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Health Policy Analysis and Perspective

Transforming Hospital Quality Improvement Through Harnessing the Power of Artificial Intelligence

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ABSTRACT

This policy analysis focuses on harnessing the power of artificial intelligence (AI) in hospital quality improvement to transform quality and patient safety. It examines the application of AI at the two following fundamental levels: (1) diagnostic and treatment and (2) clinical operations. AI applications in diagnostics directly impact patient care and safety. At the same time, AI indirectly influences patient safety at the clinical operations level by streamlining (1) operational efficiency, (2) risk assessment, (3) predictive analytics, (4) quality indicators reporting, and (5) staff training and education. The challenges and future perspectives of AI application in healthcare, encompassing technological, ethical, and other considerations, are also critically analyzed.

Keywords: artificial intelligence, quality improvement, risk assessment, patient safety, predictive analytics

INTRODUCTION

Overview of Artificial Intelligence (AI) in Healthcare

Big data in healthcare are characterized by its vast heterogeneity and complexity, encompassing laboratory tests, diagnostics, biomedical data, electronic health records data (EHRs), and -omics (e.g., genomics, epigenomics, transcriptomics, etc.).[1]

The sheer magnitude and intricacy of these data surpass the capabilities of medical professionals, potentially impeding the delivery of high-quality healthcare services.[2] Mostly, compared with other industries, healthcare has been walking at a tortoise pace in embracing artificial intelligence (AI) technologies, especially machine learning (ML).[3]

Quality professionals have the potential to unleash the capabilities of AI to enhance the quality of care, as AI has demonstrated its transformative impact across various medical domains; this was evident in its ability to navigate extensive medical imaging datasets,[4] detect patterns within EHRs,[5] make predictions,[6] support clinical decision-making,[7] and unveil valuable insights concealed within the unstructured narratives in EHRs.[8] AI encompasses diverse concepts, algorithms, and models, using computers or machines to simulate human intelligence. To enhance the clarity of our discussion, we will highlight the following specific AI subfields: ML, deep learning, and natural language processing (NLP).[9,10] ML primarily involves processing extensive patient data and outcomes to develop algorithms for predictive and classification tasks on future datasets. Conversely, deep learning is a subset of ML, which applies multilayered artificial neural networks to examine and analyze intricate data. Last, NLP uses ML techniques to understand, summarize, translate, and extract meaning from human language and unstructured text.[11]

Overview of Quality Improvement in Healthcare

High-quality healthcare services improve the chances of achieving positive health outcomes for individuals and entire populations.[12] Striving for excellence in patient care revolves around quality improvement, representing a dynamic and systematic approach to enhance healthcare delivery.[13] Quality improvement is implemented through various methodologies, strategies, and tools aimed at bridging the quality gap.[14] These include Six Sigma, Lean, and Plan-Do-Study-Act;

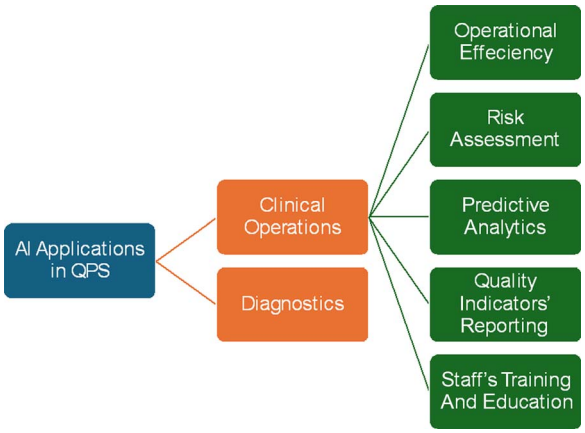

Figure 1. Artificial intelligence applications in hospital improvements.

in the process, various analytical and process improvement tools are used, including Failure Modes and Effects Analysis (FMEA), root cause analysis (RCA), Ishikawa diagram (fishbone), and value stream mapping.

