since a single untoward event if happens creates a disaster at field level and the trust on the public health system is breached. Any

untoward event like an adverse event following immunization if not being handled properly can bring a setback to the entire program.

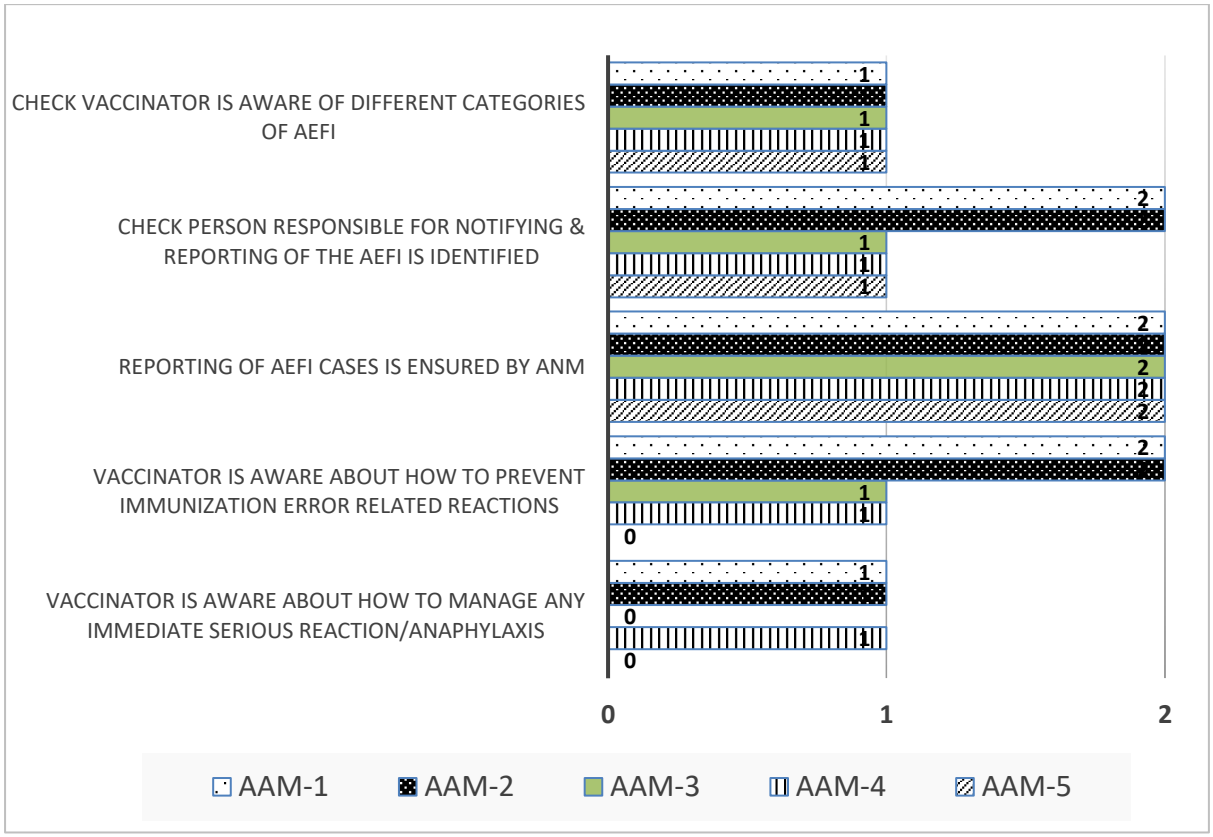


Figure 1: AEFI awareness and management

Taking five exclusive points based on the knowledge and management of AEFI it is known that:

AEFI reporting is strong in terms of documenting and proper reporting to the necessary levels in the system. A full compliance is noted for all the assessed AAM. This shows the well-established mechanism of reporting and documenting the AEFIs at facility level.

There is a variation noted when it comes to identification of the person responsible who will be responsible for reporting the AEFI. In ideal practice AEFI has to be notified by anyone who identifies it first while the system reporting should be by the health worker mostly the ANM or the CHO. AAM-1 & AAM-2 health staff was clear about the process while it was unclear with the other AAM showing unclarity about the role and accountability in AEFI reporting.

One of the most important preventable AEFI is the AEFI happening due to immunization error. On assessment of the knowledge related to prevention of immunization error the response was variable. Some facility staff have adequate awareness while staff from AAM-3, AAM-4 & AAM-5 showed partial knowledge. This showed a gap in the safe injection practice raising a doubt on the technical competency for preventing immunization errors.

Among the lowest performing aspect of AEFI was management of any immediate serious or severe reaction and anaphylaxis. As most of the vaccinators haven't experienced any such serious events in past, they were ignorant about the management rather do not gave importance

to the preparedness to tackle any serious AEFI thinking this to be mostly a medical event which doctors will manage.

The awareness about the categories of AEFI was moderate to low and mixed response was received when health workers were asked to differentiate about the main reporting categories of AEFIs. Clear differentiation between minor and severe AEFI was not seen as well as the availability of the required definition of the severe and serious AEFI was not available with any of the health workers across all AAM. It thus suggested an urgent need for regular staff orientation on identifications, classification of the different types of AEFIs.

A broader picture on the AEFI for the assessed health centers showed that the AEFI reporting systems are functioning properly but raises a concern about the practical knowledge and the emergency preparedness of the health workers especially the ANMs was lacking. These further points that the current immunization program is more compliant towards the reporting system more than the capability-based preparedness for management of the adverse events following immunization.

The low scores noted across all the AAM in the anaphylaxis management are critical as anaphylaxis is the life-threatening event and can lead to immediate death if not managed immediately. The inadequate knowledge in recognition and inadequate preparedness of the health worker will lead to delayed response and can be a potential event affecting the beneficiary safety and be detrimental to the public confidence in the immunization program.

There is variation between the health facilities which reflects that there could be an unequal implementation of training, supervision and monitoring practices. Hence it can be known that the facilities which has a strong mechanism of supervision score higher while the one with lower scores has a scope of targeted capacity building support.

For the immunization activities provided through the clinical services the analysis is divided into 4 levels.

1. **High Performing areas (80% to 100%)**
    - Documented reporting of AEFI cases ensured by anms
    - The Reconstituted vaccines are not used beyond recommended time
    - Adrenaline in Anaphylaxis kit is within expiry
2. **Moderate Performing areas (70% to 80%)**
    - Identification of a person responsible for AEFI reporting
    - Vaccine Vial monitor been checked before use of vaccine
    - Availability of Anaphylaxis kit
    - Awareness about Vit-A shelf life
    - Open vial policy followed by ANMs

The staff is partially aware of reporting structure of AEFI. Refresher training is needed to read the VVM before using it, clarity on the components under open vial policy and use of Vit-A once the bottle is opened with practical demonstration. Anaphylaxis kit should have 3 ampules of Adrenaline, 3 cotton swabs, 24G/25G needle and 1ml syringe with detachable needle with Job aids.

3. Low Performing areas (70% to 50%)

- Awareness of serious reaction and anaphylaxis management
- Waste segregation after immunization
- Knowledge of AEFI categories
- Beneficiary estimation & vaccine calculation based on the population

There are concerning gaps with respect to knowledge of AEFIs, its response pointing that the reporting system is in place but unaware about the proper reporting leading to poor AEFI surveillance. Immunization waste disposal in an improper way increases a concern for safety for all the beneficiary as well as the health workers. Basic target and logistics calculations are required for proper planning and execution of the immunization services.

4. Poor Performing areas (50% and below)

- Inadequate beneficiary tracking
- Possible dropouts in immunization
- Weak follow-up mechanism
- Missed vaccinations increasing susceptible cohorts for diseases

The poor performing areas need immediate attention in the form of regular capacity building training, microplanning, reinforce due-list tracking system, ensure regular counterfoil updates and hands-on mentoring by the supervisors and mentors.

The assessment demonstrates a strong institutional performance for the delivery of the immunization services and supervision mechanism. Good outreach functionality is noted though the available documents and records suggestive of better community participation. However certain important gaps are noted in the operational and the clinical acumen of the health staff especially related to the AEFI management, vaccine safety protocol, estimation of the due beneficiary, tracking and follow up to ensure no child is left without a due dose of vaccine. Regular capacity building programs, supportive supervision and improvement in the compliance be given immediate attention to strengthen the overall immunization quality as per standards laid down in the NQAS module of AAM.

Discussion and Managerial Implication

Discussion

The immunization assessment done for the selected Health centers under the Ayushman Arogya Mandir framework demonstrates a strong performance in service provision and support systems,

with an overall compliance score of 71.1% for the 18 parameters taken into consideration. The findings suggest that the facility has effectively institutionalized the routine immunization services, supportive supervision mechanisms and reporting systems for adverse events following immunization (AEFI). The highest score for service provision and support services through the Jan Arogya Samiti governance support indicates that the health system infrastructure and programmatic implementation are functioning satisfactorily.

The achievement of 100% compliance in immunization service availability reflects the strengthening of primary healthcare delivery through AAMs and aligns with the objectives of Universal Immunization Programme (UIP) and Ayushman Arogya Mandir operational guidelines. Similar findings have been reported in several studies done in assessing immunization readiness in primary healthcare facilities where regular outreach sessions and supervision contributed significantly to improved service delivery outcomes.

The strong performance in supportive supervision, community outreach activities, field monitoring highlights the critical role of Community Health Officers (CHOs), ANMs and the community participation platforms such as VHSNCs and Jan Arogya Samitis in ensuring continuity and quality of immunization services. Regular capacity building programs, effective mentoring and supportive supervisory visits have raised its importance through many public health studies to improve frontline worker performance, accountability and adherence to immunization protocols.

Despite the encouraging overall performance during the assessment, several operational and clinical gaps were identified. The low scores related to anaphylaxis management, AEFI categorization, waste segregation and beneficiary tracking systems indicate weaknesses in practical competency and adherence to standard immunization safety protocols. These findings are important because immunization safety and emergency preparedness are essential components of quality immunization services under NQAS standards.

The limited awareness among vaccinators regarding management of serious AEFI and anaphylaxis is a matter of concern. A small delay in recognition and response to such event can compromise patient safety and public confidence and have dire consequences on the immunization programs. Similar competency gaps have been noted among frontline immunization staff in some studies from developing countries, especially the low and middle income settings where inadequate refresher training and limited hands on demonstrations affected emergency preparedness and response.

The poor performance observed in maintenance and utilization of immunization tracking bags (30%) suggests the weakest chain in beneficiary tracking and follow-up systems. These Ineffective tracking mechanisms can contribute to missed immunization opportunities, increase in the dropouts and incomplete vaccination coverage leading to accumulation of susceptible

cohort of children which in turn may give rise to disease outbreaks. Tracking of beneficiary is particularly important in outreach settings as the whole process of outreach sessions and required logistics planning is dependent on the due-list management forming the backbone of session planning and follow-up activities.

Moderate compliance in open vial policy awareness, VVM checking and vaccine logistics management further indicates that although staff possess basic operational knowledge, consistent adherence to vaccine safety practices requires strengthening. These gaps may indirectly contribute to vaccine wastage, cold chain breaches and lead to reduced efficiency of immunization sessions.

Overall, the assessment highlights that while structural and organizational aspects of immunization services are well established in the health centers, gaps do persist in process-level quality and technical competencies. This reflects the need for continuous capacity building, supportive supervision and competency-based monitoring to sustain and improve immunization quality standards at the primary healthcare level aligned with the NQAS framework.

Managerial Implications

The outcomes of the assessment have several important managerial and programmatic implications to strengthen the immunization services within Ayushman Arogya Mandirs and primary healthcare facilities.

1. Strengthening Capacity Building Systems

The assessment gaps identified in the AEFI management, anaphylaxis identification and response, immunization waste segregation and vaccine handling indicate the need for regular capability-based training for ANMs, CHOs, and frontline workers. Program Managers should institutionalize regular refresher trainings, Hands on training, demonstrations, filed mentoring to ensure enhancement of practical skills rather than relying solely on theoretical orientations.

2. Enhancing Supportive Supervision

Although the supportive supervision systems look functional during the assessment, supervisory visits should be focused and emphasis be more on observational assessment and corrective mentoring related to immunization safety practices. Every supervisor should use the Supervisory checklists to monitor the immunization activities which should cover AEFI preparedness, Utilization of the immunization tracking bag, Biomedical waste segregation at session site, Open vial policy compliance, cold chain maintenance and should provide feedback for timely interventions which in turn will improve adherence to protocols.

3. Improving Immunization Safety processes

Strengthening the emergency preparedness protocols for addressing serious type of AEFIs in as evident with the low level of awareness among the health workers to manage serious AEFIs at session sites. Program Managers should ensure Availability of updated anaphylaxis kits, Job aids

availability with the Kits, display of emergency response algorithms, Mock drills for vaccinators and Clear reporting pathways for AEFIs and its address. This would improve patient safety and maintain public trust in immunization services.

4. Strengthening Beneficiary Tracking Mechanisms

The poor utilization of tracking bags reflects the weak follow-up systems. Program managers should prioritize availability and actual use of the tracking bags, regular due-list verification, counterfoils be used to track the missed or due children, digital or paper-based beneficiary tracking audits would be helpful. The use of U-win digital platform in near future will help the tracking of beneficiaries and will ease the process of follow up. Assigning responsibilities and making people accountable for outreach sessions would be a better solution for tracking the missed and will help improve the immunization coverage.

5. Reinforcing Quality Assurance through NQAS

The assessment demonstrates the utility of NQAS-based evaluations in identifying operational gaps within immunization services. The responsible program managers can use such assessments as continuous quality improvement tools by Conducting periodic internal assessments, developing corrective action plans, Tracking key process indicators, Taking inputs from the quality assurance teams in the block or districts

This approach will support institutionalization of quality culture within primary healthcare systems.

6. Policy and Programmatic Implications

The findings suggest that immunization quality improvement should move beyond service availability indicators and focus more on ability-based process indicators. Policymakers at district, state or higher level may consider integrating immunization quality indicators into routine monitoring, strengthening skill-based certification systems, enhancing supportive supervision budgets, developing standardized mentoring modules for AEFI and vaccine safety to ensure that no beneficiary is left behind from his right.

The assessment highlights that achieving a high immunization coverage alone is not sufficient without ensuring the quality, safety and continuity of immunization services. Strengthening the work competencies of frontline healthcare workers, enhancing supportive supervision, and improving beneficiary tracking mechanisms are critical for sustaining immunization program outcomes and advancing comprehensive primary healthcare quality under the Ayushman Arogya Mandir and National Quality Assurance Standards (NQAS) framework.

Conclusion and Future Directions

The present assessment of immunization services done under the Ayushman Arogya Mandir framework demonstrates that the facility is very successful in ensuring availability, continuity and supportive supervision of immunization services as reflected by the overall score of 71.1%.

Strong performance in service provision, AEFI reporting systems and community-based support mechanisms indicate that key structural and organizational components of immunization delivery are functioning effectively at the maximum level with 100%.

However, the assessment identified significant gaps in technical competencies and process-related quality indicators, particularly in areas such as anaphylaxis identification and management, AEFI categorization, beneficiary tracking mechanisms, biomedical waste segregation and vaccine safety practices. These findings emphasize the need for continuous capacity building, strengthened supportive supervision, and improved adherence to standard operational protocols among frontline healthcare workers to ensure safe and quality immunization services.

The findings highlight that achieving quality immunization services requires not only adequate service coverage but also robust systems for safety, monitoring, emergency preparedness, and better follow-up. Strengthening these operational areas will be essential for sustaining immunization quality and advancing the objectives of National Quality Assurance Standards (NQAS) and comprehensive primary healthcare under Ayushman Arogya Mandir initiatives.

Overall, the assessment provides important insights into facility level quality improvement needs and highlights the value of periodic quality assessments in identifying operational gaps, monitoring service standards and guiding corrective actions to strengthen routine immunization services within the primary healthcare system, especially the Ayushman Arogya Mandirs.

Future efforts should focus on regular expertise-based training and refresher sessions for ANMs and CHOs in AEFI management, Anaphylaxis response, Vaccine logistics, Waste segregation, Open vial policy implementation, Practical demonstrations. Supportive supervision should evolve from routine monitoring to mentorship-oriented supervision with emphasis on Observation of immunization practices, Real-time corrective feedback, Periodic skill assessments, Use of structured supervisory checklists. Future strategies may include strengthening digital beneficiary tracking systems through electronic due-list monitoring with effective use of U-win platform, mobile-based tracking tools, Integration with routine HMIS platforms, Automated reminders for missed beneficiaries

Additional focus is required on strengthening vaccine safety surveillance through regular mock drills for anaphylaxis management, availability of AEFI kits, feedback mechanisms and increase in the community awareness regarding vaccine safety. Continuous Quality Improvement under NQAS with internal and external assessments with regular monitoring on the process outcomes through gap identifications and robust review mechanisms

Further research studies may explore the Impact of supportive supervision on immunization quality outcomes, Barriers to effective AEFI preparedness among frontline workers, Role of digital tracking systems in reducing immunization dropouts, Comparative assessments across

different healthcare settings and districts. Longitudinal studies may also help evaluate the sustainability of quality improvement interventions over time.

Strengthening the immunization quality at the primary healthcare level requires a balanced emphasis on service coverage, technical competency, safety preparedness and continuous quality improvement. Addressing the identified operational gaps through targeted interventions, regular capacity building and sustained monitoring can substantially enhance the safety, efficiency and equity of immunization services under the Ayushman Arogya Mandir framework.

Conflict of Interest

There is no conflict of interest. The study utilized secondary programmatic data collected as part of routine government health center assessment done by the author. Confidentiality and anonymity of facilities and personnel have been maintained. No identifiable information has been disclosed.

Ethical Considerations

The assessment of the health facilities on selected parameters was conducted using secondary data obtained from routine government health facility quality assessments under the Ayushman Arogya Mandir/NQAS framework. Confidentiality and anonymity of the health facilities and healthcare personnel were strictly maintained throughout the analysis and reporting process.

The data is used solely for academic and quality improvement purposes. No individual or facility specific identifiers have been disclosed in this document. As the study involved analysis of routinely collected programmatic data, formal informed consent was not required. All procedures were carried out in accordance with applicable ethical principles for public health program evaluation and data confidentiality.

Limitations of the Study

The present assessment has certain limitations that should be considered while interpreting the findings. First, the study was based on secondary data collected through routine facility assessments under the Ayushman Arogya Mandir - NQAS framework by the author. So, the accuracy of findings depended upon the completeness and quality of the recorded observations.

Second, the assessment was conducted in a limited facility setting and may not be applicable to other health facilities and their performance in other districts or states. Hence, it cannot be generalized to all facilities.

Third, the analysis primarily focused on process and service delivery indicators and did not include beneficiary perspectives, client satisfaction or long-term immunization outcomes such as coverage improvement or reduction in dropout rates in the immunization of the areas catered by the health facilities.

Also, some of the methods involved observation by the assessor and the indicators or the outcomes may subject to the assessor’s bias.

The study could not touch upon the broader aspects of health systems like availability of human resources, logistics and supply chain disruptions, financial resources which may influence the immunization service quality

Despite these limitations the assessment provides important operational insights into immunization service quality, the health workers preparedness and areas requiring strengthening within the Ayushman Arogya Mandir framework.