Overview of AI in Quality

Lately, the discussions about the integration of AI in healthcare have sparked a debate among medical professionals, raising questions about whether it will surpass their capabilities or challenge their roles. We envision a harmonious collaboration orchestrated by quality-focused professionals. This collaboration in the form of AI applications operates on the two following fundamental levels: The diagnostic and treatment level, directly impacting the quality of care and patient safety, and the clinical operations level, indirectly influencing quality and patient safety through (1) operational efficiency, (2) risk assessment, (3) predictive analytics, (4) quality indicators reporting, and (4) staff training and education (Fig. 1). We are integrating AI into quality, which promises to unlock novel opportunities for enhancing patient care safety and quality.[15] However, while AI holds immense potential to improve patient care quality and safety, it faces various challenges, including technological, ethical, and other hurdles.

APPLICATIONS OF AI IN HOSPITAL BASED-IMPROVEMENT LEVEL

Diagnosis and Treatment Level

The World Health Organization acknowledges patient safety as a significant global health concern that demands attention worldwide.[16] In high-income countries, approximately 1 in every 10 patients experiences harm while receiving hospital care.[17] This harm can stem from various adverse events, with 50% being preventable.[18] Preventing medical errors and adverse events across a broad spectrum of processes and procedures is a pillar of patient safety. Patient safety aims to achieve high reliability in a healthcare system that inherently carries risks. The primary risky area where medical errors tend to happen is therapeutic interventions. Remarkably, treatment errors do not occur in isolation; according to the Swiss cheese model, multiple systems errors (represented as holes in the cheese) had to align perfectly for the adverse event to happen. Table 1 presents the Emergency Care Research Institute's primary 10 concerns regarding patient safety in 2023 concerning treatment and diagnosis,[19] along with the potential of AI to assist in addressing these crucial issues, such as mental health issues,[20] clinicians operating beyond their expertise,[21] delayed identification and treatment of sepsis,[22] inadequate coordination of care for complex conditions,[23] oversight of medication safety,[24] medication errors,[25] unintentional administration of neuromuscular blocking agents,[26] and preventable injuries due to overlooked care or treatment.[27]

Clinical Operations Level

This holistic integration approach reflects managing various operational aspects of clinical operation, including operational efficiency, risk assessment, predictive analytics, quality indicators reporting, and training and education.

Operational efficiency

Physicians allocate 27% of their working hours to direct clinical interactions with patients, while a significant portion, approximately 49.2%, is dedicated to tasks related to EHRs and administrative tasks. Even during the time spent with patients in the examination room, physicians devoted 52.9% of their attention to EHRs and administrative duties.[28] In our capacity as quality professionals, we underscore the significance of enhancing operational efficiency. Operational efficiency is the improvement in the measurable input-output ratio,[29,30] which may vary based on the context; for instance, in outpatient settings, the output may be measured in terms of correct diagnoses, while input factors can include clinic congestion and bottlenecks. AI creates more opportunities for frontline healthcare staff to efficiently engage in direct patient care.[31] This optimization of workflows and resource allocation encompasses aspects,[32] including predicting patient volumes,[33] aiding appointment management, [34] facilitating communication, addressing supply chain demands,[35] ensuring equitable workload distribution,[36] optimizing staff schedules,[36] and automating processes.[37] These improvements also extend to appointment scheduling,[34] electronic check-ins at medical facilities,[38] automated reminders for follow-up appointments,[39] and immunization schedules for children,[40] as well as the usage of AI-driven algorithms for determining drug dosages and issuing warnings regarding potential adverse effects when prescribing combinations of multiple medications.[38]

Table 1. AI-based solutions to top 10 patient safety Emergency Care Research Institute's (ERCI) concerns in 2023