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VENOMOUS ENCOUNTERS: MITIGATING SNAKEBITE RISK AND ENHANCING CLINICAL OUTCOMES IN RURAL COMMUNITIES

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Abstract

Snakebite envenoming is a significant yet neglected public health issue in many tropical and subtropical countries, disproportionately affecting rural populations in Africa, Asia, and Latin America. Globally, approximately 5 million snakebites occur annually, resulting in 2.7 million cases of envenoming and up to 138,000 deaths, with many more suffering amputations or permanent disabilities. In India, an estimated 58,000 deaths occur each year, primarily due to bites from the "Big Four" venomous snakes: Indian cobra, common krait, Russell's viper, and saw-scaled viper. Most cases occur in agricultural communities, particularly during the monsoon season, where delays in seeking effective medical care—often caused by reliance on traditional healers, low awareness, and limited access to antivenom—contribute to high mortality. Despite the publication of standard treatment guidelines (STGs) in 2017, implementation remains inadequate, compounded by gaps in medical training, limited confidence in anti-snake venom (ASV) administration, and insufficient life-support skills among healthcare workers. Clinical manifestations range from local tissue damage to systemic complications, including neurotoxicity, coagulopathy, renal failure, and shock, necessitating prompt identification, first aid, and administration of antivenom within the critical "golden period." Effective management also relies on accurate identification of the snake species, structured referral pathways, and comprehensive case tracking to inform evidence-based interventions. Prevention strategies require a multipronged approach: promoting personal protective measures such as safe sleeping practices and footwear, managing environmental risk factors, and engaging communities through behavior change communication and education campaigns. Strengthening rural healthcare infrastructure, ensuring uninterrupted antivenom supply, training all healthcare personnel—including traditional healers—in early recognition and referral, and integrating AI-assisted case-based surveillance with geolocation can enhance preparedness and reduce delays. Research into traditional practices such as Ayurveda, when systematically studied, may complement evidence-based treatment. National and global frameworks, including the WHO strategy and India's National Action Plan for Snakebite Envenoming (NAPSE), emphasize empowering communities, ensuring safe treatment, strengthening health systems, and fostering coordinated partnerships. Integrated, data-driven, and multi-stakeholder interventions are critical to reducing mortality, disability, and the overall burden of snakebite envenoming in rural India.

Keywords: Snakebite, India, Public Health, Rural Health, Envenomation, Antivenom, Hemotoxicity, Supportive care, Fluid resuscitation & Coagulopathy.

Introduction

Snakebite is a neglected public health issue in many tropical and subtropical countries, with most cases occurring in Africa, Asia, and Latin America. In Asia alone, up to 2 million people are envenomed by snakes each year, while in Africa, an estimated 435,000 to 580,000 snakebites annually require treatment. Snakebite envenoming disproportionately affects women, children, and farmers in poor rural communities within low- and middle-income countries. The World Health Organization (WHO) estimates that about 5 million snakebites occur globally each year, resulting in up to 2.7 million cases of envenoming, and published reports suggest between 81,000 and 138,000 deaths annually. Additionally, snakebite envenoming leads to as many as 400,000 amputations and other permanent disabilities. Many cases go unreported, as only a small proportion of victims seek medical care at clinics and hospitals, meaning the true burden of snakebite is likely much higher than official statistics indicate.

Recognizing its significance, WHO added snakebite envenoming to its priority list of neglected tropical diseases (NTDs) in June 2017. In India, the Million Death Study reported approximately 45,900 annual snakebite deaths, with around 90% of bites caused by the 'big four' snakes—the common krait, Indian cobra, Russell's viper, and saw-scaled viper. Bites from venomous snakes can trigger acute medical emergencies, including severe paralysis that may impair breathing, bleeding disorders leading to fatal haemorrhage, irreversible kidney failure, and extensive local tissue damage resulting in permanent disability or limb amputation. Children are particularly vulnerable, experiencing more severe effects more rapidly due to their smaller body mass.

Most deaths and serious complications from snakebites are entirely preventable through the timely availability of safe and effective antivenom. High-quality antivenom is the most effective treatment to prevent or reverse the venomous effects of snakebites. In India, rural populations heavily depend on agriculture, and during the rainy season, when they work extensively in muddy and waterlogged paddy fields, the risk of snakebite increases as this coincides with the breeding season of snakes. Raising awareness in these communities about distinguishing venomous from non-venomous snakes and adopting preventive measures is crucial. However, in many cases, snakebite victims first consult traditional healers, which can delay access to effective medical treatment.

Snakebite remains a major public health concern in India, causing an estimated 58,000 deaths annually. Effective prevention must begin at the grassroots level and be complemented by timely and appropriate treatment to reduce mortality and morbidity, especially in rural areas. Most victims belong to economically disadvantaged populations, where the death of a single earning member can have devastating financial and emotional consequences for the family. As a globally recognized neglected tropical disease, addressing snakebite envenoming requires more than awareness campaigns. Ensuring the availability of antivenom injections, equipping healthcare staff with adequate knowledge and skills for snakebite management, and fostering systematic

learning from past cases are all critical steps for strengthening prevention strategies, improving treatment protocols, and ultimately minimizing avoidable deaths. Although standard treatment guidelines (STGs) for the management of snakebite were published in 2017, their implementation remains inadequate across both public and private healthcare systems in India. The majority of snakebites occur in rural and tribal areas, where transportation facilities are limited—particularly during midnight hours—contributing to higher mortality rates. In response to this pressing issue, a national consultation involving all stakeholders was held in New Delhi in August 2022. Subsequently, the Ministry of Health and Family Welfare (MoHFW), Government of India, announced the launch of a dedicated national program for the prevention and control of snakebite envenoming (SBE) in September 2022. This initiative is a significant and welcome step, making India the first country in Asia to implement a national program specifically aimed at snakebite prevention and control. Drawing on our experience in snakebite research in India, we outline the key challenges and propose strategic recommendations across three levels: community, health system, and policy.

The Ministry of Health and Family Welfare (MoHFW), Government of India (GoI), declared the launch of a national program for prevention and control of SBE in the month of September 2022. A significant challenge in snakebite prevention and control at the health system level is the limited preparedness of medical personnel. Snakebite management receives little to no attention in the medical curriculum, and interns often have no exposure to treating snakebite cases during their training. As a result, many medical officers (MOs) in state health services lack practical experience in managing envenoming. There is also no uniform protocol consistently followed for snakebite treatment across healthcare facilities, leading to variability in care. Many MOs at Primary Health Centers (PHCs) and Community Health Centers (CHCs) lack confidence in administering anti-snake venom (ASV), often due to fears of anaphylactic reactions, compounded by inadequate life-support skills to manage emergencies. These gaps in knowledge, experience, and practical skills hinder timely and effective treatment, contributing to preventable morbidity and mortality from snakebites in rural and resource-limited settings.

Common Venomous and Nonvenomous Snakes in India

In India, most venomous snakebite cases are caused by the so-called “Big Four” snakes: the Indian Cobra (*Naja naja*), Common Krait (*Bungarus caeruleus*), Russell’s Viper (*Daboia russelii*), and Saw-scaled Viper (*Echis carinatus*). These species are responsible for most of the morbidity and mortality associated with snakebites in the country. However, the distribution of these snakes is not uniform across India. Their presence in a particular region is influenced by various ecological and environmental factors, including the type of local habitat, patterns of rainfall, altitude, and the availability of prey species. Understanding the geographical distribution of these snakes is crucial for targeted public health interventions, including community awareness campaigns, antivenom distribution, and healthcare preparedness in high-risk areas.

Indian Rock Python (*Python molurus*)- non venomous

Rat Snake (Indian Rat Snake – *Ptyasmucosa*) - non venomous

Rat Snake (Indian Rat Snake – Ptyasmucosa)- non venomous

Banded Krait (*Bungarus fasciatus*)- highly venomous

Indian Cobra (*Naja naja*)- Highly Venomous

Oriental Ratsnake (*Ptyas mucosa*)- non-venomous

Bronzeback Tree Snake (Common Bronzeback – *Dendrelaphis tristis*)- non-venomous

Common Sand Boa (*Eryx conicus*)- non-venomous

Clinical Features of Snakebite

Snakebite envenoming manifests with a wide spectrum of clinical features, ranging from local tissue damage to severe systemic complications, depending on the species of snake, the amount of venom injected, and the victim's individual susceptibility. Local symptoms often appear immediately at the bite site and may include fang marks, localized pain, and swelling, accompanied by redness, heat, and inflammation. Bruising, lymphangitis, and enlargement of nearby lymph nodes are common, while more severe local reactions may lead to blistering, secondary infections, abscess formation, and, in extreme cases, tissue necrosis. These local signs serve as the initial indicators of envenoming and can help guide early medical assessment.

Beyond the bite site, **Systemic symptoms** can be life-threatening and involve multiple organ systems. Neurotoxic effects may present as weakness, drowsiness, visual disturbances, cranial nerve paralysis, and respiratory distress. Haematological complications, such as coagulopathy, can result in persistent local bleeding or spontaneous systemic haemorrhages—including in gums, epistaxis, haematuria, rectal bleeding, vaginal bleeding, haemoptysis, hematemesis, or even intracranial haemorrhage—potentially leading to shock, hypotension, or cardiac arrhythmias. Renal involvement may progress to acute kidney injury, and in severe cases, pulmonary oedema, conjunctival chemosis, and multi-organ dysfunction can occur. Gastrointestinal symptoms such as nausea, vomiting, abdominal pain, malaise, and prostration are also common. In pregnant women, snakebite can precipitate antepartum haemorrhage, posing significant maternal and foetal risks.

The chronic phase of envenoming, which may persist for months or even years after the bite, can lead to long-term sequelae, including generalized weakness; hormonal disturbances such as hypothyroidism; loss of secondary sexual characteristics; amenorrhea in women; loss of libido; and testicular atrophy in men. These chronic complications highlight the need for ongoing medical monitoring and rehabilitation in snakebite survivors. Overall, the clinical presentation of snakebite envenoming is highly variable, requiring prompt recognition, appropriate supportive care, and timely administration of antivenom to prevent both immediate and long-term morbidity.

a. Diagnosis and First Aid

Snakebite envenoming is a medical emergency that requires prompt and appropriate intervention to reduce morbidity and mortality. The World Health Organization (WHO) provides comprehensive first aid and transport guidelines emphasizing timely action and correct practices. Immediate steps include reassuring the victim to reduce anxiety, immobilizing the affected limb at or slightly below heart level to slow venom spread, and removing any tight clothing or jewellery near the bite site to prevent constriction as swelling occurs. Recording the exact time of the bite is essential for determining the timing of antivenom administration. Victims should be

transported as quickly as possible to the nearest medical facility equipped with antivenom and trained personnel. It is crucial to avoid harmful practices such as cutting or sucking the bite site or applying tourniquets, ice, or electrical shocks, as these interventions can exacerbate injury and worsen outcomes.

The syndrome approach plays a pivotal role in the diagnosis of snakebite envenoming by classifying cases based on predominant clinical features, which helps guide treatment and anticipate complications. Neurotoxic envenoming, commonly seen with cobra and krait bites, presents with cranial nerve paralysis, ptosis, and respiratory weakness. Vasculotoxic (hemotoxic) envenoming, often associated with Russell's viper and saw-scaled viper, manifests as bleeding, swelling, and clotting defects. Myotoxic envenoming, typically seen with Russell's viper, is characterized by muscle pain, dark urine, and generalized weakness.

Immediate medical interventions include the continuation of first aid; close monitoring of vital signs such as airway, breathing, and circulation; and administration of polyvalent antivenom (ASV) based on clinical presentation and local guidelines. Supportive care may involve fluid resuscitation, blood transfusions, mechanical ventilation, and dialysis when required. Monitoring the progression of envenoming is critical: patients with neurotoxic features require observation for respiratory distress and may need intubation or ventilation; those with vasculotoxic features should undergo frequent 20-minute whole blood clotting tests (WBCT) to assess coagulopathy; and patients with myotoxic features need monitoring of urine output and renal function.

Where available, laboratory tests provide additional confirmation and guidance for treatment, including complete blood counts (CBC) to detect anaemia or leucocytosis, coagulation profiles for clotting abnormalities, D-dimer testing for disseminated intravascular coagulation, basic metabolic panels to monitor renal and electrolyte status, liver function tests, and WBCT in resource-limited settings. Adhering to WHO-recommended first aid and transport protocols, using the syndrome approach for early recognition, and implementing timely supportive care, including antivenom administration, are critical steps in improving clinical outcomes and reducing mortality and long-term complications from snakebite envenoming.

b. Management of Snakebite

In India, the World Health Organization (WHO) provides detailed guidelines for managing snakebite envenoming, highlighting the critical importance of prompt and appropriate intervention. The initial pain following a snakebite is usually caused by the mechanical puncture of the skin, often accompanied by a burning or throbbing sensation at the site. Swelling typically develops and may gradually spread up the affected limb, while nearby lymph nodes, such as those in the groin or armpit, can become tender and swollen. The WHO advises administering antivenom when such symptoms appear, as they may indicate systemic envenoming, which can be life-threatening if not addressed promptly.

Antivenom remains the only specific treatment for snakebite envenoming and should be given based on clinical indications. These include progressive local tissue damage, signs of systemic toxicity such as hematologic abnormalities (for example, prolonged prothrombin time or low platelet counts), airway compromise, or cardiovascular instability. In India, polyvalent antivenoms are preferred, as they are effective against the "Big Four" venomous snakes: the Indian cobra, common krait, Russell's viper, and saw-scaled viper.

Supportive care is equally essential in snakebite management. WHO guidelines emphasize maintaining airway, breathing, and circulation (ABCs) as the cornerstone of treatment. This involves ensuring adequate ventilation, managing shock through appropriate fluid resuscitation, and monitoring for complications such as renal impairment or coagulopathy. Unlike other emergencies, the Glasgow Coma Scale is not routinely applied during initial assessment; instead, clinical signs and symptoms guide treatment decisions. Furthermore, the National Action Plan for Prevention and Control of Snakebite Envenoming (NAPSE) underscore the importance of timely antivenom administration and comprehensive supportive care to reduce morbidity and mortality associated with snakebites.

Public Health Perspective

There remain significant gaps in awareness, transport, and treatment when it comes to managing snakebite cases, particularly in rural and semi-urban areas. Awareness among the general population is very low—even educated individuals often lack knowledge about appropriate first aid measures and the importance of reaching a health facility promptly after a bite. Instead, many victims first seek help from traditional or Ayurvedic practitioners, relying on unproven remedies for which proper scientific research and validation are still lacking. This practice leads to critical delays in transportation and the initiation of life-saving medical care. By the time patients reach a hospital, their condition often worsens due to the progression of envenoming. Furthermore, at the treatment level, there are additional challenges such as inconsistent availability of anti-snake venom, inadequate cold-chain maintenance, and limited adherence to standardized treatment protocols by healthcare providers. These combined gaps — in community awareness, timely transport, and medical preparedness — contribute to preventable morbidity and mortality from snakebite envenoming, highlighting the urgent need for integrated education, system strengthening, and research-based policy interventions. Educating traditional healers on prompt treatment and timely patient referral is crucial, as significant time is often lost due to community reliance on their beliefs and practices following a snakebite. Training healthcare workers is crucial for improving the early recognition, management, and referral of snakebite cases. Many frontline workers, especially those other than doctors—such as nurses, ANMs, and community health workers—often lack adequate training to identify the serious complications that can arise from snakebite envenoming. Strengthening their knowledge through regular, structured training

programs can help them understand the clinical signs of severity, initiate appropriate first aid, and make prompt referrals to higher facilities. Equally important is developing coordination between peripheral and referral centers to ensure that patients receive timely and continuous care. Training should also emphasize the use of available data for local planning, awareness generation, and improving reporting systems. Moreover, motivating healthcare workers to recognize snakebite as a medical emergency can foster a sense of urgency and responsibility in managing such cases.

At the same time, it is essential to understand that snakebites are not only a medical issue but also a form of animal–human conflict. Rapid environmental changes, deforestation, and human encroachment into natural habitats often force snakes to move closer to human settlements, increasing the risk of encounters. Therefore, awareness about preserving natural habitats and avoiding unnecessary disturbance to snake habitats should also be integrated into community and health worker training programs. Promoting coexistence and ecological balance is an important step toward reducing snakebite incidents and ensuring a safer environment for both humans and wildlife.

It is also critically important to identify the snake species involved in a bite to distinguish between venomous and non-venomous snakes. Accurate identification helps guide the urgency and type of medical intervention required, including the appropriate use of anti-snake venom, and prevents unnecessary treatment in cases of non-venomous bites. Moreover, knowing the species can aid healthcare providers in anticipating specific complications associated with different venoms, such as neurotoxic effects from kraits and cobras or hemotoxic effects from vipers. Community awareness about recognizing common venomous and non-venomous snakes, coupled with prompt reporting and, where safe, photographing or capturing the snake, can significantly improve clinical outcomes, reduce delays in treatment, and optimize resource utilization in rural healthcare settings.

Maintaining a detailed history of past patient records, including the exact time of death following a snakebite, is crucial for conducting a thorough audit of each case. This practice will facilitate a better understanding of the circumstances leading to mortality, thereby helping to inform strategies to reduce the overall death rate from snakebites.

Prevention Strategies

Preventing snakebite incidents requires a combination of personal protection, environmental management, and community-based education efforts involving multiple stakeholders. Promoting safe sleeping practices, such as using bed nets, sleeping on raised cots, and keeping living areas clean and free of debris, can greatly reduce the risk of nocturnal snakebites. Similarly, encouraging the use of protective footwear while walking in fields or forests or during

midnight hours helps minimize accidental bites, especially in rural areas where barefoot walking is common.

In addition to personal precautions, environmental management plays a vital role in reducing snake–human conflict. Efforts should focus on maintaining clean surroundings, managing rodent populations (which attract snakes), and avoiding the destruction of natural snake habitats. This approach requires the involvement of multiple stakeholders, including local communities, NGOs, nonprofit organizations, herpetology and wildlife conservation groups, as well as veterinary and forest department staff. Collaborative action can ensure safe rescue and relocation of snakes, community awareness about co-existence, and timely response to snake sightings.

Furthermore, community education and behavior change communication (BCC) are key strategies for long-term prevention. Innovative and culturally appropriate methods such as wall paintings at health centers, street plays, puppet shows, and village-level demonstrations can effectively spread awareness.

Timeliness of Care

The "Golden Period" for effective snakebite treatment is within the first few hours post-Envenomation. To make use of this golden period, early first aid—such as reassuring the patient, immobilizing the affected limb, and avoiding harmful practices like cutting, sucking, or tying tight tourniquets—is essential. Simultaneously, the patient should be transported as quickly as possible to the nearest health facility where ASV and supportive care are available. Educating communities about the importance of this golden period, improving access to emergency transport, and ensuring round-the-clock availability of antivenom at primary and secondary healthcare centers can significantly reduce snakebite-related morbidity and mortality. In short, every minute counts — timely action during the golden period is the difference between life and death in a snakebite emergency. Delays in reaching adequately equipped medical facilities can significantly impact patient outcomes related to mortality or morbidity. Research from Maharashtra's SDH in Dahanu shows that delays exceeding three hours between snakebite occurrence and admission to a first referral unit significantly correlate with higher fatality rates, underscoring the urgency of prompt medical care.

National guidelines firmly stress the need for administering anti-snake venom as early as possible to mitigate complications and improve survival outcomes.

The combined cases clearly demonstrate that public awareness regarding snakebite prevention and early treatment is critically important. In many instances, victims delay seeking help—often visiting traditional healers or relying on unscientific remedies—leading to a dangerous loss of time within the "golden hour" for effective treatment. For example, victims of cobra or Russell's viper bites have as little as two hours, and for krait bites, about five to six hours, to receive antivenom before fatal outcomes become far more likely. Moreover, studies confirm that lack of

awareness and inappropriate first aid practices significantly contribute to snakebite deaths, while community education programs can substantially improve treatment-seeking behaviors and outcomes. Equally important is the timely documentation of each patient's clinical journey, from the moment of snakebite through recovery or death. Proper record-keeping at every level of care—including subcenters, PHCs, and referral facilities—is essential to identify gaps in management and prevent future errors. Such documentation also supports training, quality improvement, and system accountability.

Finally, referral pathways must be prompt, coordinated, and informed. Healthcare providers need to understand the urgency of envenomation cases and recognize potential complications early. Referrals should be executed quickly, leveraging transport services when available, and supported by structured case information to ensure continuity and efficacy of care.

Recommendations

Improving snakebite prevention and management requires a comprehensive, multi-pronged approach that addresses both community practices and health system preparedness. A critical step is strengthening the supply chain of antivenom to ensure that safe and effective doses are consistently available at all levels of healthcare, especially in rural and high-risk areas. Alongside this, community awareness must be promoted by educating people about the risks of snakebites, preventive behaviours such as safe sleeping practices and protective footwear, and the importance of seeking prompt medical care. It is equally important to dispel reliance on traditional or unscientific remedies and emphasize that timely administration of antivenom is life-saving and often the only effective treatment for envenoming.