Healthcare Issue	Brief Description[19]	How AI Can Help (with Evidence/Example)
Mental health	COVID-19 has worsened mental health conditions among children. In 2020, there was a 29% rise in anxiety and a 27% surge in depression among kids aged 3–17, compared with the figures from 2016.	AI can enhance the diagnosis, prediction, treatment, and rehabilitation of mental health conditions such as pediatric attention-deficit/hyperactivity disorder[20]
Clinicians working outside competency	A national survey conducted in 2022 among registered nurses revealed that 26% were assigned or moved to clinical areas beyond their usual expertise or areas requiring new skills. Additionally, 46% indicated they did not receive training or preparation before this reassignment.	Google's DeepMind has developed AI tools like CoDoC. This tool has effectively reduced false positives in medical imaging by 25%, aiding clinicians in decision-making, especially when they lack specialized training or experience.[21]
Delayed sepsis identification and treatment	With each hour of delay in delivering antimicrobial treatment within the initial 6 hours, the survival rate decreases by an average of 7.6 percentage points.	AI can assist in the surveillance of patients with severe sepsis. A randomized trial showcased the efficacy of an AI-supported sepsis monitoring system, resulting in a notable reduction of the average hospital stay by 2.7 days and a substantial decrease in in-hospital mortality by 12.4 percentage points, translating to a relative reduction of 58%.[22]
Poor care coordination for complex conditions	In a recent investigation involving 7568 patients, around 40% (equivalent to 2884 individuals) acknowledged facing at least one problem in care coordination, with nearly 10% disclosing the occurrence of avoidable issues such as redundant tests, medication interactions, and visits to the emergency department or hospital admissions.	AI can help streamline care coordination by analyzing patient records and suggesting optimal care pathways. An example is Google Health's AI system, which helps organize patient data more efficiently, thus aiding in care coordination (Google Health).[23]
Overlooking medication safety beyond "five rights" identified as (patient, drug, dose, route, and time)	A query of the ECRI and the Institute for Safe Medication Practices Patient Safety Organization's database identified 81 reported incidents associated with the five rights.	AI can analyze medication administration patterns and predict potential errors, improving overall safety.[24]
Medication errors from inaccurate patient lists	Medication reconciliation errors account for as much as half of all medication errors and play a role in 20% of adverse drug events.	AI systems can expedite the evaluation and analysis of patient data, enabling rapid and precise handling of essential information, like medical records, diagnostic findings, and continuous monitoring.[25]
Unintentional administration of neuromuscular blocking agents (NMBs)	Over 154 cases spanning 5 years were analyzed, and it was found that NMBs were administered mistakenly in nearly 50% of all incorrect medication errors.	Employed as a valuable asset in gauging the risk of anaphylaxis preceding the initiation of medical intervention[26]
Avoidable injury due to missed care or treatment	A review of 42 studies revealed that 55% and 98% of nurses reported failing to complete at least one necessary care task during their assessment period.	AI can help identify gaps in care by analyzing patient treatment histories and alerting healthcare providers to overlooked treatments. An AI system developed by DeepMind has been used to predict acute kidney injury, which often goes unnoticed, thereby preventing potential harm.[27]

Risk assessment

AI plays a fundamental role in enhancing risk assessment. FMEA and RCA are the cornerstones of risk assessment in healthcare.[41] They are inherently intertwined. FMEA acts as the chronological counterpart to RCA, with its gaze set on the present moment focused on understanding the future risks and the consequences of every potential cause. In contrast, RCA investigates past events aimed at uncovering the cause behind each conceivable consequence. AI is a potent asset in healthcare risk mitigation, augmenting conventional approaches such as RCA and FMEA.[42] While for RCA analysis, generative pre-trained transformers (GPT) can assist in the development of RCA tools to help identify root cause analysis, such as Fishbone diagrams, by identifying and categorizing potential causes for a given problem into areas such as people, processes, and technology and probing into specifics for each category. It helped prioritize the causes based on their potential impact and suggested outlining steps to address them, which could be used to create a visual Fishbone diagram; however, it is worth noting that AI

cannot create quality tools accurately; thus, the need for graphical tools is still warranted. Examples of using AI in FMEA are highlighted later in the case study section.

Predictive analytics

Predictive analytics is revolutionizing patient safety, particularly in the International Patient Safety Goals (IPSG) outlined by the Joint Commission.[43] Hospitals can foresee and mitigate risks like fall incidents and hospital-acquired infections by harnessing data. For instance, predictive models can identify patients at high risk for falls, allowing for tailored preventive measures[44]; similarly, analytics can detect patterns in infection rates,[45] guiding targeted hygiene protocols. These tools extend to other IPSG areas, such as improving medication safety and surgical care. This proactive stance, backed by data-driven insights, enhances patient care and aligns with IPSG's commitment to safety and quality.