Ensuring comprehensive case tracking is another essential strategy. Recording each patient's timeline—from the bite, through referral, to treatment outcomes—can provide valuable data to inform improvements in healthcare delivery, identify bottlenecks, and guide targeted training programs for healthcare workers. Creating robust systems to accurately track and report snakebite cases and deaths is necessary to understand the true burden of the problem and develop evidence-based policies.

Modern communication tools — including social media platforms, television, and radio — can reinforce these messages, and repetitive advertisements on TV or radio can be particularly effective in reminding people about safe practices and the importance of prompt care. In addition, establishing a toll-free number that is physically monitored by healthcare workers can motivate patients to seek immediate care, provide guidance during emergencies, and reduce delays in treatment. Through a combination of education, collaboration, environmental responsibility, and accessible emergency support, communities can significantly reduce snakebite risks and promote safer coexistence between humans and snakes.

Strengthening referral protocols is equally critical to minimize delays in care. This includes fostering timely and structured referrals between peripheral and higher-level health facilities, with clear communication of the patient's clinical status and interventions already provided. Utilizing available emergency transport systems effectively can further reduce delays in reaching appropriate treatment. At the same time, strengthening rural health infrastructure—including equipping primary and community health centers with trained staff, essential drugs, functional equipment, and reliable communication networks—is vital for improving response to snakebite emergencies. Together, these measures can ensure that communities are well-informed, healthcare providers are confident and prepared, and snakebite victims receive timely, evidence-based treatment, ultimately reducing morbidity and mortality.

Strengthen Referral Protocols

To improve outcomes in snakebite management, it is essential to foster timely and structured referral systems with clear communication between different levels of healthcare facilities. Proper documentation and transfer of clinical details—such as the patient's condition, vital signs, and interventions already provided—ensure continuity of care and enable better decision-making at higher centers. Utilizing available emergency transport systems, including ambulances and community-based referral mechanisms, can significantly reduce delays in reaching facilities equipped with antivenom and advanced treatment options. Alongside these measures, strengthening rural health infrastructure is equally important. This includes ensuring the availability of trained personnel, essential drugs, functional equipment, and reliable communication networks at the primary and community health centre levels. Together, these steps can build a more responsive and efficient referral chain, ultimately reducing morbidity and mortality associated with snakebite envenoming in rural areas.

There is an urgent need to study and conduct systematic research on the role of Ayurveda in the management of snakebite cases. In many parts of rural India, Ayurveda and other traditional systems of medicine remain the most preferred and accessible form of treatment, especially where modern healthcare facilities and antivenom supplies are limited. People often turn to Ayurvedic practitioners immediately after a snakebite, trusting their remedies and traditional healing practices that have been passed down through generations. However, there is limited scientific evidence to support the efficacy and safety of these treatments. Therefore, it is important to undertake detailed research to document the commonly used Ayurvedic formulations, assess their pharmacological properties, and evaluate their potential as supportive or complementary therapies alongside standard medical treatment. Such studies will help identify the possible therapeutic benefits, minimize harmful practices, and integrate validated traditional knowledge into public health strategies for snakebite management. By bridging the gap between traditional wisdom and modern science, Ayurveda-based research can contribute to safer,

evidence-based approaches for treating snakebite victims and strengthening community-level health response.

Implementing AI-assisted, case-based surveillance with integrated location tagging can greatly enhance the accuracy and efficiency of snakebite data collection and analysis. By using artificial intelligence to track and analyse reported cases in real time, health authorities can identify high-risk areas, seasonal patterns, and emerging hotspots with greater precision. The inclusion of geolocation data allows for the mapping of exact sites of snakebite incidents, which helps in understanding geographical trends and guiding targeted interventions such as antivenom distribution, awareness campaigns, and training of healthcare providers in vulnerable regions. Such a system can also enable faster reporting and response by linking health facilities, field workers, and policymakers through a centralized digital platform. The insights derived from AI-based analytics can support evidence-based policy formulation and resource allocation, ensuring that preventive and treatment efforts are directed where they are needed most. Providing healers with adequate training to recognize early warning signs “Red Flags”. Snakebite cases are crucial, ensuring they can make timely referrals to healthcare facilities for urgent management.

Global and National Frameworks for Reducing Snakebite Mortality and Morbidity

On 23 May 2019, the World Health Organization (WHO) launched a comprehensive strategy for the prevention and control of snakebite envenoming. This strategy aligns with the objectives of WHO's 13th General Programme of Work and the Sustainable Development Goals, emphasizing the role of individual countries as the focal point of a coordinated global response. The strategy outlines specific priorities aimed at achieving measurable outcomes and impact, guided by four key objectives: empowering and engaging communities, ensuring safe and effective treatment, strengthening health systems, and enhancing partnerships, coordination, and resource mobilization through strong collaboration.

In India, the National Action Plan for Snakebite Envenoming (NAPSE) provides a structured framework for the management, prevention, and control of snakebite envenoming, reflecting global efforts to reduce snakebite-related deaths and disabilities by 50% by 2030. NAPSE details the strategic components and delineates the roles and responsibilities of all relevant stakeholders. The plan includes activities across human, wildlife, tribal, and animal health sectors, with implementation coordinated at multiple levels. To ensure effective oversight, each state is required to nominate State and District Nodal Officers (SNOs and DNOs) who will coordinate activities with their counterparts in the State and District Snakebite Prevention and Control committees, thereby facilitating an organized and accountable approach to mitigating the burden of snakebite envenomation nationwide.

Conclusion

Snakebite envenoming continues to be a serious yet preventable cause of death and disability in rural India. Most cases occur among agricultural workers during the monsoon season, coinciding with heightened snake activity. Delays in seeking appropriate medical care—often due to reliance on traditional healers, lack of awareness, and inadequate access to antivenom—remain critical barriers to survival. Case evidence from the field underscores that timely administration of anti-snake venom. Within the "Golden Period" is vital to preventing mortality and long-term complications.

In-depth research on every snakebite case is crucial for improving patient outcomes and public health strategies. This includes collecting detailed data on the patient's medical history, co-existing illnesses (comorbidities), and the specifics of the current snakebite incident. It is also highly beneficial to study the snake that caused the bite, especially when villagers bring it with them.

Addressing this public health challenge requires a multi-pronged approach: ensuring uninterrupted availability of quality antivenom, strengthening rural healthcare infrastructure. Training all healthcare workers—including traditional healers—in early recognition and referral and implementing effective community education programs. Systematic documentation and data-driven decision-making can further enhance prevention strategies and optimize patient outcomes. An integrated and coordinated effort from policymakers, healthcare providers, and community stakeholders is essential to reduce the burden of snakebite and save lives.

Snake Bite Management Mnemonic (SAANP)

S – Stay calm & immobilize (reassure patient, restrict movement)

A – Avoid harmful practices (no tourniquet, no cutting/sucking)

A – Assess symptoms (look for swelling, bleeding, neuro signs)

N – Nearest hospital referral (urgent transport)

P – Polyvalent Anti Snake Venom (ASV) (start as per protocol)

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HARNESSING ARTIFICIAL INTELLIGENCE IN INDIAN HOSPITALS: APPLICATIONS, CHALLENGES, AND FUTURE DIRECTIONS

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Abstract

Artificial Intelligence (AI) is revolutionizing the healthcare sector worldwide by bringing solutions to problems that have been around for a very long time. In India, conditions like patient overcrowding, insufficient resources, and old facilities are making a strong case for AI to become a significant player in this sector. This systematic review study of 41 peer, reviewed articles that analysed AI applications in Indian hospitals over the period from 2015 to 2024 along with similar studies in other countries lead to six categories of AI benefits: diagnostics, hospital operations, telemedicine, predictive analytics, personal health care (personalized medicine), and implementation barriers. The results showed that the use of AI in diagnostics and telehealth has brought about the most significant improvements in terms of accuracy, accessibility, and continuity of care; nevertheless, these advantages have not been evenly distributed since the adoption of technology has encountered issues such as technology gaps, regulatory uncertainty, ethical problems, and lack of digital capability. Generally, the review points to the fact that AI can radically transform Indian hospitals, if there is a reform in policies to pave the way for implementation and capacity building, thus facilitating healthcare providers' and technology partners' collaboration.

Keywords: Artificial Intelligence, Indian Hospitals, Systematic Review, Diagnostics, Telemedicine, Predictive Analytics, Personalized Medicine, Healthcare Management.

Introduction

Artificial intelligence (AI) is undoubtedly among the major innovations that disrupted the healthcare sector. It is revolutionizing the methods of hospital diagnosis and patient care while significantly facilitating clinicians to efficiently manage their patients. At present, AI finds multiple medical applications worldwide: the technology has been used to plan and guide surgeries, analysed huge datasets and images for research, offer patient management services, etc. In India, the demand for such technology is at its utmost as the country accounts for only 1% of the worldwide healthcare workforce but almost 18% of the world's population. Thus, it is becoming increasingly difficult for the healthcare system to cope, and there is currently a ratio of 1 doctor per 1, 511 people in India (which is below the level of 1 doctor per 1, 000 people as recommended by the World Health Organization (WHO)). Since more than two, thirds of the Indian population live in rural areas where access to modern medical facilities is limited, AI is

more than just a technological advancement; it is, in fact, a crucial tool to tackle the existing healthcare challenges. Use of AI in India has been seen in different areas such as telemedicine platforms powered by Natural Language Processing (NLP), mechanisms for diagnosing TB in public hospitals, predictive modelling to predict hospital admissions due to COVID, 19, and so on; nonetheless, the rate of adoption has been patchy. Major obstacles to system, wide adoption have been identified as lack of digital infrastructure, fragmented Electronic Health Records (EHR) systems, high up, front costs, and ethical considerations.

Although various international reviews have already explained how AI affects health care systems, there do remain pieces of data contradicting each other in relation to the use of AI products in India. It is almost negligible the studies that are done on the integration of AI in hospitals in a holistic manner. Even those that do, might isolate their focus on diagnostic application or telemedicine or hospital operations only (telemedicine versus operations). Therefore, this systematic review is a synthesis of 41 peer, reviewed articles from 2015 to 2024 that have been divided into six areas, namely: (1) diagnosis; (2) hospital operations; (3) telemedicine; (4) predictive analytics; (5) personalised medicine; and (6) barriers to adoption. This review will also serve as an assessment of AI capacity to radically alter health care delivery in Indian hospitals, identifying the avenues, the challenges, limitations, and the current state of AI in these hospitals.

Artificial Intelligence (AI), possibly the single biggest disruptive technology in healthcare today, has the potential to completely transform how hospitals deliver care to patients around the world. Today, AI applications are being used in patient management, pathology, radiology, and health information systems globally. On the other hand, there are various serious problems that hampers the patient's quality of care such as a poor patient to doctor ratio, lack of access to healthcare (both geographically & economically), limited digital infrastructure (to name only a few), which is still making AI a necessity as an innovation in India, but will also help in providing more equitable access to healthcare services.

While there has been a lot of global research on the role of artificial intelligence (AI) in the healthcare industry, a systematic literature review focusing solely on the use of AI by hospitals in India is still scarce. The lack of systematic literature is thus a major gap in research considering India's situation which is characterized by limited resources, funding issues, and the complexities of healthcare needs of a huge and diverse population. The main purpose of this review is to gather the existing literatures to better understand the current state of AI in Indian Hospitals; the benefits associated with the use of AI in Indian Hospitals; and what limits the widespread implementation of AI in Indian Hospitals.

Methodology

The systematic review was done according to the established methodology for performing systematic reviews. The researchers created a comprehensive search strategy that was used to search databases such as PubMed, Scopus and Google Scholar to search for literature published between the years 2015 to 2024. The search terms that were applied in the literature search included "artificial intelligence," "machine learning," "Indian hospitals," "diagnostics," "telemedicine," "predictive analytics," and "healthcare management." The inclusion criteria for the articles were based on whether they were peer-reviewed, review articles and case studies. In addition, the search of global literature was also considered to gain a comparative perspective where applicable. Any study that was not related to healthcare, or where the study focused only on purely AI technical models (without a hospital-based application) was excluded from the systematic review. Following the selection process, 41 articles were included for analysis. These were critically reviewed and thematically categorized to highlight the significance of AI in Indian hospital settings.

Results and Findings

1. AI in Clinical Diagnosis

The diagnostic areas in which AI has achieved the greatest level of success to date include radiology, oncology, pathology, and cardiology. There are many examples from India providing evidence of the ways in which AI has been and is being applied to transform the healthcare sector. For instance, some state TB programs in India are now using Qure.ai's AI-based tool for chest X-ray interpretation to improve the accuracy of detecting TB and to reduce the time taken to report on chest X-ray results. Similarly, Niramai uses thermal imaging and AI-based systems to conduct early breast cancer screenings in community camps in order to offset the financial barriers and social stigma associated with breast cancer screening. Finally, some AI-based systems are being piloted by AIIMS Delhi and Narayana Health to improve the early detection of arrhythmias and heart failure through echocardiography. However, most AI-based diagnostic tools are still in a validation phase and their generalizability is limited due to a lack of available large-scale Indian datasets.

2. AI for Administrative Effectiveness and Hospital Operations

The potential for optimizing hospital workflows using artificial intelligence (AI) is enormous. There are many examples from around the world where AI has been successfully applied to improve patient scheduling, triage, and electronic health records (EHRs). Fortis Healthcare in India has piloted predictive algorithms to enhance patients' flow through hospitals and bed occupancy, while Apollo Hospitals has incorporated AI-based clinical decision support systems to expedite emergency room triage of patients. Large-scale deployment of many of these systems will be problematic for smaller hospitals since many of them suffer from inadequate IT

infrastructure and the upfront costs associated with the technology can be prohibitive. Additionally, the lack of standard, interoperable systems means that fewer than 30% of Indians have adopted EHRs and the existence of many "siloed" systems limits any access to data that could facilitate administrative efficiencies through the application of AI.

3. AI in Remote Healthcare and Telemedicine

Telemedicine developed quickly and relied heavily on the use of Artificial Intelligence (AI) tools to help facilitate communication and interaction between patients and doctors over extended distances, using AI technology to help identify symptoms through chatbots powered by AI, such as the Mfine and Practo Virtual Chat Services. Chronic disease monitoring modules were designed using AI-augmented technologies to aid in the monitoring of chronic illnesses remotely, with a special focus on those in rural communities, through government-supported platforms such as eSanjeevani. During COVID-19, Apollo TeleHealth used wearable monitoring devices with AI capabilities that enabled monitoring of patients quarantined in semi-urban and rural areas. While there are several barriers to accessing these types of systems because of uneven internet access and lack of technology knowledge and use skills, the popularity of these tools confirms that telemedicine is one of the best and most quickly growing uses of AI technology in India.

4. AI in Predictive Analytics for Public Health and Resource Planning

Healthcare facilities across India were depending on predictive analytics to assess demand for several types of hospital resources during emergency situations such as the COVID-19 pandemic. Hospitals and policymakers have been able to make better decisions when allocating necessary resources by utilizing predictive analytics tools, such as the computer-created predictive models developed by IIT Delhi and IIT Hyderabad that were used for forecasting the number of cases expected, admissions to the hospital, and required amounts of oxygen. Many other tertiary care facilities across India, such as AIIMS Bhubaneswar, are also working with AI systems to predict how many ventilators will be needed in the units (i.e., ICUs) of their facilities. Various Indian states such as Karnataka and Maharashtra are also studying the use of predictive models in relation to tracking disease outbreaks and identifying risks for pregnant women. While many of these uses are still in the research stage, they continue to have insufficient formal implementation as part of the resource management systems in hospitals.

5. AI in Therapeutics and Personalized Medicine

There is no denying that personalized medicine has only recently begun to emerge in India, however it is gaining ground quite clearly. Genomic based AI is being used at Tata Memorial Centre (Mumbai) in partnership with AI firms for individualised planning of cancer treatments, whereas in much the same way, MedGenome Labs use AI to help analyse genomic data for the diagnosis of rare diseases and work to improve oncology through precision medicine. Even

though these efforts are displaying strong evidence of the value of AI towards advancing personalised medicine in India, both still are limited to private laboratories and tertiary hospitals due to their high cost and infrastructure resource requirements. Widespread adoption of these research use cases across Indian institutions is further limited by the lack of a comprehensive genomic database that considers the genetic diversity of various communities throughout India.

6. Barriers to Adoption

Table 1: Applications, Opportunities, and Barriers of AI in Indian Healthcare

Theme	Key Applications	Opportunities	Barriers in India
Diagnostics	Radiology (X-ray/CT scans), oncology, pathology, cardiology, and TB detection	Improved accuracy, faster diagnosis, and early detection of diseases	Limited validation on Indian datasets, high cost of implementation
Hospital Operations	Triage, patient scheduling, electronic health records, workflow optimization	Reduced waiting time, better resource utilization, improved efficiency	High setup costs, poor system interoperability, and resistance to change
Telemedicine	AI-powered chatbots, decision-support tools, and remote monitoring devices	Extends care to rural/underserved areas, continuity of care during pandemics	Digital divide, poor internet connectivity, and a lack of trained staff
Predictive Analytics	Forecasting admissions, bed occupancy, epidemic trends (e.g., COVID-19 models)	Resource planning, pandemic preparedness, and proactive hospital management	Mostly research-based, with limited integration into routine hospital practice
Personalized Medicine	Genomics, drug discovery, precision oncology, AI in therapeutics	Tailored treatments, potential for advanced care in tertiary hospitals	Lack of genomic datasets, weak infrastructure, and high costs
Barriers to Adoption (Overall)	—	Potential to transform Indian healthcare delivery	High financial burden, shortage of AI-trained clinicians, unclear regulations, ethical and privacy concerns

Numerous hurdles make it difficult for hospitals in India to incorporate artificial intelligence (AI) into their facilities, although these systems show promise. Overwhelmingly expensive projects to implement and a lack of trained professionals to work with AI have become recurring issues also

affecting implementation. Additionally, an absence of definitive guidelines for the use of AI within the healthcare system, including issues related to data privacy and liability, increases the uncertainty related to the ethical use of AI in the healthcare industry. Although "interoperable" electronic health records are being developed through initiatives such as the Ayushman Bharat Digital Mission (ABDM), implementation has been slow and inconsistent throughout India. In particular, clinicians resist adopting AI technology, frequently citing their lack of skills to use the systems and/or concerns that they will be replaced by it. Therefore, implementing AI in Indian hospitals will not occur until there are systemic reforms within the workforce (particularly upskilling), a more definitive regulatory framework, and more significant collaborations between the public and private sectors in order to achieve anything but pilot projects.

Discussion

According to the findings of the review, AI is having a considerable impact on hospitals in India while simultaneously placing them at a crossroads between progressing toward new technologies and integrating them into everyday practice. The diagnostic field has seen the greatest advancements. For example, AI models developed for diagnostic imaging (e.g., radiology, pathology, oncology) have already demonstrated superior accuracy and performance compared with their non-AI counterparts. AI-enabled diagnostic imaging for detecting cancer and TB has shown great potential in India; however, generally speaking, most of the research demonstrating this type of technology will not be definitive because they lack sufficient validation using the local datasets for India (generally). Hospital operational improvements are expected from various forms of AI applications such as digital triage systems, digital scheduling systems, and the integration of electronic health records. However, there are major structural challenges related to fragmented digital systems, low levels of interoperability between different digital systems, and high upfront costs that prevent widespread adoption of these types of AI-enabled solutions in Indian hospitals. The ability of AI to help provide support for patients living in rural and underserved areas can be seen from the experience of delivering telemedicine services during the COVID-19 pandemic. Lack of human resources was compensated for by telemedicine capabilities; however, the continuity of care through telemedicine solutions was accomplished due to the use of wearable monitoring devices, chatbots using AI for patient health assessments, and AI decision support systems. By making investments in both internet connectivity and support for increasing the level of digital literacy of residents living in rural and underserved areas, India can continue to close the gap in the quality of healthcare between rural and urban citizens.

Predictive analytics has been used for the first time in predictive modelling for pandemic preparedness through models that predict hospital admission, ICU occupancy, and epidemic

outbroke. These predictive tools will remain in academic settings and do not currently exist within most routine hospital management systems.

In contrast to the rapid growth of precision oncology (genomics) internationally, personalized medicine is still at the early stage of development in India due to a lack of genomic datasets, infrastructure, and financial resources. However, some tertiary hospitals in India who are working with these technologies report a strong future.