Quality indicators reporting

Accurately gauging and overseeing quality indicators is crucial for patient safety and delivering top-tier healthcare.[46] AI plays a pivotal role in monitoring and reporting quality metrics and ensuring compliance with regulatory standards and accreditation.[47] In this context, the AI research GPT assistant offers a wealth of resources, providing access to over 200 million scholarly articles (chat.openai.com/g/g-bo0FiWLY7-consensus). This tool provides valuable insights and advice on best practices for setting specific targets and benchmarks for these indicators and empowers quality professionals to access precise information quickly, request clarifications, and pose quality questions supported by evidence. The encouraging development is that AI aids in reducing the workload of demanding and time-consuming tasks, including the summarization and drafting of documentation, policies, procedures, and various administrative duties.[48] This application of AI not only streamlines operational processes but also sets the stage for its more complex capabilities in the realm of EHRs by using NLP capabilities. EHR holds an abundance of data, encompassing patient demographics, medical histories, lab results, scanned documents, and treatment plans. AI algorithms can analyze this vast array of data, uncovering patterns and trends that human practitioners might overlook.[49] These patterns often align with crucial quality indicators, such as infection rates, medication errors, or readmission rates.[50] This detection leads to enhanced patient outcomes, lower healthcare costs, and the continual improvement of the overall quality of care given to patients. As AI progresses, its contribution to quality advancement in healthcare is poised to become even more significant.

Staff training and education

We are inherently visual creatures; this is where game-like technologies such as virtual and augmented reality (AR) can make a substantial impact by enhancing and enriching the learning process for future quality health professionals without direct interaction with actual patients.[51] It is worth noting that these techniques have been extensively used for training medical students, but their application in training quality staff has been relatively limited.[52] Using AR in training certified professionals in healthcare quality foundations, such as Lean Sigma or the Model for Improvement, is a groundbreaking approach that revolutionizes skill development and competence. AR empowers learners with immersive, interactive experiences, allowing them to practice and refine their abilities in real-world quality improvement scenarios. Through AR simulations, trainees can address complex quality challenges with hands-on precision, from streamlining processes to initiating impactful improvement projects. This innovative technology provides immediate feedback, fosters engagement, and accelerates the learning curve, ensuring that certified healthcare quality professionals are well-equipped with the practical skills and confidence needed to drive excellence in patient care and quality initiatives

FMEA CASE STUDY

Similar to FMEA, AI has the capability to preemptively identify risks. However, with more advanced predictive capabilities, it can broaden the range of identified failure modes and accelerate the assessment process. We thoroughly examined an FMEA process designed to improve the safety of medication dispensing in a teaching hospital.[42] The process was both labor-intensive and time-consuming, necessitating the involvement of 2 groups of specialist pharmacists, who met 5 times for 2 hours each across a span of 2 months. Our team of authors employed GPT-4 to pinpoint potential failure modes. In a relatively brief period, GPT-4 has uncovered a vast range number of failure modes. This collaborative approach establishes a benchmark that has the potential to improve and streamline the risk assessment process, which will eventually result in optimizing staff utilization for direct patient care. However, the actual calculation of the risk priority number for each failure mode should be done by qualified professionals within the relevant context because risk priority number calculation involves assessing the severity, occurrence, and detectability, which are highly dependent on specific operational details, patient demographics, and other contextual factors.

CHALLENGES AND LIMITATIONS

Despite its transformative potential, the application of AI in healthcare has challenges and limitations.[53] Table 2 illustrates primary obstacles and constraints encountered in AI healthcare implementations, with

Table 2. Challenges and limitations of artificial intelligence (AI) in healthcare