There are very clear differences between low-income and high-income countries. In contrast to North America/Europe, India is still primarily piloting the implementation of AI in hospitals. To close the gap between low-income & high-income countries, a phased approach must be implemented.

- **Short-Term Goal**: Prioritize artificial intelligence in the areas of telemedicine and diagnostics, where the benefits of using AI can be fully realized almost immediately.
- **Mid-Term Goal**: Continue to implement interoperable electronic health record systems and improve the digital infrastructure that supports them.
- **Long-Term Goal**: Develop legal frameworks that properly regulate and define how AI will function within healthcare; establish ethical boundaries for AI; and properly train health care professionals on how to utilize AI.

In conclusion, AI is already beginning to alter the hospital environment in India; however, to fully realise its potential, systemic barriers must first be eliminated. India has the opportunity to establish itself as a leader in developing an efficient and equitable delivery system for AI-enabled healthcare through investments, appropriate regulatory frameworks, and collaboration among doctors, legislators, and technology partners.

A review of the literature relating to the use of AI within hospitals demonstrated both the increasing importance of AI in Indian hospitals and the barriers to the wider use of AI, as well as the demonstrated benefits associated with the application of this technology.

AI is helping clinicians make clinical decisions (diagnostic judgment) improve and reduce delays in making a diagnosis through its most matured application of AI, which is changing the way we diagnose patients today; however, the current studies are mostly small sample size studies so require to have the same level of validation for diagnostic judgement with more patient-specific data from India. Artificial intelligence (AI) has the potential to improve how hospitals operate by using better methods for allocating resources, optimizing workflows and scheduling, etc. However, because of limited funds as well as poorly integrated digital systems, hospitals have yet to adopt this technology on a large scale.

During COVID-19, one of the biggest ways that AI has been implemented in India is through telemedicine. Telemedicine creates more equitable access to healthcare by continuing to reduce the disparity in healthcare delivery between rural and urban communities.

Predictive analytics holds enormous possibilities for both resource management (particularly via predictive modelling, linked to patient demographics and conditions) and preparedness for infectious disease outbreaks like those caused by pandemics. While the usefulness of predictive analytics was illustrated during the COVID-19 pandemic, there has yet to be much practical application of predictive analytics in daily hospital operations.

In terms of personalized medicine, the use of personalized medicine and AI-based drug development has very little established presence or history in India and is thereby still very much in its infancy. However, the advancement of AI/drug development and genomics is happening quickly outside India; the structural and economic barriers to adopting these technologies in India remain excessive.

There are numerous barriers (e.g., cost, data privacy, regulatory uncertainty, clinician resistance) to the integration of AI technology into healthcare and hospitals; however, due to the rapid pace at which AI is being integrated into healthcare systems in high-income countries (e.g., developing nations), Indian facilities are still stuck in pilot-project mode and have formed mostly partnerships with technology firms to leverage AI technologies.

The development of a phased approach is required:

- Prioritize the use of AI in telemedicine and diagnostics,
- Develop the digital (i.e., electronic medical record) infrastructure, and
- Create ethical, workforce education and training, and regulatory standards/requirements to ensure long-term success).

Limitations

The limitations of this review need to be taken into consideration. The number of studies analysed does not give a complete picture of the variety of AI applications in hospitals across India. Many of the studies included were pilot or small-scale studies, therefore this lacks the ability to generalise findings from all hospitals in India. The studies were also sourced from the international literature, it is likely that the specific issues that affect how AI is used in India (such as affordability, digital inequality and the shortage of healthcare workers) may not have been accounted for fully. Finally, as AI technologies evolve quickly there may have been an emergence of new technologies/AI applications since the concluding date of this review.

Conclusion

On a global scale, Artificial Intelligence (AI) is redefining the overall healthcare landscape; however, this trend holds an even greater value in India due to its vast population, inadequate healthcare resources, and pronounced disparities in access and health outcomes. This article reviews the ways in which AI has contributed positively to diagnostics, telehealth, and predictive analytics to date. Furthermore, the use of AI in hospital operations and personalized medicine are still in the early stages of development. To maximize the potential of AI within India's hospitals,

system-wide changes will be required, including creating a strong digital foundation, establishing a sound regulatory framework, ensuring ethical oversight, and building clinician capabilities. These components will be necessary for transitioning AI from initial testing to established clinical practice. Given these challenges are successfully addressed, AI will become a significant factor in the transformation of Indian hospitals through increasing the efficiency, equity, and patient-centeredness of the care provided by hospitals.

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DIGITAL HEALTH REVOLUTION: UNLOCKING INDIA'S DIGITAL HEALTH FRAMEWORK

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Abstract
Equity in healthcare is about universal health coverage, for which digitalization of healthcare is a key component. An initiative by Government of India, Ayushman Bharat Digital Mission (ABDM) has set an exemplary standard for digital health. ABDM, which operates on a patient-centric, consent-oriented, federal, and interoperating system, can overcome the existing challenges of affordability, accessibility, and safety in the healthcare system? This text helps in understanding ABDM through the lens of telemedicine, its affordability and accessibility, ABDM architecture consisting of EHR and HMIs, AI and ML in digital health, Digital health literacy and barriers to eHealth, and ethical and regulatory concerns related to digitalization. Additionally, the challenges leading to insufficient expansion and implementation are highlighted for developing strategies to enhance health outcomes.
Keywords: Ayushman Bharat Digital Mission (ABDM), Interoperability, Consent Manager, AI and ML, Digital Health, Ethics, Digital Health Literacy, Telemedicine, HMIS.

Introduction

The World Health Assembly in 2005 urged member states to promote accessible and affordable universal health coverage through eHealth. In subsequent years, member states were asked to develop strategies for eHealth, and later, Digital Health 2020-2025, was taken up by member states. Potential use of digital Health was recently considered as an important part of Sustainable Development Goals 2030. Digital Health, comprising tools such as Virtual care, Internet of Things, artificial intelligence, wearable devices, blockchain, and data analytics, leads to improved health outcomes through quality diagnosis, decision-making in treatment, clinical trials, and personalized medicine. The Vision of the Global strategy on digital Health is to develop and adopt Digital Health for everyone and everywhere; to prevent, detect, and respond to epidemics and pandemics, and to promote Health. For the inclusion of low- and middle-income countries, global solutions and shared services should be included in the national health strategies of these countries. Digital Health can be a potential accelerator for UHC, monitoring of NCDs, as well as access to medicines and treatments (Organization, Global strategy on digital health 2020-2025, 2021).

The Indian healthcare system comprises a vast network of healthcare facilities, healthcare professionals, and a large population, which presents challenges like fragmented data capture by

multiple stakeholders and a lack of standardization, resulting in the compartmentalization of digital health assets. Data in the healthcare system is sensitive and complex, making digitalization a challenging task. Recognizing this fact and with the aim of addressing the challenges, the National Health Authority of India developed an approach for universal health coverage and digitalization of HealthCare - an integrated and unified system, known as the National Digital Health Ecosystem. The National Health Policy released the National Digital Health Blueprint in 2019. National rollout of NDHM, as Ayushman Bharat Digital Mission, was launched in September 2021 with the vision of achieving universal health coverage in an efficient, accessible, affordable, inclusive, safe, and timely manner. The mission of ABDM is to create a Digital platform that leverages data, information, and infrastructure while maintaining security, privacy, and confidentiality. ABDM is an open, interoperable ecosystem that operates on principles such as Consent-based sharing, Federal architecture, and Digital Public goods, making it a Digital Public Infrastructure (DPI) initiative. Core modules of ABDM include ABHA, Health Facility Registry, Healthcare Professionals Registry, Personal Health Records (PHR) Application; these modules are designed to bring about quality and standards in the Indian Healthcare system. As of August 2025, ~79.91 Cr ABHA accounts have been created, ~4.18 Lac health facilities have been registered~ 6.79 Lac Healthcare Professionals have been registered and ~67.19 Cr health records have been linked with ABHA. (Delhi, Ministry Of Health And Family Welfare, 2025)

This chapter aims to understand Digital health and ABDM through five major themes: ABDM Architecture consisting of Health management information systems and electronic health records, Artificial intelligence and machine learning, Telemedicine, Digital Health literacy, and the Ethical and Regulatory aspects of digitalization in HealthCare. Extensive global literature, along with the Indian scenario in Digital health, has been studied and explained, including the challenges identified, implementation barriers, and strategies for equitable Healthcare. Literature reviewed for this chapter includes official documents, peer-reviewed academic literature, and other sources of information. This chapter does not include any primary data; instead, it focuses on secondary data and statistics, with a primary focus on digital health infrastructure, its implementation, and governance.

ABDM Architecture- Electronic Health Records and Health Management Information Systems

The primary aim of ABDM is to create interoperability among different digital health systems. This architecture is built on the principle of privacy by design, which ensures data security. ABDM uses existing digital public goods and Jan Dhan Aadhaar Mobile (JAM) Trinity as a base. The architecture is designed in a way with its key features: decentralised digital health data and applications, the location of health facilities, and citizens having autonomy over processing

their health data, accessibility to providers only through permissions and consents. In this system, data storage is performed at a particular location, typically a healthcare provider, such as a doctor or a hospital. Digital health tools used by patients will be stored on the server or devices. Hence, digital health records can be stored at multiple places, as per the choice of providers or patients. The data collected through registries is stored centrally. (National Health Authority, 2021)

The ABDM stake comprises JAM digital public goods, including UPI, Aadhaar, and the digital locker. Health data exchange encompasses infrastructure like digital registries, health claim standards, and health information exchange. The technical standard adapted for interoperability is Fast Healthcare Interoperability Resources (FHIR) which structures data and helps in secure exchange of information (Standards, 2025).

The unified health interface includes telemedicine APIs, lab and drug APIs, as well as other services. User applications that fall under public and private innovation include individual apps and platforms such as Arogya Setu, eSanjeevani, as well as health provider apps like HMIS and LMIS (National Health Authority, 2021).

The core building blocks of ABDM include: Ayushman Bharat Health Account (ABHA), a unique 14-digit health ID that can be created online or in assisted mode, free of charge; it links medical records and provides consent-based access to these records. The Healthcare Facility Registry (HFR), a digital database of healthcare facilities, provides information about facility type, ownership, and location. The Healthcare Professional Registry (HPR) is a digital registry of verified healthcare professionals. Verification is done through professional councils. Doctors from both the Allopathy and AYUSH systems can integrate with ABDM. Currently, Doctors and Nurses are integrated with the digital platform, while planning to integrate pharmacists and allied health professionals in the future. Personal Health Records (PHR): They are digitally stored health records, with consent-based access granted to individuals. Registry includes Lab reports, Imaging reports, prescriptions, and other relevant documents. (National Health Authority, 2021)

The Information flow is based on: Health information providers, which consist of doctors, who are the primary point of contact for Health record generation. Points of request for accessing health records are the doctors who are categorised as health information users. Health information exchange, managed by the concerned manager, facilitates the exchange of health-related information (National Health Authority, 2021).

Health management information system: ABDM has not recommended any specific health management information system, but has given general guidelines for how the system should be. Definitive given from the mission ensure that the process of digitalization is not hindered by the information system. Principles recommended for HMIS include that the tools should be user-friendly, the system should include all the necessary modules for operation of that specific

healthcare facility, and modules should be integrated, end-to-end. Additionally, the mission includes integrating HMIS with digital health standards such as ICD, LOINC, and SNOMED-CT. This system helps in providing unique code for health Terminologies and brings about uniformity in the process. It also helps in the efficient use of AI and ML-based technologies. Another recommendation that a standard HMIS should have is Natural Language Processing (NLP), which is helpful for real-time monitoring. Another component, the health facility registry, is secure because the data transmitted is over HTTPS (Hypertext Transfer Protocol Secure), ensuring robustness. ABDM has specially developed the Health Information Exchange and Consent Manager (HIE-CM) for managing consent and data requests between users and providers. Unified Health Interface (UHI) serves as an open network of End-User Applications (EUAs) and Health Service Provider (HSP) Applications. UHI allows users to book OPD, Teleconsultation, lab, and diagnostic services. It also supports grievance redressal and secure data exchange. The ABDM sandbox works for the integration of various health system components. It connects IT platforms with ABDM building blocks for efficient health tech services. Sandbox fosters understanding between Health Information Providers, Users, and Health Repository Providers.

The healthcare professional registry encompasses various systems of medicine, including Ayurveda, Homeopathy, Unani, Yoga, and Siddha. This feature of ABDM aligns with the goal of the National Health Policy 2017, which is to mainstream AYUSH for preventive and promotive practices in health. Mainstreaming of AYUSH through ABDM can be achieved with capacity building and infrastructure development, particularly in clinics (Welfare, 2017). Additionally, data collected from the registry through prescriptions and reports can be beneficial for evidence-based decision-making in traditional practices. Summing up, electronic health records are created and linked through ABHA ID, while maintaining consent; HFR should be complaint with given standards of HMIS, HPR is monitored and approved by concerned approving managers and PHR are managed through an application (National Health Authority, 2021) for efficient working of ABDM.

Artificial Intelligence and Machine Learning in Digitalization of Healthcare

AI and ML-based health tech tools such as wearable devices, radiology and Imaging, diagnostics, prediction models, and personalized healthcare models are gaining interest in the ongoing environment of data-driven solutions. Global AI in healthcare was valued at ~29.01 billion USD in 2024 and is estimated to have CAGR of 44% by 2032. (Pawar, 2025)

Artificial intelligence is the ability of machines to perform tasks that require human intelligence, such as learning pattern recognition, decision-making, language understanding, and image processing. Machine learning is a tool used to frame algorithms that represent a dataset to produce a desired output. Deep learning is a sub-theme of machine learning that uses artificial

neural networks. Artificial neural networks are a machine learning algorithm that contains nodes, which are connected like neural networks in the human brain. These nodes receive input from the provided data or other nodes, weights are applied to these inputs, and the resulting output is provided. In deep learning, there are multiple layers of neural networks, which may use architectures such as convolutional neural networks (CNN) and recurrent neural networks. CNNs are used for processing medical images, and models are used for sequential data analysis in natural language processing (NLP). NLP makes the model understand human language and generate text.

Artificial intelligence is now significantly changing the current clinical medicine scenario. It has solutions for the diagnosis, management, and treatment of patients. Huge, intricate datasets can be processed using NLP and deep learning for efficient clinical outcomes. NLP algorithms can also extract insights from unstructured data, such as electronic health records, physician notes, and medical literature. Prediction models are used for the early detection of diseases and the management of chronic conditions such as cancer. AI is also involved in genomics, accelerating the discovery of genetic variants associated with various disorders. AI tools can be used to predict the treatment and for management of rare diseases. (Aravazhi, 2025)

For improving diagnostic accuracy, early detection, personalised medicines, and integration of AI with calorimetric biosensing and multimodal data fusion are some of the scalable solutions. Studies are being conducted on AI-driven multimodal calorimetric models, a conceptual framework that suggests mobile-based calorimetry with biomedical data such as clinical, and environmental data sets, and imaging using low-cost tools for real-time monitoring and predictive models. This model consisted of five interconnected stages: calorimetric biosensing, preprocessing, signal conditioning, multimodal data fusion, interpretable AI modelling, and real-time inference. Such models can be used for inclusive patient care. (Hagos, 2025)

A clinician-AI collaboration framework can be developed for efficient patient outcomes. Components involved in this framework include the clinician AI communication desk, scientist, helpdesk, quality assessment board, and ethical review board (Nasarian, 2024).Along with the usefulness of AI and ML in healthcare systems, the use of AI brings about ethical and regulatory challenges, medical-legal issues, and cybersecurity threats (kaladharan, 2019). The core ethical principles for AI in healthcare, as put forth by global agencies include: Autonomy, beneficence, justice and non-maleficence (Fahrud, 2021).Due to the black box nature of AI models, difficulties in interpretability and a lack of trustworthiness for clinicians are seen (Aravazhi, 2025). These regulatory aspects may include data privacy laws, such as HIPAA, and data sharing issues. AI models must undergo regulatory compliance through clinical studies to ensure the safety and efficacy of the model. XAI (Explainable AI) in healthcare and medicine has gained

significant Interest among researchers in recent years. For creating transparency in black box models, XAI implementation is a significant tool (Hagos, 2025).

One example of AI in human immunology is explained further to facilitate an understanding of personalised treatments for immunological system disorders. Projects are underway to develop a global standardized immune profiling to present the overall population. In vivo immune cell-based sensors can be used for real-time monitoring of physiological changes, generating datasets for AI modelling. Neural networks and foundational models can provide predictive analysis for a large number of data sets in human immunology. A comprehensive array of individual factors, such as immune profiles, socio-economic factors, etc, which are represented as personal immune state embedding, can be converged for precise monitoring, prediction, and modulation of immune health (Lej, 2025).

The use of AI, along with robotics and the Internet of Medical Things, can significantly drive the healthcare system towards profound solutions to challenges. Use of AI and robotics can help address accessibility barriers through early detection, diagnosis, and treatment. For instance, robot assisted Surgery had largest revenue share in healthcare AI, in 2024 (Pawar, 2025).

The NHS had proposed technology like Artificial intelligence and machine learning for integrating primary, secondary, and tertiary levels of healthcare facilities (National Health Authority, 2021). ABDM is based on the Application Programming Interface (API), allowing proprietary technologies and open-source solutions to integrate seamlessly. This design allows interoperability and exchange of data (Bank, 2023).

Although AI and ML are not widely integrated into digital health systems currently, some clinical decision support systems are under development, such as connecting all ICUs, operating ventilators, and utilizing AI in remote diagnosis, as well as 3D printing technologies, etc. Blockchain technologies are being leveraged to create ABDM. Cloud Computing is also being studied for integration into ABDM. Looking forward, healthcare system can expect integration of AI into National Health Mission. (Bank, 2023)

Telemedicine- Application towards Accessibility and Cost Effectiveness

For equity in healthcare, telemedicine is an essential component (Salsabilla, 2021). Nowadays, telemedicine is adopted for chronic disease management, remote consultations, collaborative diagnostics, real-time monitoring, patient engagement, and accessibility to healthcare services. (Azzolini, 2025)

Telemedicine provides the opportunity for equal access to healthcare, overcoming geographical barriers, and aids in addressing insufficient public infrastructure. Telemedicine can be an alternative option in low-income countries where healthcare services are not affordable. Studies on use of telemedicine for chronic disorders have shown that it can reduce the societal cost by USD 7.92 per consultation. (Baek, 2025)

In a study examining the cost-effectiveness of telemedicine in India, Bangladesh, and Hong Kong, which compared telephone-based support in managing pressure ulcers in individuals with spinal cord injuries, the cost-effectiveness of telemedicine was found to be 41%. In India, particularly in Gujarat, the use of a health programme for child, maternal, and neonatal healthcare management was found to be cost-effective. This mobile health intervention was considered cost-effective from a programme perspective at an incremental cost of $74 per life year saved. For better information, improved healthcare outcomes, and decreased discrepancies in the healthcare system, telemedicine can be a significant tool. As the use of smartphones increases, the availability of the Internet and its application in electronic health records is expected to expand for telemedicine in the future (Salsabilla, 2021).

Although telemedicine has numerous benefits, digital health literacy can be a barrier to extensive use of telemedicine. Lack of access to required technology by patients and providers may hinder the quality of care and may act as a barrier to telemedicine implementations. In a national sample of physicians' surveys, it was found that 48% of medical and 33% of primary care physicians used telemedicine themselves (Salsabilla, 2021).The expansion of 5G technology is expected to mitigate connectivity by providing speed up to 20 Gbps, that can be helpful for real time monitoring (Health, n.d.).

Perceived barriers, as reported by 70% of the respondents, included the use of technology in telemedicine platforms. Access to telemedicine technologies, such as smartphones, computers, and tablets, accounted for 64% of the limitations. Barriers related to reliable broadband connectivity consisted of 33%. It was also reported that organizational and environmental facilitators, such as perception of quality of care delivered, favourable reimbursement policies, and financial benefits through telemedicine, compared with in-person care were influencing utility of telemedicine (Wiley, 2024).

Hospitals utilize various platforms for telemonitoring to collect data, thereby decreasing the time wasted and lessening the worsening of conditions, ultimately providing therapies for newly diagnosed diseases. It is also beneficial for the course of rare genetic diseases, through a better understanding, and the use of multidisciplinary methods. Teleconsultations between healthcare professionals are useful for advice and therapies on various disorders. Tele-training can be used for teaching and learning by healthcare professionals. Use of large language models (LLMs) can prove to be beneficial for interconnection among healthcare professionals (Azzolini, 2025).

In terms of accessibility and efficiency, a study conducted among outpatients in an urban hospital in Bengaluru found that 87.3% of participants found ABDM beneficial for record keeping and accessibility. Increased efficiency was reported by 54% of participants. Helpful during an emergency was reported by 12.7% of participants. Many participants believed it to be efficient in terms of managing patients by doctors.

India's eSanjeevani has carried out over 163 million consultations as of 2023, showing massive expansion of telehealth (Sood, 2025). eShushrut Lite HMIS, that supports small healthcare facilities, comes with the feature of ABDM compliance. Costing ₹299 per month, this modular HMIS can be affordable option for small healthcare facilities, planning for digitalization of their services (Delhi, Update on Ayushman Bharat Digital Mission, 2024). ABDM with it's feature of Scan and Share, QR code based OPD registration is gaining interest of individuals as it reduces the OPD waiting time from 30-40 minutes to 5-10 minutes. As of November 2024, 6.64 Crore tokens have been generated, saving 3.3 Crore person-hours. Patients can scan QR codes using PHR Apps and avail healthcare facilities in minimal time. Thus, digital health and initiatives like ABDM can serve purpose of making healthcare accessible and cost effective (Arjun, 2024).

Digital Health Literacy

"Digital literacy refers to the ability to use information and communication technology to find, evaluate, create, and communicate information, requiring both cognitive and technical skills." (Organization, Global strategy on digital health 2020-2025, 2021)

Health literacy is defined by WHO as "The cognitive and social skills which determine motivation and ability of an individual to gain access to understand and use information in ways which promote and maintain good health" (Yang, 2022) (Kessel, 2022)

In a study on digital health literacy, four attributes were identified: Goal driven regulation, information processing, communication, and utilization. Goal-driven regulation refers to the ability of an individual to monitor and regulate the knowledge translation process, which involves information processing, communication, and utilization for accurately meeting the goals. Information processing encompasses the ability to effectively structure information by navigating it, evaluating it, and determining its relevance. Communication and digital health literacy are the capacities of both the sender and receiver, which include lay users, common health professionals, and digital health systems; they together engage in reciprocal information exchanges and expression. (Ban, 2024)

The Efficient use of digital tools for health care is also determined by patient engagement and their initiative in using these tools. Digital literacy plays an important role in making healthcare settings inclusive. Socio-demographic factors play a significant role in determining digital literacy among patients. A study conducted in Germany on digital health literacy and socio-demographic factors showed that 24% of participants were using variables for health. Variable use was comparatively lower among the geriatric age because of a lower educational background, below-average household income, and living in small cities. Integration of variable devices, which are beneficial for physical fitness management, healthier lifestyle, early detection, patient monitoring, and personalized care, etc, is followed by challenges known as the digital divide, which is influenced by disparities in accessing and using technologies. Marginalised

communities' men suffer more in terms of inaccessibility to digital tools. Thus, it is observed that Socio-demographic factors such as age, income, education, and location have a significant influence on the use of digital health devices (Pan, 2024). Another influential factor includes interpersonal factors and technological aspects. Involvement from families, social networks, and health professionals may positively affect the digital health literacy coverage. From a global perspective, social and cultural factors, policies, human resources, and healthcare accessibility may also influence overall digital health literacy (Ban, 2024). For improving digital health literacy, healthcare professionals should actively encourage their patients to engage in digital health. Patients may be taught new health skills, health-related digital skills, and their practical implementations. Awareness among the general public and vulnerable populations can be increased to expand the accessibility of healthcare through digital health. Medical education can be accompanied by digital health literacy for increased use of digital health (Ban, 2024)

Discussing about Indian scenario of digital health literacy, A study conducted can provide insights: 150 outpatients in an urban hospital in Bengaluru were consider, examining their knowledge, attitudes, and practices regarding ABDM. The study showed that only 8% participants knew about ABDM, although their knowledge regarding teleconsultation was high. Approximately 12% of participants had heard about ABDM, and 3.3% knew about the ABHA card. Only 0.7% of participants had created an ABHA number. Patients with a Health ID card and number were 26%. Only 33.3% of Participants were aware of any type of digital health records. Only 2% had created an online health record by themselves, and 17.3% participants knew about the National Health portal run by the government. Most awareness of digital health initiatives was from television (82%). One-fourth of participants were aware of laws regarding data protection. More than 92% of participants were ready to make a health ID. One of the important concerns with digitalisation in healthcare was Data safety and privacy (60%).

Studies have shown that a gender disparity exists in the use of digital tools. In 2023, 31% of women in South Asia were less likely to access mobile phones than men (Khadka, 2025) (Barboni, 2018). This kind of utilization disparity can also be faced by older adults, for whom ABDM has a significant element called the assisted mode of enrolment. To avail this assisted mode in creating an ABHA ID, individuals can visit a nearby facility compliant with ABDM (Sharma, 2022). It can be summarized that though digital health architecture will be of pivotal change, but considering and addressing challenges related to digital health literacy are of key importance. (Arjun, 2024)

Ethical and Regulatory Aspects

Information ethics is considered a subdomain of applied ethics. It revolves around the uses and misuses of Information Systems and technology (Floridi, 2010).It provides standards for processing, storing, analysing, and sharing information. (Ruotsalainen, 2020)

Digital health system, with its rich potential to transform the healthcare system, present new ethical challenges and considerations for implementation. Ethical challenges may arise from technologies, stakeholders, data analysis tools, and a lack of Rigor in regulatory mechanisms. Another critical concern is digital divide, that may exclude the vulnerable populations because of lacking digital literacy. (Nebeker, 2019)

Digital health decision-making framework, as described in an article on ethics in digital health, encompasses respect for persons, beneficence, and justice. Respect for users, justice, security, and consents must be managed and prioritized for enhancements in the safe use of technology. Privacy in digital health consists of personal data exchange in the form of sharing digital health records/ diagnostic reports. Data collection and storage protocols, particularly in terms of data accessibility, should be rigorously addressed. Benefits and risks should be studied along with the tool's validity and Reliability for better ethical compliance. While including vulnerable and marginalised populations, conditions should be made such that they are protected from any harm when developing information systems. Privacy concerns, societal impact, efficiency, and risk assessment need to be considered. (Nebeker, 2019)

As the digital health ecosystem involves different stakeholders, including businessmen who work for profit, the business ethics might be beneficial for providers and stakeholders, but may cause harm to users, more specifically in terms of privacy and personal data security. Misuse of data may not only cause social harm but also psychological harm to end users. Data breaches may act as a threat including ransomware attacks and unethical hacking. (Ruotsalainen, 2020)

Trustworthiness of systems depends on business and ethics model, trust features and privacy levels, methods used in design and implementation, and compliance with laws. For an ethical and regulatory compliant model, computer ethics, medical professional ethics, consequentialism and utilitarianism are to be considered. Consequentialism here specifies results of services to a person’s health, and utilitarianism refers to PHI being available to medical researchers and public health professionals for population study on health. (Ruotsalainen, 2020)

Various authors state privacy, trust, usability, autonomy, security, safety and value orientation for ethical inclusions (Scott Lederer, 2002) (Blobel, 2020). Intellectual property rights can also be taken into consideration for consent to data exchange (Ruotsalainen, 2020).Data sharing practices should make use of informed consents and compliance with HIPAA rules as well as rules of regulatory bodies of particular country.

In India, as ABDM acts as a platform of interconnection between different digital health systems, and storage of data is in the same place as it used to be, no particular laws are required for the implementation of this mission. To get the digital health ecosystem compliant, the Digital Health Management Policy has been implemented for consent-based arrangement of the system. Consent is important while linking health records and generating a digital health ID, while

approval of HFR and HPR is monitored by the respective regulatory authority. HIE-CM is an essential tool for improving security and consent-based data exchange in ABDM. Data sharing in ABDM is efficient as it is based on the Health Data Management Policy, Data Protection Bill, Information Security Policy and various other applicable policies (National Health Authority, 2021). The Digital Personal Data Protection Act (DPDP Act), 2023 provides framework for governing digital health data in India. Penalty of up to ₹250 Crore can be imposed for major non-compliance of regulations (Secure, 2025). Expansion of digital health tools will only prove beneficial when ethical and regulatory principles are followed, hence rigorous security and privacy policies can be given a thought in terms of digital health.

Case Study of ABDM Integration through a Private Health-Tech Firm- Eka Care

Eka Care, which became one of the first Private Platforms to register as both a Health Information Provider (HIP) and a Health. Information User (HIU), expanded its reach through its Eka ABDM Connect API by involving more individuals, doctors, and health facilities. It has generated ~1.8 Crore ABHA IDs, ~2.85 Crore PHR links, ~3,150 HFRs, and ~3,500 Doctors registered, with a record linkage success rate of 2025 above 93%, peaking at 97%. AI scribe, Intelligent Patient Summary, Anonymized Health Datasets, and Continuous UX refinements are some of the key innovations in progress by Eka Care. With upcoming milestones of NHCX Integration and PM-JAY Integration, and achieving expansion in ABDM, Eka Care has significantly driven ABDM among private partnerships. (Care, 2025)

Conclusion

Digitalization of the Healthcare system has tremendous opportunities for growth in the future. With the upcoming revolution in AI and its integration with healthcare facilities, accessible and affordable universal health coverage can be expected. ABDM, with its interoperability and federal digital ecosystem, highlighting its core modules, can ensure effective health outcomes. ABHA ID, with its consent-based sharing, HFR and HPR that brings the health system under a single roof and PHR, which facilitates personal health data exchange, has highlighted the digital health ecosystem of the national digital health mission. Certain challenges in terms of infrastructure and its adoption, digital divide due to digital literacy, acceptance of telemedicine, and ethical and regulatory concerns still prevail. ABDM, with its assisted mode, public-private partnership, mainstreaming AYUSH, and encompassing ethical challenges through consent-based sharing, is becoming a pivotal change in overcoming these challenges. To bridge the gaps and overcome the challenges, recommendations can be stated as follows: subsidies should be provided for upgrading infrastructure, including software and hardware, especially in remote areas. ABDM awareness campaigns can be conducted to enhance workflow. Digital health literacy can be increased by initiating e-learning Programs, and assisted consulting services. Accountability in terms of ethical and regulatory practices can be practised so that users are

aware of safety and data privacy. Rigorous implementation of policies should be practised for an equitable digital health ecosystem.

The national health stack can be beneficial for providing holistic healthcare data related to epidemiology, which can then be used for policy making. Through this digitalization, portability can be achieved for both users and providers. Large health databases can be generated for statistical analysis, which in turn can help in real-time monitoring and data-driven policy making. For achieving the goals of NHM, an overview of schemes can be generated. Fraud detection in health insurance and schemes can achieved with health data analysis (Aayog, 2018). Thus, with improved clinical efficiency, integration of technology, enhanced digital public infrastructure in healthcare settings and effective policy making, equity and access in healthcare can be achieved.

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DETERMINANTS OF INDIVIDUALS' CHOICE OF HEALTHCARE PROVIDERS IN INDIA

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Abstract

India's healthcare system is characterized by a pluralistic structure comprising public, private, and informal healthcare providers, offering individuals multiple options for seeking healthcare services. Understanding the determinants influencing healthcare provider choice is essential for improving access, equity, affordability, and the overall responsiveness of the health system. This chapter examines the multidimensional factors shaping individuals' choice of healthcare providers in India through a comprehensive review of existing literature, complemented by empirical insights from a qualitative study conducted in an urban primary healthcare setting in Navi Mumbai. Drawing upon Andersen's Healthcare Utilization Model, the chapter analyses the interaction of predisposing, enabling, need-based, and health system factors that influence provider selection. The findings demonstrate that healthcare provider choice extends beyond individual preferences and is significantly shaped by socio-demographic characteristics, economic status, cultural beliefs, perceived quality of care, accessibility, affordability, trust, previous healthcare experiences, and health system performance. While public healthcare facilities remain the preferred choice for preventive services due to affordability, trust in government programmes, and community outreach by frontline health workers, private providers are generally favoured for curative services because of perceived quality, convenience, specialist availability, and continuity of care. The study also highlights the continued reliance on informal healthcare providers in underserved settings where accessibility, affordability, and social relationships outweigh concerns regarding formal qualifications. Furthermore, healthcare provider choice is dynamic, with many households adopting hybrid patterns by switching between public and private providers depending on healthcare needs and experiences. The chapter concludes that strengthening primary healthcare, improving quality and responsiveness of public services, regulating private healthcare, and addressing socio-economic inequities are critical for promoting equitable healthcare utilization and advancing India's progress towards Universal Health Coverage (UHC).

Keywords: Healthcare Provider Choice, Health-Seeking Behaviour, Public and Private Healthcare, Healthcare Utilization and Universal Health Coverage (UHC).

Introduction

India's healthcare system is inherently pluralistic, with public, private, and the "in-between" informal providers, and is characterized by multiple systems of medicine. While the public sector primarily focuses on promotive, preventive, and curative services, the private sector largely emphasizes curative care. These providers operate within diverse social, geographic, and economic contexts. As a result, individuals and families often find themselves navigating multiple healthcare providers, and choosing a provider is an important aspect of healthcare-seeking behavior. This has significant implications for access, equity in utilization of services, and affordability of quality healthcare services. While public health facilities provide affordable care, they are often perceived as overcrowded, underfunded, and of substandard quality. In contrast, private providers- encompassing small individual-run clinics to large tertiary care centres- are usually associated with better perceived quality of care, and shorter waiting time, although at a higher cost. Additionally, a range of informal providers, usually referred to as "quacks," provide services without formal medical qualifications. Within this context, provider choice goes beyond individual preference to encompass decisions influenced by social, economic, systemic, and cultural factors.

Healthcare provider choice is closely linked to equity and the overall performance of health systems. A heavy reliance on the private sector for curative services is associated with higher out-of-pocket expenditures and an increased risk of households being pushed into poverty. At the same time, underutilization of key preventive services, such as immunization, may hinder public health goals. Hence, it is essential to understand the determinants that influence the choices of certain providers over others to design responsive and equitable health systems.

This chapter aims to synthesize existing literature on the determinants of healthcare provider choice in India, with a focus on the complex interplay of social, systemic, financial, and cultural factors. Rather than treating provider choice as merely an individual decision, the chapter adopts a broader analytical perspective that situates such choices within a wider contextual setting.

Methodologically, the chapter combines a review of literature with evidence from both rural and urban settings, supplemented by illustrative insights from an urban study conducted by the author in Navi Mumbai. These empirical evidences are used to supplement existing literature. By aligning localized field observations with broader literature, the chapter aims to enhance the understanding of how healthcare provider choice operates within the Indian context.

Theoretical Perspectives on Provider-Choice

Healthcare provider choice can be understood better by situating it within the broader framework of health-seeking behavior, which is the process by which individuals with a health-related problem seek an appropriate remedy. (Khadka *et al.,* 2022). In complex health systems, such as India's, where various systems coexist, health-seeking behavior involves navigating multiple

providers for diverse healthcare needs. Both demand-side factors and supply-side characteristics influence this choice. Rather than operating independently; they factors interact to shape how services are utilized. It is particularly relevant to low- and middle-income countries like ours, where formal healthcare systems coexist with informal providers and systemic inequities persist.

Health-seeking behaviour is not an isolated event. It is a constantly evolving process that is integral to an individual's experience, identity, and a complex interplay of various other contextual factors. Communities also inherit health beliefs, values, norms, and practices concerning various health issues. An individual's choice is therefore a result of various needs and cannot be accounted to a single event or factor. Particularly in the context of the Indian health system, traditional healers are key providers of care, and individual preferences could be incorporated to create a responsive healthcare system. (Das & Das, 2017).

Andersen's Model and Provider Choice

Theoretical models, particularly Andersen's healthcare utilization model, have demonstrated factors that lead to the use of health services. According to the model, the usage of health services is determined by predisposing factors, enabling factors, and need factors. (Jiang *et al.,* 2023). Drawing from Andersen's model, this chapter situates healthcare provider choice within broader determinants that shape healthcare utilization.

Demand- and Supply-Side Factors

Demand-side factors include socio-demographic characteristics such as age, gender, geography, education, health literacy, occupation, caste, social networks, and income. They influence awareness of healthcare needs, health beliefs, and access to care. Gender norms in households also play a critical role in health-seeking behaviour and provider choice. Apart from these factors, perceived quality of care, past experiences with providers, and trust also play a key role in influencing provider choice. On the supply side, accessibility, quality of care, and affordability are important factors influencing provider choice. Long waiting times, low service quality, and lack of respectful treatment have often discouraged utilization of government facilities.

Determinants of Healthcare Provider Choice in India

A substantial body of literature demonstrates that provider choice goes beyond individual preferences, to include decisions rooted in and influenced by system-level features and household dynamics. This section aims to brings together literature across socio-demographic, systemic, cultural, and socio-economic dimensions, as well as their variations across services.

Socio-Demographic and Cultural Determinants

Characteristics such as age, gender, education, income, caste, class, and occupation not only influence access to healthcare but also shape the choice of care providers. Evidence from multiple studies demonstrates that socio-economic advantage is associated with a greater reliance on the private sector. Likewise, deprivation is associated with an increased reliance on public or

informal care. For instance, a recent study conducted in West Bengal highlights that younger elderly age groups and individuals from the general social category have a higher chance of utilizing private healthcare services than those of older age groups and SC/ST groups. Additionally, while literacy level seemed to have no significant impact, married status also shapes provider choice. Married individuals are more likely to utilize private care than single, divorced, separated, or widowed individuals. Higher-income groups and employment increase the usage of private services. Interestingly, the presence of health insurance is associated with a preference for government services, suggesting that schemes may primarily facilitate access to public health facilities. It was also observed that individuals with normal BMI were more likely to seek private care. (Halder & Kasemi, 2025). Gender and social identity further shape these patterns. A study conducted in North India showed that women and Muslims, in rural North India, were less likely to access healthcare and were more likely to consult with unqualified healthcare providers. (Iles, 2018). Another study conducted in West Bengal found that the services of rural, unqualified health practitioners were particularly valuable to women and older people in rural areas, underscoring the role of gender norms and mobility constraints in seeking care. (Debsarma & Choudhary, 2025). Income-related disparities are also evident. A study conducted in Karnataka found that lower-income households often preferred public health facilities due to the availability of free medications and affordability. In contrast, higher-income individuals preferred private facilities for better care and access to specialized doctors. (Kamath *et al.,* 2024). Evidence also shows that years of schooling, place of residence, health insurance, and household wealth status significantly influence the choice of public and private health facilities for older adults in India. (Rahaman *et al.,* 2022). Together, these findings indicate that provider choice is deeply embedded in social and economic capacities.

Financial and Health-System Related Factors

Health-system factors play a critical role in shaping provider choice in India. Despite sustained attempts to improve the infrastructure of public health facilities, the gap in service delivery remains high. People residing in urban areas generally face a choice between public and private healthcare providers; however, rural residents have fewer options. The public sector is overly centralized and expansive, yet it continues to suffer from weak management. In contrast, the mushrooming private sector is largely unregulated. As a result, about 65% of Indians largely rely on the private sector, regardless of the availability of government health facilities in the area. One of the major disadvantages of the public health system, particularly in remote areas, is the issue of specialist unavailability and doctor absenteeism. (Barik & Desa, n.d.). Low trust in government facilities is also a key driver in private care preference. (Agarwal & Joshi, 2025). Several studies have observed that a shortage of essential medicines in public health facilities leads to an increased reliance on the private sector; in some cases, even doctors in government

hospitals may refer patients to private pharmacies to procure medications. Additionally, private facilities operate for longer working hours, offering convenience to patients. These facilities also offer multiple services in one location, thus reducing the time spent on travel and coordination. (Brindley *et al.,* 2024). A study revealed that structural inefficiences in the public health system, such as long distances to government facilities, often result in high indirect costs, including transportation expenses and loss of daily wages, poor quality of medicines, and resource unavailability, leading to an increased reliance on rural, unqualified health practitioners. Estimates suggest that 50-80% of rural areas in India have primary care provided by informal providers in rural India. ("Of Quacks and Crooks," 2016). This is further compounded by the unaffordability of formal private health facilities. Health beliefs and perceptions also shape reliance on informal care. Rural residents often believe that unqualified health practitioners are suitable for addressing minor health issues, influenced by poor health education awareness and the embedded nature of an informal health system. (Debsarma & Choudhary, 2025). Studies have also highlighted that reasons for relying on quacks include the affordability of treatment, approachability, and the dignified and respectful behavior of providers, as well as perceived detailed health check-ups, flexibility, and lower drug costs. This approach increases reliance from the marginalized and deprived populations. (Ghosh *et al.,* 2025). Informal care practitioners have often provided doorstep and convenient treatment to people from economically weaker sections, making it an easy choice for them. Overall, these health system constraints interact with socioeconomic aspects of populations to shape provider choice.