Theme	Definition	Challenges
Technological challenges		
Data quality, data access, dataset size	The success of AI models heavily depends on the quality of the data they are trained on. Accessing relevant and diverse datasets can be a challenge. In some cases, organizations may face legal or ethical constraints on sharing or acquiring data, limiting the availability of comprehensive datasets. Training robust AI models often requires large datasets.	• Inaccurate, biased, or incomplete data can lead to biased or unreliable AI predictions. Legal and ethical constraints on data access • Resource-intensive management of large datasets Obtaining and managing such extensive datasets can be resource-intensive and pose challenges for organizations with limited access to substantial data.
Interoperability, usability, integration	The ability of AI systems to work seamlessly with other systems and be user-friendly	• Lack of standardized interfaces • Complexity in integrating AI with existing systems • Resistance to change in workflows
Black box theory	The difficulty arises from the absence of clarity in AI decision-making procedures	• Lack of interpretability in AI decision-making processes
Ethical challenges		
Privacy	Protection of individuals' personal information and adherence to privacy regulations	• Infringement on individuals' privacy rights • Balancing utility with data protection • Complying with privacy regulations
Trust	Building confidence in AI systems and their outcomes.	• Opacity in AI decision-making • Instances of bias and high-profile failures • Building transparency and accountability
Consent	Obtaining permission from individuals for the use of their data in AI applications	• Obtaining informed consent for data use - Challenges in maintaining consent as AI evolves or is repurposed
Other challenges		
Socioeconomic inequality	Exacerbate socioeconomic inequalities	AI in healthcare could improve medical services for those who can afford cutting-edge AI tools while leaving others behind
Acceptance		Staff fear the loss of their jobs, and patients are concerned about the loss of personal interaction and empathy

a focus on three principal categories: technological hurdles encompassing data quality, data accessibility, dataset magnitude, interoperability, usability, integration, and black box theory; ethical considerations involving privacy, trust, and consent; and additional challenges such as socioeconomic disparities and acceptance.

FUTURE PERSPECTIVES

This review has highlighted several emerging futuristic opportunities. Perspectives on using AI applications have been extensively explored from the viewpoints of healthcare professionals, such as managers, physicians, nurses, and technicians.[54] However, there has been a notable absence of studies assessing the perceptions of quality professionals. Additionally, our FMEA case study suggests the need for further exploration to expand AI's capabilities beyond the construction of quality tool components and extend it to the creation of visual tools. Furthermore, there is a growing potential for exploring new avenues in research and development, including integrating AI into qualitative research.[55] In our case study, accrediting ChatGPT as an author on research papers has generated mixed reactions within the scientific community,[56] which warrants further investigation. Moreover, the development of Bio-GPT,[57] extensively trained in biomedical literature, holds promise in addressing the issue of hallucinations.[58] This becomes crucial when seeking best practices and benchmarking.

It is essential to exercise caution when relying on AI results lacking comprehensive assessment to prevent erroneous conclusions. Therefore, establishing a gold standard benchmark for evaluating AI tools, similar to a gold standard in diagnostics, becomes imperative.[59] Additionally, the use of AI assistants in drug discovery and development is expected to accelerate the drug development process,[3] potentially reducing time to market. Furthermore, improving the efficiency of patient recruitment in randomized controlled trials could help mitigate biases in study

designs,[60] which will eventually impact supply chain demands and operational efficiency.

RECOMMENDATIONS FOR HOSPITAL ADMINISTRATORS AND POLICYMAKERS

Recommendations for hospital administrators should focus on the advocacy for hospital-specific research to improve implementation as follows:

- Advocate for deploying AI tools to improve hospital operational efficiency, including optimizing workflows, reducing time on administrative tasks, and improving patient care through more efficient resource allocation.
- Implement AI-driven risk assessment tools like FMEA and RCA to enhance the predictability and manageability of potential risks in hospital settings.
- Encourage the use of predictive analytics to improve patient safety. AI can foresee potential safety issues like fall risks or hospital-acquired infections, allowing for the proactive implementation of preventive measures.
- Use AI to monitor and report quality indicators more accurately, ensuring compliance with health standards and regulations. AI can streamline data collection and analysis, providing real-time insights into patient care and safety outcomes.
- Invest in educating and training healthcare staff on AI technologies, using advanced simulation tools like virtual reality and AR for training purposes.

This can help healthcare professionals gain practical experience without direct patient involvement. Adequate training and incentives should also address employee resistance. As for recommendations to policymakers, questions of ethics and legality should be at the forefront of decision-making efforts.

CONCLUSION

This paper highlights the transformative role of AI in improving healthcare quality. It emphasizes AI's potential to transform the quality of care and patient safety by influencing multiple levels of care on diagnostic and clinical operations levels. At the same time, it acknowledges technological, ethical, and social challenges like data privacy and black box theory and acceptance. Thus, ethical oversight is fundamental to harnessing the transformative power of AI in healthcare, ensuring its beneficial and equitable application for hospital quality improvement.

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