Illustrative Empirical Insights from an Urban Indian Context

Situating the Empirical Context

To complement existing literature on healthcare provider choice in India, this chapter draws on illustrative insights from a qualitative study conducted in an urban primary healthcare setting in Navi Mumbai, Maharashtra. The study area represents a rapidly urbanizing, predominantly middle-class neighbourhood, characterized by the high availability of both public and private health facilities, ranging from small clinics to large tertiary care centres. Residents living in this area have access to multiple healthcare options within a short distance, including an urban primary health center, a private clinic, and tertiary-level private hospitals. This context offers great relevance for examining provider choice. Unlike remote or underserved areas, the crucial challenge here is not the absence of facilities, but rather how individuals and families navigate a complex and pluralistic healthcare system that offers multiple choices of providers.

Analytical Approach

The empirical insights presented here are informed by a perspective on healthcare-seeking behavior. By valuing the interpretations and experiences of caregivers, the study employs a social constructivist approach to capture the contextual factors, social dynamics, and social

norms that influence decision-making regarding provider choice in urban settings. The approach reiterates how household-level characteristics interact with health system factors and shape provider choice.

The analysis prioritizes the narratives of frontline providers and caregivers, highlighting that decisions to seek care are socially embedded ones and are influenced by prior experience, expectations, and trust.

Overview of the Study Design

The study employed an exploratory qualitative design to capture in-depth perspectives on healthcare provider choice. Data was recorded through semi-structured interviews with caregivers of young children as well as frontline workers involved in service delivery. Caregivers were selected to reflect diversity in socio-economic status and patterns of service utilization (public, private, or mixed). Frontline workers, including ASHAs and ANMs, worked within the catchment area of the UPHC, offering insights into the challenges of service delivery and community engagement from the supply side. Interviews focused on caregivers' experiences with immunization services, the reasons for choosing specific providers, their perceptions of quality and trust, and interactions with healthcare workers. On the other side, provider interviews explored outreach experiences, service challenges, and perceptions of community behaviour. All interviews were conducted in local languages and later transcribed for analysis.

Analytical Process

The process followed Braun and Clarke's framework for thematic analysis, using both deductive and inductive approaches. Analysis involved iterative coding and theme development, allowing context-specific patterns influencing provider choice to emerge. Rather than presenting the findings as discrete results, the identified themes are presented in relation to a broader dialogue on healthcare utilization and provider choice.

Public-Sector Utilization: Trust, Cost, and Care

The decision of choosing public health facilities was primarily shaped by perceptions of affordability, trust in government-provided vaccines, and sustained engagement with frontline health workers. Even within an urbanized setting, cost-free services emerged as a strong motivating factor. Caregivers compared vaccines offered at PHCs to those in private facilities, concluding that the same vaccines were being provided without the financial burden associated with private healthcare. Trust in public immunization services was reinforced by the perception of vaccines being safe. Caregivers felt that vaccines provided in government facilities were "standard" or "fresh, reflecting confidence in government services.

Another important driver of the utilization of public health facilities was the role of grassroots health workers, particularly the ANMs and ASHAs. Regular follow-ups, reminders, and interpersonal engagement helped create a sense of familiarity and accountability among

community members. Door-to-door visits by ASHAs for awareness campaigns further enhanced the personal relationships built by frontline workers, acting as a crucial mechanism sustaining the choice of public health facilities. Outreach sessions further enhanced accessibility, reduced opportunity costs, and minimized waiting time, making the services of government health centers more convenient for residents.

Constraints in Choosing Public Health Facilities

Despite the above enabling factors, several constraints limited the use of the public sector for child immunization services. One of the most significant concerns raised by parents was the irregular availability of medical officers and paediatricians. Parents looked at immunization visits as opportunities for broader child health consultations, and the absence of specialists led to uncertainty among caregivers. This preference for holistic care reflects a deeper expectation of integrated service delivery, where immunization is not viewed as an isolated service, but rather as part of routine care. The limited availability of certain vaccines disrupted continuity of care, as parents frequently cited confusion arising from the need to obtain some vaccines from private facilities while relying on PHCs for others. This fragmentation in availability prompted several families to either alternate between providers or entirely to private services to avoid uncertainty.

Other constraints, including rigid OPD timings, also affected service utilization. The fixed morning hours of PHCs conflicted with the schedule of working parents, making attendance difficult without taking time off from work. Unlike private centres that offered evening consultations, PHCs were perceived as less responsive to the needs of urban populations. This misalignment emerged as a significant barrier to service utilization.

Information gaps further compounded these challenges. Several community members were unaware of services available at the PHC, reflecting weakness in communication, signage, and visibility at public health facilities. In the absence of updated information, initial perceptions of service inadequacy persisted, despite improvement in the availability of certain services later.

Private-Sector Utilization: Convenience, Continuity of Care, and Social Value

Private healthcare facilities were predominantly associated with perceptions of superior care, efficiency, and quality. Clean infrastructure, respectful behaviour of doctors, and the consistent presence of specialists contributed to the perception that the private sector was better equipped to address holistic healthcare needs. The availability of "painless" vaccines played a particularly influential role in helping parents choose private services to minimize adverse reactions and discomfort for their children.

Continuity of care emerged as a key factor leading families to choose private providers. Parents who had used private facilities for deliveries often continued to use the same providers for other services as well. Social influence also shaped private sector usage, with recommendations from peers and neighbours reinforcing perceptions of service quality and safety. In many instances,

the choice of private services was closely linked to social status and identity, reflecting urban norms and aspirations.

At the same time, high costs were viewed as a significant deterrent, prompting families to avoid private services altogether. Concerns about over-medicalization, the administration of unnecessary vaccines, and profit-oriented practices further erode trust in private clinics. Interestingly, perceptions of weaker monitoring in private facilities led some parents to prefer government services for vaccination, which were viewed as accountable and standardized.

Provider Switching and Hybrid Utilization

The study revealed fluid patterns of provider choice, with some families switching between public and private providers over time. Translations from PHCs to private facilities often followed negative experiences such as perceived pain, adverse effects, waiting time, or dissatisfaction with service quality and cleanliness. On the other hand, shifts from private to public services were largely driven by cost considerations and increased awareness of service availability at PHCs. These choice patterns highlight the adaptive and non-linear nature of decision-making in urban settings.

Overall, the study reiterates that provider choice is shaped by a complex interplay of cost, convenience, trust, perceived service quality, and social norms.

Provider Choice Across Types of Healthcare Services

Healthcare provider choice also varies significantly depending on the type of service required and the perceived severity of the condition. Preventive services such as child immunization services, perinatal care, and other public health outreach activities are largely provided through public health facilities. Evidence from a community-based study conducted by CMC Vellore found that about 80% respondents relied on government facilities for preventive care. (Srinivasan *et al.,* 2017). Similarly, an analysis of cross-sectional survey data from 2005 to 2011 revealed that 67% of ANC and 73% of PNC services were utilized in public health facilities, underscoring the central role of the state in providing preventive maternal health services. However, even for preventive care, provider choice is not absolute, with many groups opting for private providers. Curative services are predominantly delivered through the private sector, particularly for acute and chronic conditions, as well as outpatient care. Together, these patterns demonstrate that provider choice is influenced not only by socio-demographic determinants and structural factors, but also by the type of service required, service delivery expectations, and perceived needs.

Implications for Health Systems and Policy

Patterns of provider choice in healthcare offer significant insights into how populations perceive and navigate the healthcare system. In a pluralistic system like ours, provider choice serves as a key indicator of the health system's performance and responsiveness. Understanding the

determinants that lead households and individuals to choose one provider over another- across various services- has significant implications for health policy and system design. Provider choice is not merely the availability of services, but the trust that communities place in various components of the health system. The increased reliance on the private sector, even among marginalized groups, signals perceptions about the quality and convenience of the public health system. At the same time, the dominance of government facilities in preventive service delivery underscores the credibility of public health programs. The shift towards private providers also highlights the gap in the public sector, particularly its ability to meet evolving expectations in the urban and peri-urban contexts. From a policy perspective, this implies that provider choice can be viewed as a valuable feedback mechanism on the performance of health systems. Strengthening public healthcare facilities goes beyond infrastructure upgrades: involving respectful care, stronger communication, a reliable presence of doctors and specialists, and improved service delivery, that can help reinforce trust in the public health system.

Public health facilities need to be repositioned as not merely low-cost alternatives, but as centres that are trustworthy and provide quality services. Recognising that provider choice is embedded in socio-economic realities and addressing them is crucial. Targeted communication is necessary to address myths and misconceptions surrounding the safety and effectiveness of public health services.

Provider choice also has significant implications for the country's pursuit of Universal Health Coverage (UHC). Strengthening primary healthcare is therefore central to shaping provider choice and enhancing health equity. Improving the functioning of primary health centres across rural and urban areas is an urgent requirement, ensuring that comprehensive packages of integrated services are delivered. Sustaining community trust in public health facilities for preventive services is critical. Policies should also aim to regulate the quality and standards of private facilities and address the presence of informal providers, in order to promote safe, equitable, and quality care.

Conclusion

This chapter highlights that healthcare provider choice in India is a multidimensional, nonlinear phenomenon, shaped by a complex interplay of sociodemographic, cultural, financial, and health system factors. As individuals navigate a pluralistic healthcare system, their choices are influenced not only by availability and affordability but also by trust, experience, perceived quality, and social norms. The review of literature, complemented by empirical insights, demonstrates that provider choice is contextually grounded; yet, broadly consistent patterns exist, where public health facilities dominate preventive care, whereas private providers are preferred for curative care. Informal providers play a key role in resource-limited settings. The chapter presents perspectives that highlight the need for policy interventions to improve public

health facilities, while also regulating private providers. Future research should focus on longitudinal studies to understand how provider choices evolve over time, as well as the impact of urban-rural disparities, in order to enrich the understanding of provider choice in complex health systems. In conclusion, healthcare provider choice provides a clear lens through which the equity and responsiveness of health systems can be viewed. By addressing these determinants of provider choice effectively, we can ultimately advance towards the broader goal of Universal Health Coverage.

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QUALITY ASSESSMENT OF AN EMERGENCY DEPARTMENT IN AN ACADEMIC MEDICAL CENTER: A MIXED-METHOD APPLICATION OF THE DONABEDIAN STRUCTURE–PROCESS–OUTCOME FRAMEWORK

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Abstract

Emergency Departments (EDs) in Indian tertiary care hospitals operate under conditions of high patient volume, complex case mixes, and acute resource constraints. This book chapter presents a condensed and analytically refined account of a mixed-method study conducted at a 32-bed ED of an Academic Medical Centre in Maharashtra, India. The Donabedian Structure–Process–Outcome (SPO) framework was employed to systematically evaluate ED quality across three domains. Quantitative data were drawn from 3,138 patient records over a 30-day study period (June 2025) and six-month secondary data (n=19,506). A structured patient satisfaction survey was administered to 100 respondents, and qualitative insights were gathered through semi-structured interviews with 11 ED staff members, supplemented by 30 days of direct observation. Findings revealed significant structural gaps including the absence of a 12-lead ECG machine, fully paper-based clinical documentation, and inadequate staffing. Process analysis identified diagnostic delays as the dominant operational bottleneck, with an average of 29.4 delayed diagnostic reports per day. Outcome analysis yielded an overall patient satisfaction score of 3.80/5, with nursing behavior (2.81/5) and communication clarity (2.98/5) as the lowest-rated domains. An in-department mortality rate of 7.65 per 1,000 patients and 65 safety incidents over six months were documented. Eight evidence-grounded recommendations are proposed. This chapter contributes a replicable SPO-based mixed-method framework for ED quality evaluation applicable to similar resource-constrained tertiary care settings in India.

Keywords: Emergency Department, Donabedian Model, Structure-Process-Outcome, Hospital Quality Assessment, Patient Satisfaction, Tertiary Care, India, Mixed Methods, Healthcare Quality Improvement.

Introduction

Emergency Departments represent the most dynamic and pressure-intensive interface between communities and healthcare systems. In India, the dual burden of communicable and non-communicable diseases, coupled with a growing urban population, has dramatically increased ED utilization over the past two decades. Tertiary care teaching hospitals, which serve as the apex of the public health infrastructure, bear a disproportionately high burden of emergency

visits often serving as the first and only accessible point of care for complex, multi-system illnesses and trauma. Despite this critical role, the systematic evaluation of ED quality in Indian tertiary care hospitals remains limited. Most published work focuses either on structural audits or patient satisfaction surveys in isolation, without integrating these with operational process data and clinical outcome indicators. This fragmentation makes it difficult to identify root causes of quality deficits and design targeted interventions.

The Donabedian Structure–Process–Outcome (SPO) model, first articulated by Avedis Donabedian in 1988, remains the most widely validated framework for healthcare quality evaluation. Its tripartite architecture — assessing the resources available (structure), the activities performed (process), and the results achieved (outcome) — provides a causally coherent lens through which quality deficits can be traced from their systemic origins to their patient-level consequences. When applied with a mixed-method design, the SPO model enables a depth of institutional analysis that neither quantitative nor qualitative methods can achieve independently.

This chapter presents the findings of a study conducted in the Emergency Department of a tertiary care teaching hospital in Maharashtra, India, with the dual aim of (1) generating a rigorous institutional baseline for quality improvement and (2) demonstrating a replicable mixed-method SPO evaluation methodology applicable to similar settings across India.

Study Design and Methodology

Research Framework

A mixed-method descriptive research design was adopted, integrating four complementary data sources to ensure triangulation and contextual validity. The study was conducted at the Emergency Department of a tertiary care teaching hospital in Maharashtra over a 30-day primary study period (June 2025), with supplementary six-month secondary data analysis (January–June 2025).

Data Sources

Table 1: Summary of Data Sources

Data Source	Method	Sample / Period	Purpose
30-Day ED Records	Secondary Data Extraction	n = 3,138 patients (June 2025)	Operational trends, volume, disposition
Six-Month ED KPIs	Secondary Data Extraction	n = 19,506 patients (Jan–Jun 2025)	Longitudinal trends, safety indicators
Patient Satisfaction Survey	Structured Questionnaire (Likert Scale)	n = 100 respondents	Outcome – patient experience
Staff Interviews	Semi-structured Qualitative Interviews	n = 11 ED staff members	Process gaps, structural challenges
Direct Observation	Observation Checklist	30 days across peak/off-peak hours	Workflow, triage, communication

Patient satisfaction data were collected using Cochran's formula (Z=1.96, margin of error=10%, p=0.5), yielding a minimum sample of 96, rounded to 100. Staff interviews were conducted using purposive sampling, targeting personnel with a minimum of six months of experience across clinical and administrative cadres. Quantitative data were analyzed using descriptive statistics in MS Excel; qualitative data were subjected to thematic analysis with coding across five major themes. Ethical clearance was obtained and all participant data were anonymized.

Key Findings: A Donabedian Analysis

a. Structure: A Department in Transition

The Emergency Department occupies approximately 4,000 square feet across four triage zones (Black, Red, Yellow, Green) with 32 functional beds and a six-bed ED-linked ICU. While the physical infrastructure enables routine emergency functioning, several critical structural gaps were identified.

Table 2: Summary of Key Structural Findings

Structural Component	Status	Critical Gap
Total ED Area	~4,000 sq ft / 32 beds	No
12-Lead ECG Machine	Not available	Yes — only single-lead present
Electronic Medical Records (EMR)	Not available	Yes — fully paper-based
Digital Triage System	Not available	Yes — no timestamp/logging
Nurse-to-Bed Ratio (per shift)	3 nurses / 32 beds	Yes — below standard
Helper Cadre (per shift)	2–3 helpers	Yes — critically insufficient
Portable Ultrasound	Available (newly installed)	No
Ambulance Back Gate	Structurally available	Partially — not operationalized

- **Equipment:** The department lacks a 12-lead ECG machine — a basic requirement for any ED managing an average of 1.13 CPR cases per day. Biomedical engineering support operates on a reactive-only model with no preventive maintenance schedule, creating equipment reliability risks during patient surges.
- **Staffing:** With 14 nurses rotating across three shifts (approximately 3 per shift) for 32 beds, the nurse-to-bed ratio falls significantly below recommended standards. The helper cadre, at only 2–3 per shift, is critically inadequate, forcing nurses to perform non-clinical tasks and compromising bedside monitoring.
- **Digital Infrastructure:** Clinical documentation remains entirely paper-based. The hospital uses a Hospital Management Information System (HMIS), but no dedicated ED module exists. There is no digital triage system, no bed dashboard, inadequate PACS

integration, and MLC documentation require approximately 30 minutes per case — a significant burden on clinical staff time.

b. Process: High Volume, Persistent Bottlenecks

The ED manages an average of 104.6 patients per day (range: 94–127), with Medicine accounting for 61.1% of cases, followed by Surgery (13.6%) and Orthopedics (6.9%). A combined ICU and inpatient admission rate of 34.1% indicates a high-acuity caseload.

- **Diagnostic Delays — The Primary Bottleneck:** An average of 14 delayed laboratory reports (>2 hours) and 15.4 delayed radiology reports per day were recorded, totaling 870 delayed diagnostic events over the 30-day study period. Contributing factors include manual sample transport (no pneumatic tube system), absence of PACS integration, and a shortage of radiology technicians during night shifts. This single bottleneck is responsible for the majority of excess ED length of stay.
- **Triage Vulnerability:** The department applies the START triage approach, but operates without a dedicated triage desk, digital logging, or enforced colour-coded zone demarcation. Triage responsibilities are shared between CMOs and available nurses, creating inconsistency in patient prioritization, particularly during peak inflow periods.
- **Length of Stay:** The overall average ED length of stay is 55.2 minutes, ranging from 15 minutes (minor Medicine cases) to 180 minutes (Neurology cases). While acceptable for stable presentations, Neurology and Pediatric cases consistently exceeded benchmarks, largely attributable to diagnostic delays and specialist response times.
- **Interdepartmental Coordination:** All interdepartmental communication relies exclusively on telephone calls. The absence of a real-time bed status dashboard or intranet portal results in ICU transfer delays and extended ED wait times for admitted patients.

c. Outcome: Resilient Results, Preventable Gaps

- **Patient Satisfaction:** The overall patient satisfaction score was 3.80 out of 5.0. The highest-rated dimensions were Cleanliness and Hygiene (4.02/5) and Availability of Medicines and Services (3.95/5). Critically, Nursing Behavior scored 2.81/5 and Clarity of Information about Condition scored 2.98/5 — both below the 3.0 acceptability threshold, representing the most actionable outcome gaps.
- **Mortality:** The in-department mortality rate was 7.65 per 1,000 patients — contextually appropriate for a department managing an average of 1.13 CPR cases and 1.0 brought-dead case per day. Mortality was most frequently associated with severe trauma, multi-organ failure, and cardiac arrest on arrival, and is not indicative of avoidable in-hospital deaths.
- **Safety Incidents:** Six months of safety data (January–June 2025) recorded 29 needle prick injuries (mean 4.83/month) and 36 spill incidents (mean 6.0/month). These figures

reflect persistent occupational and infection control risks attributable to the absence of needle-stick prevention training, inadequate waste management infrastructure, and the high workload per staff member.

Table 3: Patient Satisfaction Survey – Mean Scores (n=100)

Satisfaction Dimension	Mean Score (1–5)	Performance Level
Cleanliness and Hygiene in ED	4.02	Very Good
Availability of Medicines & Services	3.95	Good
Behavior of Doctors	3.82	Good
Overall Satisfaction with Emergency Care	3.80	Good
Availability of Water, Toilet, Seating	3.64	Good
Time to Receive First Treatment (Waiting Time)	3.50	Moderate
Ease of Registration & Initial Documentation	3.20	Moderate – needs improvement
Clarity of Information About Condition	2.98	Below average – critical gap
Behavior of Nursing Staff	2.81	Below average – requires urgent attention

Recommendations and Conclusion

Evidence-Based Recommendations

The following eight recommendations are directly grounded in the study's quantitative and qualitative findings, prioritized by urgency and potential impact:

Table 4: Summary of Recommendations

No.	Priority	Recommendation	Key Evidence	Timeline
1	Critical	**Implement ED-Specific EMR with Digital Triage and Bed Dashboard** — fully digitize clinical documentation, integrate real-time bed status, auto-alerts for critical lab values, and digital triage timestamp logging	29.4 delayed reports/day; 30 min/MLC case; no real-time bed visibility; paper-based records creating administrative burden on clinical staff	Immediate
2	Critical	**Install Pneumatic Tube System and Establish Priority Diagnostic Protocols** — eliminate manual sample transport for labs; negotiate ED-priority radiology protocol with night-shift PACS access for real-time imaging	14 lab + 15.4 radiology delays/day; 870 delayed diagnostic events in 30 days; manual transport identified as primary bottleneck	Immediate

3	Critical	**Redesign Nursing Workflow Through Task Delegation Framework** — formally define non-clinical tasks (sample transport, escorting, documentation) to be handled by helpers, freeing nurses exclusively for bedside clinical care	Nurses performing non-clinical tasks; nursing behavior score 2.81/5 — lowest rated parameter; helper cadre critically underutilized for their defined role	Immediate
4	High	**Establish Dedicated Triage Infrastructure with Enforced Colour-Coded Zoning** — create a fixed triage desk at ED entry, enforce START protocol with digital logging, implement structured attendant pass system to decongest treatment zones	No demarcated triage area; relatives blocking stretcher pathways; prioritization inconsistent during peak hours; ambulance back gate not operationalized	3–6 months
5	High	**Procure 12-Lead ECG Machine and Shift to Preventive Biomedical Maintenance** — replace reactive-only equipment management with a scheduled preventive maintenance calendar across all critical devices	1.13 CPR/day with only single-lead ECG available; no preventive maintenance schedule; equipment shared during surge creating reliability risk	3–6 months
6	High	**Implement SBAR Handover Protocol and Real-Time Interdepartmental Communication System** — standardize shift handovers using SBAR framework; deploy WhatsApp/intranet broadcast as interim solution for ICU bed status and specialist coordination	Telephone-only communication causing ICU transfer delays; no formal handover protocol; resident coverage gap 16:00–20:00 hrs creating coordination vulnerability	3–6 months
7	Medium	**Deploy Structured Patient Communication Protocol with Multilingual Support** — station a Patient Relations Executive during peak hours; introduce multilingual information leaflets and digital display boards explaining ED process, wait times and patient rights; implement 48-hour grievance redressal system	Communication clarity score 2.98/5; nursing behavior score 2.81/5; May 2025 grievance spike of 9 with no documented follow-up; diverse linguistic patient population	6–12 months

8	Long-Term	**Establish ED Clinical Governance Framework** — monthly quality dashboard tracking 6 core KPIs (ALOS, delayed diagnostics, satisfaction score, NPI rate, mortality, grievances); monthly Mortality and Morbidity review meetings; written surge escalation protocol with trigger thresholds for high-volume days	24 in-department deaths in 30 days with no structured case review; patient volume peaked at 127/day with no surge plan; data currently siloed with no unified monitoring system	12+ months

Conclusion

This chapter has demonstrated that the Donabedian Structure–Process–Outcome framework, when applied through a rigorous mixed-method design, offers a powerful and actionable lens for evaluating emergency care quality in resource-constrained Indian tertiary care hospitals.

The central finding is one of institutional resilience in the face of systemic inadequacy. The Emergency Department is delivering broadly acceptable clinical outcomes — reflected in a 3.80/5 patient satisfaction score and a contextually appropriate mortality rate — despite significant structural deficits in digital infrastructure, staffing, and equipment. This performance reflects the dedication and adaptability of its clinical workforce, but it cannot be a substitute for systemic adequacy. The structural deficiencies identified are producing measurable, preventable process inefficiencies that in turn generate avoidable outcome deficits.

Diagnostic delays averaging 29.4 delayed reports per day across laboratory and radiology services are the single most impactful operational bottleneck and must be addressed with priority. The nursing behavior and communication clarity scores, both below the 3.0 acceptability threshold, represent outcome gaps that are directly traceable to structural understaffing and the absence of patient communication protocols.

The eight recommendations proposed herein are not aspirational but operational each is grounded in specific, quantified evidence from this study. They form a structured, sequenced improvement roadmap that any comparable ED can adapt and implement.

More broadly, this study offers a replicable methodological template for ED quality evaluation in India. The integration of administrative records, patient surveys, staff interviews, and direct observation provides a depth of institutional understanding that no single method can achieve. As India continues to scale up its emergency care infrastructure under the National Health Mission, the systematic application of the Donabedian framework in teaching hospital EDs offers a scientifically credible, implementable, and cost-effective path toward quality improvement.

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ARTIFICIAL INTELLIGENCE (AI) IN TELEMEDICINE AND DIGITAL HEALTH PLATFORMS

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Abstract

Telemedicine and Digital Health platforms are expanding the possibilities for clinicians to deliver high-quality patient care using next-generation technology. Advances in Artificial Intelligence (AI) will continue to distinguish telemedicine from traditional face-to-face medical care by providing improved diagnostic accuracy and real-time predictive analysis of clinical outcomes, while allowing for more advanced forms of remote patient monitoring. The use of AI will continue to play a crucial role in Telemedicine as it utilizes various new technologies, such as machine learning, natural language processing, and intelligent automation, to create an entirely new system of data-driven healthcare that is far beyond basic remote consultations. This study analyzes the evolution of AI in telemedicine, especially with respect to clinical decision support systems, virtual health assistants (VHAs), predictive analytics, and administrative automation. By reviewing several existing telehealth systems during the COVID-19 pandemic, including IDX-DR, Babylon Health, and various forms of remote patient monitoring, the researchers highlighted the integration of AI into telemedicine as an essential part of improving overall healthcare delivery and accessibility. Despite these advantages, the previously outlined disadvantages, such as algorithmic bias, data privacy concerns, regulatory uncertainty, and interoperability issues, will continue to hinder the widespread adoption of telemedicine and AI. Finally, this chapter discusses future opportunities surrounding XAI, standardized measuring/evaluating methods for clinical validation, and creating equitable access to AI technology on a global basis through AI technology in healthcare.

Keywords - Artificial Intelligence, Telemedicine, Digital Health, Remote Patient Monitoring, Predictive Analytics, Clinical Decision Support.

Introduction

Telemedicine is the process of using information and communication technologies to deliver healthcare services over long distances through remote consultation, diagnosis, and patient monitoring. While originally designed to improve access to healthcare in underserved areas, telemedicine has evolved into an advanced digital health service platform that leverages technologies such as video conferencing, mobile applications, and electronic health records (Adeghe *et al.,* 2024). The integration of AI into telemedicine has transformed healthcare delivery. This enables greater accessibility, supports personalized care and strengthens diagnostic

accuracy (B. S., 2025). Recent studies have highlighted the growing emergence of Artificial Intelligence in expanding the capabilities of telemedicine, particularly through applications such as automated diagnostics, virtual assistants, predictive analytics, and continuous patient monitoring (Adeghe *et al.,* 2024). The advancement of these technologies is crucial because it is evident that those living in rural areas with limited resources benefit from improved access to specialist care, enhanced clinical decision-making, and decreases in healthcare disparity due to the application of AI (Nwankwo *et al.,* 2024). Despite its rapid adoption, there is a lack of consolidated understanding of how AI is reshaping telemedicine platforms, particularly in terms of clinical effectiveness, ethical risks, and future scalability. This report provides an overview of the role of Artificial Intelligence in Telemedicine, focusing on its clinical applications and future challenges.

Evolution of Telemedicine

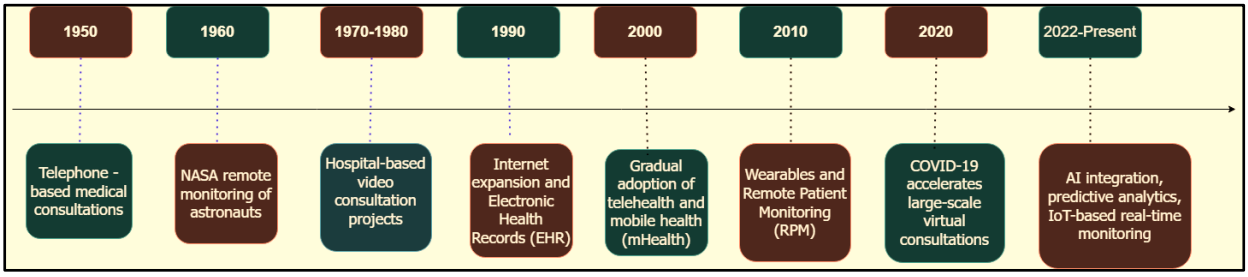

Figure 1: Evolution of telemedicine from early remote consultations to AI-enabled digital health platforms

Source: Created based on literature from Mbanugo (2025), De Micco *et al.* (2022), Pulimamidi (2023), and Pfeifer (2023)

The origin of telemedicine can be traced to the middle of the twentieth century, beginning with telephone-based medical consultations and early milestones such as NASA's remote monitoring of astronauts in the 1960s and hospital-based video consultation projects, followed by rapid progress with the start of the Internet and electronic health records in the 1990 (Mbanugo, 2025). Telemedicine has undergone significant transformations over the past decade. Although there was some gradual adoption of telemedicine in the early 2000s, its larger integration into practice remained limited until the COVID-19 pandemic. The COVID-19 pandemic has served as a critical catalyst for this transformation, accelerating the adoption of telemedicine across hospital settings. Studies conducted both during and after the COVID-19 pandemic indicate a rapid increase in the use of virtual consultations and remote follow-ups by patients (De Micco *et al.,* 2022).

The latest advancements demonstrate that AI in telemedicine services has steadily progressed in several medical fields, including dermatology, ophthalmology, maternity services, and oncology (De Micco *et al.,* 2022). This reflects the evolution of telemedicine development processes,

which began as a limited virtual consultation tool. However, it has progressed to a more complex platform designed to enhance health outcomes. Significantly, telemedicine services are expanding beyond remote monitoring and chronic disease management, merging with wearable technology and IoT sensors to enable real time tracking of patient's health status (Pulimamidi, 2023). Recent analyses of clinical information systems have highlighted that telemedicine development is more likely to integrate with data science and AI, as well as mobile health solutions and digital health technologies, to enhance patient care and decision support (Pfeifer, 2023). Overall, telemedicine has evolved from a simple consultation tool into an advanced AI-enabled platform, shaping the future of healthcare delivery.

Artificial Intelligence in Healthcare: An Overview

Artificial Intelligence is an integral part of healthcare, offering tools to enhance clinical decision-making, optimize workflows, and improve patient outcomes. It comprises machine learning, deep learning, and natural language processing, which create a system with the ability to analyze complex medical data and deliver actionable insights. Rapidly expanding health-related digital data, as well as progress in electronic health records and artificial intelligence-based data science, provide opportunities for new applications of automated clinical decision support systems and improved healthcare through data-driven insights (Patel, 2023). AI-powered remote patient monitoring enables the continuous analysis of sensor data to predict health deterioration and provide early intervention. Additionally, some automated interfaces using natural language processing in multiple languages improve the effectiveness of telemedicine services by overcoming language barriers, including sign language (B. S., 2025). Furthermore, AI provides personalized interventions and predictive decision support by analyzing data from wearables and sensors to enable tailored treatment of diseases. Through continuous monitoring and conversational coaching systems, AI improves patient engagement across a range of chronic conditions (Du *et al.,* 2025).

Thus, Artificial Intelligence has evolved as an essential component of modern healthcare systems, enabling diagnosis, monitoring, decision-making, and personalized care. This technological foundation shows the expanding role of AI in telemedicine and digital health platforms, where its impact on remote healthcare delivery is increasingly evident.

Applications of AI in Telemedicine and Digital Health Platforms

a. Enabled Telemedicine During and After COVID-19

The use of telemedicine and AI-enabled services was demonstrated during the COVID-19 pandemic. Evidence from post-pandemic deployments has revealed that AI-enabled telemedicine services can handle a wide range of outpatient visits remotely and virtually through the use of features such as automated patient assessment, automated scheduling for follow-up appointments, and triaging patients based on their risk of developing a serious medical

condition. Survey-based studies have reported that AI-driven decision-support tools enable healthcare systems to prioritize high-risk patients remotely while reducing unnecessary in-person visits, resulting in improved service efficiency without compromising patient safety (De Micco *et al.,* 2022; Anthony, 2020).

b. Virtual Health Assistants

One of the most clinically validated applications of AI in telemedicine is AI-assisted diagnostic accuracy. By using an artificial intelligence system to analyze X-ray and MRI scans, Artificial Intelligence algorithms can achieve a level of accuracy with these images that is comparable to or better than that of human specialists. For instance, studies have shown that AI can detect symptoms of diseases such as pneumonia or cancer rapidly with greater accuracy than traditional methods (Esteva *et al.,* 2017). Not only does this technology accelerate the diagnostic process, but it also ensures that patients receive timely treatment, which is critical in life-threatening conditions. Apart from the diagnosis process, AI-powered virtual health assistants improve the patient experience by providing instant answers to frequently asked questions and assisting with appointment scheduling. These assistants rely on natural language processing (NLP) to interact with patients and ensure a personalized experience. Research has shown that AI-assisted interactions can elevate patient satisfaction, which in turn promotes adherence to treatment plans (Patel, 2023). In telemedicine services offered in rural areas, these technologies greatly increased the scope of screenings and eliminated delays in referring patients to specialists (Nwankwo *et al.,* 2024; Mbanugo, 2025).

c. Predictive Analysis and Remote Health Monitoring (RPM)

Another remarkable benefit of AI in telemedicine is remote patient monitoring (RPM), which showcases its predictive analytics capabilities. The use of predictive analytic algorithms can analyze data collected from wearable health monitors or electronic health records, as well as provide predictive warnings about future potential health risks through analyzing data to predict future health risks for the patient. Predictive algorithms can be used to notify healthcare providers of patients who may be at increased risk for developing chronic diseases, allowing healthcare providers to take proactive measures to reduce the likelihood of hospitalization (Igwama *et al.,* 2024). Such early warnings are extremely beneficial for patients suffering from diseases such as diabetes and cardiovascular disease, ultimately leading to better patient outcomes. Studies have reported reductions in hospital readmissions and emergency interventions, alongside improvements in monitoring efficiency and early detection of clinical deterioration, ranging from approximately 30% to over 50%, depending on the disease context and monitoring protocol (Pulimamidi, 2023; Du *et al.,* 2025). These outcomes reflect a shift from reactive care models to proactive, data-driven intervention frameworks (De Micco *et al.,* 2022; Pfeifer, 2023).

d. Administrative Automation

Furthermore, AI enhances the efficiency of telehealth workflows by automating administrative tasks such as billing, patient follow-ups, and data entry. Virtual assistants and automated interfaces assist with symptom reporting, patient communication, and documentation in high-volume telehealth services. A study showed that AI solutions greatly improved the time spent by healthcare professionals on paperwork, allowing them to dedicate more time to patient care (Stoumpos *et al.,* 2023). Increased efficiency benefits both providers and patients by eliminating long waiting times. In summary, AI is reshaping telehealth in terms of diagnostic capability, personalized interaction with patients, predictive analytics, and operational efficiency. The growing use of AI in digital health platforms will ultimately create more accessible, efficient, and patient-centered healthcare experiences. These developments have the potential to provide equitable access to health services for underrepresented groups, making telemedicine an important part of the future of healthcare delivery.

Challenges, Limitations, and Ethical Issues

a. Technical, Ethical, and Regulatory Constraints

Although AI-enabled telemedicine offers substantial benefits, its widespread adoption is constrained by significant technical, ethical, and regulatory challenges. The integration of digital health technologies requires strict attention to data privacy and informed consent to protect sensitive patient information and ensure transparent processes that are essential to sustain trust in healthcare systems (Babawarun *et al.,* 2024).

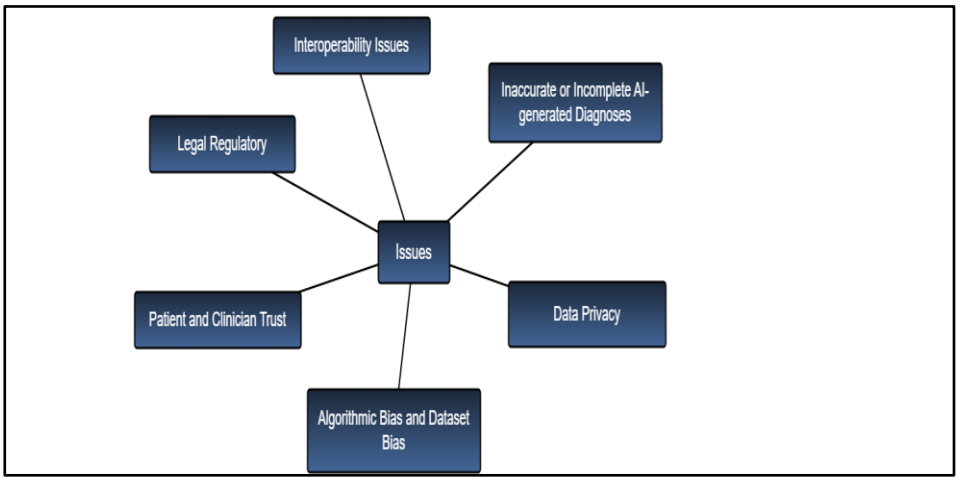

Figure 2: Major technical, ethical, clinical, and legal challenges in AI-enabled telemedicine
Source: Created based on literature from Babawarun et al. (2024), Hasanzadeh *et al.* (2025), Chin *et al.* (2023), Naik *et al.* (2022), and De Micco *et al.* (2022)

The risks associated with the development of AI programs include algorithmic and dataset biases. Algorithmic bias occurs when an AI program is developed from a dataset that does not accurately represent the target population. This bias can be introduced at multiple stages of the AI development process, which may lead to unfair or unreliable clinical estimations (Hasanzadeh

et al., 2025). The established guiding principles for healthcare algorithms state that it is important to identify and prevent bias at every stage to promote transparency, equity, and fairness in healthcare outcomes (Chin *et al.,* 2023).

b. Clinical, Legal, and Operational Limitations

Clinical limitations include the risk of inaccurate or incomplete AI-generated diagnoses, which may compromise patient safety if relied upon without human oversight. Legal and regulatory frameworks are still evolving, creating uncertainty about who is responsible when AI makes clinical errors (Naik *et al.,* 2022). Ethical concerns such as patient consent, transparency, and accountability further complicate the integration of AI into telemedicine. Technical challenges such as interoperability issues and the difficulty of integrating AI tools with existing clinical workflows can hinder adoption and limit the effectiveness of AI in telemedicine, particularly when systems are incompatible or require significant technical adjustments (De Micco *et al.,* 2022). Moreover, patient and clinician trust remain critical concerns, as individuals and healthcare professionals may be reluctant to rely on AI-driven tools without clear explanations of how decisions are made or evidence of seamless workflow integration. Together, these factors highlight the complexity of implementing AI in telemedicine safely and ethically.

Addressing these challenges requires robust governance, bias mitigation strategies, and continuous clinician oversight to ensure that AI-enabled telemedicine enhances healthcare delivery without compromising safety and trust.

Practical Case Studies in AI-Enabled Telemedicine

The practical use of Artificial Intelligence (AI) in real life for Telemedicine provides more clarity as to how the supposed advantages become a part of real-world operating systems for healthcare. Up to now, all of the references to applications and issues have been more conceptual. By reviewing previously established case studies, we can understand how various factors, including regulatory processes, workflow integration, governance structures, and contextual adaptations influence whether or not an AI-enhanced Telemedicine application is able to achieve and sustain a significant clinical impact. With the four case studies provided in this chapter, the reader will develop an understanding of the implications associated with four models of AI telemedicine implementation: 1) autonomous AI diagnostic systems, 2) a large-scale AI-based triage system, 3) an enterprise-wide remote patient monitoring system, and 4) an example of telemedicine-based artificial intelligence in least-developed countries. Each of these examples provides insight into challenges and enablers that go beyond just technical performance.

Autonomous AI Diagnostics in Primary Care: IDx-DR

The approval of IDx-DR, an autonomous Artificial Intelligence system for detecting diabetic retinopathy in the primary care setting, is considered a landmark achievement in artificial intelligence and telemedicine. In 2018, the U.S. The Food and Drug Administration (FDA)

approved IDx-DR as the first fully autonomous Artificial Intelligence diagnostic tool. The FDA's approval established it as the first AI-based diagnostic tool capable of making healthcare decisions without requiring interpretation by an expert. The IDx-DR system analyzes retinal images from patients' primary care clinics and immediately calculates whether patients should be referred to an ophthalmologist. In three multicenter trials, the IDx-DR demonstrated a sensitivity of greater than 85% and specificity of approximately 90%, meeting the predefined benchmarks for safety and effectiveness (Abràmoff *et al.,* 2023); (Abràmoff *et al.,* 2018). The FDA-cleared IDx-DR sets a precedent for the independent use of AI systems within telemedicine workflows.

To ensure adequate algorithm validation, an implementation effort for the IDx-DR system necessitated training staff in image acquisition and establishing a structured referral process to maintain continuity of care following diagnosis. The risk-based approach adopted during the FDA's review of IDx-DR assessed factors such as overarching governance for using AI within tele-ophthalmology, enabling more prompt detection of vision-threatening conditions and providing less need for unnecessary specialist visits. To successfully introduce diagnostic AI into the safe practice of telemedicine, the regulatory framework, integration into existing workflows, and previous clinical validations are all major areas that must be included.

AI Triage at Population Scale: Babylon Health

The implementation of this system covered parts of the UK as well as worldwide, allowing patients to enter their symptoms through a mobile platform and receive guidance to triage, either towards self-care, via teleconsultation, or via an urgent care provider. As anticipated, due to COVID, AI-enabled triage systems resulted in surges in demand from patients by allowing healthcare providers to prioritize higher-risk patients, thus reducing unnecessary visits to facility-based care (De Micco *et al.,* 2022).

The challenges of scaling AI were also demonstrated in the Babylon case. There is considerable skepticism regarding whether the performance data and claims have been derived from sufficiently rigorous scientific methods. In addition, professional organizations have raised concerns regarding potential overdiagnosis and a lack of algorithmic transparency for patients. Peer-reviewed evaluations, clearer communication of limitations, and regulatory oversight are some of the key concerns expressed by professionals. While Babylon's technology demonstrated a scalable and viable method for AI triage in a telemedicine setting, this case illustrated that the infrastructure/method/publishing of evaluations of AI should include strong governance and evidence-based validation, recognizing the trust of providers through the need for ongoing performance monitoring, explainability, and accountability.

Enterprise Remote Patient Monitoring: Kaiser Permanente

Kaiser Permanente's AI-based remote patient monitoring (RPM) method demonstrates how to integrate a well-developed health system. The RPM system for chronic diseases (such as hypertension, heart failure, and diabetes) uses various types of intelligent devices that transmit data to a central predictive analysis platform. These RPMs enables for the detection of early warning signs of a patient's condition deteriorating, thus allowing for proactive intervention by their doctor. Studies have shown that predictive analytics in telemedicine-based population health management have resulted in a decline in rehospitalization rates and improved chronic disease control outcomes (Pulimamidi, 2023; Du *et al.,* 2025).

The RPM approach included systems that were developed at the enterprise level, rather than being tested as a standalone pilot project. Additionally, the RPM alerts were programmed directly into the electronic health record (EHR) system, enabling clinicians to respond to patients as part of the defined care processes within their EHR system. Kaiser Permanente made significant organizational investments in its data infrastructure, information security, and workforce training to support the ongoing implementation and use of its RPM program. Integrating predictive analytics with the organization's value-based care strategy demonstrates how AI-based telemedicine can promote preventive, proactive care on a large scale. This case study illustrates that, to achieve sustainable implementations of telemedicine, systemic integration of services, active physician engagement, and evidence of measurable outcomes must be incorporated from the outset of development, simply developing predictive analytics is insufficient to ensure that telemedicine is used effectively as an intervention tool.

AI-Enabled Telehealth in Low-Resource Settings: Rwanda and Rural Deployments

Telemedicine using AI tools in developing countries provides valuable insights on the adjustments needed to use AI in telemedicine practice. In Rwanda, AI in telemedicine was introduced through government-funded digital health initiatives to improve access to specialists in rural locations. Community health workers used mobile devices with algorithms to identify patients requiring urgent care and determine appropriate referral pathways. These were two ways that the use of these systems helped reduce the impact of physician shortages and the difficulties created by geographical separation, as well as strengthening the effectiveness of referrals from regional facilities (Nwankwo *et al.,* 2024).

Unlike in wealthier nations, the successful implementation of telemedicine using AI in low-income nations involves issues related to infrastructure, digital literacy, and sustainable development. The inability to maintain reliable Internet connectivity meant that systems needed to provide some type of offline function. Building trust in the community was important for implementing these systems (culturally sensitive mechanisms to engage the community were

thus required). The priority was not to create advanced technology but to create user-friendly systems that could work in limited-resource environments and organizations. The Rwandan experience illustrates the context-appropriate AI-enabled telemedicine to leverage existing infrastructure, governance structures, and workforce realities. Supporting the success of AI-enabled telemedicine in Rwanda requires policy coordination, collaboration with the public sector to coordinate resources, and incremental capacity building (not rapid technology deployment).

The findings of this research reveal that productive AI-assisted telehealth systems require more than just proficiency at the algorithm level, they also require conformity to regulatory guidelines, smooth incorporation into workflow processes, and adaptability to different environments. When innovators design products with consideration for governance, clinical evidence, and the overall availability of telehealth resources at the system level, they will be able to create long-term value from their innovations.

Future Directions and Research Opportunities

The future of AI-based telemedicine will focus on improving the reliability and scalability of clinical care while addressing current technical, ethical, and regulatory issues. One major direction involves the development of standardized clinical validation and governance structures for AI-enabled telemedicine systems. While many AI solutions have shown excellent technical performance, there is a need for outcome-based validation of these solutions in a wide range of patients. Such evidence is important to support regulatory approval and consistent clinical adoption across healthcare systems (De Micco *et al.,* 2022).

Another area of focus is the development of explainable and transparent AI systems. As AI-driven decision support systems become the core of telemedicine, it is important to work on the interpretability of these systems to enable clinicians to verify the suggestions and build confidence in critical medical decisions (Babawarun *et al.,* 2024; Hasanzadeh *et al.,* 2025).

Moreover, the use of generative AI applications, such as voice-assisted patient support systems and automated documentation systems, is likely to expand, improving patient engagement, language support, and efficiency. It is necessary to research and assess the accuracy, fairness, and safety of these applications while ensuring equitable care delivery, especially in underserved populations (Hasanzadeh *et al.,* 2025; Abràmoff *et al.,* 2023). Large-scale clinical trials and real-world studies will be essential to determine the long-term impact, cost-effectiveness, and legal aspects of these applications, providing the necessary evidence that technological advancements are safe, efficient, and equitable in telemedicine services.

Conclusion

Artificial intelligence is changing telemedicine, creating a data-driven healthcare system. This system improves clinical results through the use of diagnostic tools, predictive analytics, virtual

assistants, and remote monitoring, among other advancements. The COVID-19 pandemic increased the adoption of this technology, illustrating that AI is critical for maintaining continuity of care. Despite this progress, challenges remain about protecting data privacy, preventing algorithmic bias, establishing regulatory clarity, ensuring that information can be shared between different systems (interoperability), and having clinicians oversee patient data to make sure it is used appropriately remain significant challenges moving forward as we continue to use AI in our practice of providing care. For example, the use of explainable AI models should help alleviate many of these concerns by allowing for greater validation of results. In addition, equitable distribution and use of AI in telemedicine worldwide will help provide more accessible, personalized, and preventative care than ever before.

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COVID-19: PATHOGENESIS, MANAGEMENT AND VACCINATION STRATEGY IN INDIA

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Abstract

The COVID-19 pandemic emerged as one of the most devastating global public health emergencies of the twenty-first century, exposing vulnerabilities in health systems, economies, and governance structures worldwide. Caused by Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2), the disease spread rapidly across nations, resulting in significant morbidity, mortality, and socio-economic disruption. This paper discusses the pathogenesis, transmission dynamics, clinical manifestations, diagnosis, management, prevention, and vaccination strategies of COVID-19, with particular emphasis on India's response. The role of public health interventions, including surveillance, testing, contact tracing, infection prevention measures, and mass immunization campaigns, is highlighted. India's phased vaccination strategy utilizing multiple vaccine platforms significantly reduced severe disease and mortality while strengthening healthcare resilience. The paper further explores the concept of pandemic preparedness in light of lessons learned from COVID-19 and examines the adoption of the WHO Pandemic Agreement in 2025 as a landmark initiative for strengthening global health security. The Agreement aims to enhance international cooperation, equitable access to health technologies, surveillance systems, preparedness financing, and coordinated responses to future pandemics. By integrating public health preparedness, legal frameworks, global solidarity, and health system strengthening, the document underscores the importance of comprehensive and equitable approaches to preventing and responding to emerging infectious disease threats. Sustained investment in preparedness, international collaboration, and resilient health systems remains essential to safeguard populations against future pandemics.

Keywords: COVID-19, SARS-CoV-2, Pandemic Preparedness, WHO, Global Health Security, Vaccination Strategy, Public Health Surveillance, Infection Prevention and Control, International Health Regulations (IHR).

Introduction

Coronavirus disease 2019 (COVID-19) emerged as one of the most significant global public health emergencies in modern history. Caused by the coronavirus 2 (SARS-CoV-2), the disease was first reported in Wuhan, China, in December 2019. Within months, it spread worldwide, leading the World Health Organization (WHO) to declare it a pandemic in March 2020. COVID-

19 has profoundly affected health systems, economies, and societies, emphasizing the critical importance of surveillance, infection control, and vaccination in containing viral pandemics.

Causative Agent and Pathophysiology

SARS-CoV-2 is an enveloped, single-stranded RNA virus belonging to the Beta coronavirus genus. It shares structural similarities with the viruses responsible for the 2003 SARS and 2012 MERS outbreaks. The virus primarily targets the human respiratory epithelium by binding to the angiotensin-converting enzyme 2 (ACE2) receptor, which is highly expressed in the lungs, heart, kidneys, and gastrointestinal tract. After entry, the viral RNA is released into the cytoplasm, initiating replication and triggering a cascade of immune responses.

The pathophysiology of COVID-19 involves both direct viral cytopathic effects and immune-mediated injury. The disease spectrum ranges from asymptomatic infection to severe respiratory failure and multi-organ dysfunction. In severe cases, an exaggerated immune response commonly referred to as a "cytokine storm" leads to diffuse alveolar damage, endothelial inflammation, and coagulopathy. These mechanisms explain the high mortality rates among elderly patients and those with comorbid conditions such as diabetes, hypertension, cardiovascular, and pulmonary diseases.

Modes of Transmission

SARS-CoV-2 primarily spreads through respiratory droplets and aerosols expelled when an infected person coughs, sneezes, or talks. Transmission may also occur through fomites contaminated surfaces that facilitate indirect spread. Airborne transmission is possible in poorly ventilated environments where aerosolized particles remain suspended for longer durations. In addition, the virus can survive for varying periods on surfaces like plastic, metal, and fabric, depending on environmental conditions such as temperature and humidity.

Vertical transmission (from mother to fetus) and fecal–oral transmission have been reported but remain less common. The infectious period begins approximately two days before symptom onset and continues for up to ten days in mild cases and longer in severe cases. Hence, timely isolation, contact tracing, and adherence to public health measures are vital in reducing viral spread.

Epidemiological Overview and Global Impact

COVID-19's global spread revealed stark disparities in healthcare preparedness and response capacity. Early in the pandemic, rapid community transmission overwhelmed hospital systems worldwide. In India, the first confirmed case was reported in Kerala in January 2020, followed by a surge of cases across major urban centers. Multiple waves of infection were observed, with the Delta variant (B.1.617.2) causing a significant rise in morbidity and mortality during 2021.

The pandemic's impact extended beyond the health sector. Economic productivity declined due to lockdowns, supply chain disruptions, and unemployment. The mental health burden increased

substantially due to isolation, uncertainty, and loss. Despite these challenges, coordinated global and national responses, including diagnostic expansion, improved clinical management, and vaccine development, contributed to gradually reducing disease severity and mortality.

Clinical Manifestations and Diagnosis

The incubation period of SARS-CoV-2 infection ranges from two to fourteen days, with an average of five days. Clinical manifestations vary widely and depend on viral load, host immunity, and comorbid status. Common symptoms include fever, dry cough, fatigue, sore throat, myalgia, headache, and anosmia. In moderate to severe cases, patients may develop dyspnea, hypoxia, and pneumonia, potentially progressing to acute respiratory distress syndrome (ARDS) and septic shock.

Diagnosis relies primarily on laboratory testing. The reverse transcription–polymerase chain reaction (RT-PCR) test remains the gold standard for detecting viral RNA from nasopharyngeal or oropharyngeal swabs. Rapid antigen tests are used for screening, particularly in field and emergency settings. Imaging modalities such as chest X-ray and high-resolution computed tomography (HRCT) provide valuable information on pulmonary involvement, often revealing bilateral ground-glass opacities. Serological assays help assess prior infection and population-level exposure.

Management and Treatment Strategies

Management of COVID-19 focuses on supportive therapy, prevention of complications, and timely escalation of care. Mild cases can be managed at home with isolation, hydration, antipyretics, and symptomatic relief, whereas moderate to severe cases require hospitalization for oxygen supplementation and close monitoring.

Pharmacological Interventions

Several pharmacological agents have been used based on disease severity:

- **Antivirals:** Drugs like remdesivir have shown modest benefits in shortening recovery time in hospitalized patients requiring oxygen therapy.
- **Corticosteroids:** Dexamethasone and other glucocorticoids are beneficial in severe cases to reduce inflammatory lung injury.
- **Anticoagulants:** Low-molecular-weight heparin is used to prevent thromboembolic complications.
- **Immunomodulators:** Tocilizumab, an interleukin-6 inhibitor, has been used selectively to manage cytokine storm syndromes.

Oxygen and Ventilatory Support

Supplemental oxygen remains a cornerstone of therapy. High-flow nasal oxygen and non-invasive ventilation are preferred before mechanical ventilation. Intensive care management may

include prone positioning (in case of, white lung / subpleural consolidations) and continuous monitoring of arterial oxygen saturation (SpO_2).

Rehabilitation and Post-COVID Care

Patients recovering from COVID-19 may experience prolonged fatigue, breathlessness, and psychological distress. Post-COVID care protocols emphasize gradual physical activity, balanced nutrition, mental health support, and monitoring of residual organ dysfunction. Yoga, breathing exercises, and stress-reduction practices are encouraged as adjuncts to recovery.

Preventive Measures and Public Health Interventions

Since no definitive cure exists, prevention remains the most effective approach to control COVID-19. Public health authorities worldwide emphasized non-pharmaceutical interventions to limit transmission. Whole – of – government, Whole – of - society approach advised by WHO to built comprehensive strategy to prevent disease and to save lives.

Personal and Environmental Hygiene

Frequent handwashing with soap and water, use of alcohol-based sanitizers, and respiratory etiquette such as covering mouth and nose while coughing or sneezing are fundamental preventive measures. Regular cleaning and disinfection of high-touch surfaces, proper ventilation, and avoidance of crowded spaces are equally important.

Social and Behavioral Measures

Physical distancing of at least one to two meters, universal masking, and isolation of infected individuals significantly reduce the risk of community spread. The slogan “Do gaj ki doori, mask hai zaroori” (two yards distance and mask are essential) became a public health message in India, reinforcing behavioral compliance.

Surveillance and Testing

Comprehensive surveillance systems are crucial for early detection and containment. India implemented large-scale testing, digital contact tracing, and mandatory quarantine for travelers and exposed contacts. Data collection through platforms like the CoWIN system and Aarogya Setu app supported decision-making and targeted interventions.

COVID-19 Vaccination: Strategy and Implementation in India

Vaccination became a transformative tool in controlling the pandemic. Following emergency authorization of several COVID-19 vaccines, India launched its national vaccination drive on 16 January 2021, one of the largest immunization programs in the world. The government adopted a phased strategy prioritizing population groups based on risk.

Phased Prioritization

The initial phase targeted healthcare and frontline workers to maintain essential services. Subsequently, vaccination extended to individuals above 60 years and those aged 45–59 years with comorbid conditions such as diabetes, cardiovascular disease, and chronic respiratory

illness. Later phases included all adults above 18 years and, eventually, adolescents aged 15–18 years.

Vaccine Platforms

Multiple vaccine platforms were approved for emergency use:

- **Viral Vector Vaccines** (e.g., ChAdOx1 nCoV-19 type - Covishield): employ a non-replicating adenoviral vector to deliver genetic material encoding the spike protein, inducing robust immune responses.
- **Inactivated Virus Vaccines** (e.g., whole-virion inactivated types – Covaxin): use chemically inactivated SARS-CoV-2 particles to stimulate immunity safely.
- **mRNA Vaccines** (e.g., Moderna, Pfizer-BioNTech types): introduce messenger RNA encoding the spike protein, enabling host cells to produce antigenic proteins that elicit immunity.
- **DNA-Based Vaccines** (e.g., ZyCoV-D): utilize plasmid DNA to produce spike proteins intracellularly.

Each vaccine demonstrated varying storage requirements and efficacy levels, but all provided substantial protection against severe disease and hospitalization.

Registration and Administration

Beneficiaries registered through digital platforms such as CoWIN, using government-approved photo identification. Vaccination sites ensured appropriate cold-chain management, infection prevention measures, and post-vaccination observation for adverse events. Completion of the full vaccine schedule with the same vaccine type was mandatory to achieve optimal protection. QR-coded digital certificates were issued upon completion.

Safety, Contraindications, and Special Groups

Common side effects included mild pain at the injection site, fatigue, low-grade fever, and myalgia. Severe allergic reactions were rare. Vaccination was deferred for individuals with active infection, recent receipt of monoclonal antibodies or plasma therapy, or acute illness. Pregnant and lactating women were included after safety evaluation and national guideline revisions, as evidence suggested favorable risk-benefit outcomes.

Impact of Vaccination

Widespread vaccination significantly reduced the burden of severe cases and deaths. Despite emergence of new variants, vaccines mitigated hospital admissions and maintained healthcare system resilience. Public education and transparent communication remained critical to overcome vaccine hesitancy and ensure equitable distribution.

Dead Body Management and Infection Control

Handling the bodies of deceased COVID-19 patients required stringent infection-control practices. Health workers were trained in appropriate use of personal protective equipment (PPE)

and hand hygiene. The body was placed in a leak-proof bag, disinfected externally, and transported safely. Embalming and autopsies were discouraged to prevent aerosol generation. Families were permitted brief final viewing under supervision, avoiding physical contact. Cremation or burial followed standard public health guidelines, ensuring minimal risk to attendees.

Conclusion

COVID-19 has demonstrated how a microscopic pathogen can disrupt global systems and human life on an unprecedented scale. The disease's causation by SARS-CoV-2 and its complex pathophysiology underline the necessity for robust public health infrastructure, early detection, and coordinated management strategies. Preventive measures masking, distancing, hygiene, and isolation remain cornerstones of control, while the introduction of vaccines has added a critical shield against severe disease. India's multifaceted response, combining large-scale surveillance, disciplined community engagement, and mass immunization, has been instrumental in mitigating the pandemic's impact. Continued vigilance, research, and equitable vaccine access will be essential to prevent future waves and strengthen resilience against emerging infectious threats.

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Healthcare Management in the Indian Context: Challenges and Innovations

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