REVIEW ARTICLE

Artificial Intelligence-Driven Clinical Decision Support in Pakistan: Implications for Primary Care Practice

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Abstract

AI-integrated Clinical Decision Support Systems (AI-CDSS) consolidate patient data with medical expertise to aid healthcare practitioners in deciding their approach. They promote guideline compliance, enhance treatment safety, and lead to more accurate diagnoses. This narrative review examines the potential role and emerging applications of AI-CDSS in strengthening primary healthcare systems by reviewing existing literature and evidence to evaluate current implementations, benefits, and limitations of AI-CDSS in the local healthcare context, with a particular focus on gaps to be addressed in the Pakistani healthcare landscape. Currently, although Pakistan is only utilizing AI-CDSS at a small scale and limited to tertiary care settings, these efforts encompass multiple domains such as drug safety, diagnostic help, and treatment planning. Findings have shown positive results and advocate for implementing AI-CDSS systems on a larger scale, which can reduce the burden on the healthcare system in Pakistan. Unfortunately, multiple concerns, such as user adoption and warning fatigue, must be dealt with before implementing a large-scale application of this system. Our research proposes a framework for the sustainable integration of AI-CDSS into Pakistan's healthcare system, with a focus on scaling solutions to primary care environments such as Basic Health Units and rural health centers. Overall, AI-CDSS holds significant potential to enhance accessibility, quality, and capacity of primary healthcare in Pakistan, provided that existing systemic and operational barriers are effectively addressed.

Keywords: *Artificial intelligence, clinical decision support systems, teritary care hospitals, primary care, digital health.*

INTRODUCTION

Artificial Intelligence (AI)- driven Clinical Decision Support Systems (AI-CDSS) unify clinical decision-making with the speed of machine learning, natural language processing, and large-scale health data, supporting real-time decision-making and early disease detection. High- and middle-income countries have rapidly adopted AI-CDSS as a major part of healthcare in radiology, oncology, and other areas of chronic, complex disease management. However, in lower- and middle-income countries (LMICs), such as Pakistan, implementation remains limited and fragmented [1]. This gap persists despite evidence that AI-CDSS could disproportionately benefit resource-constrained settings by compensating for human resource deficits and standardizing care quality [2]. In such settings, these advantages are particularly relevant to primary healthcare, where early decision-making and standardized care pathways are critical.

In Pakistan, we will use existing tertiary care hospitals as referral points for complex cases, creating significant societal pressure on health services; public hospitals are being flooded with patients and are limited by resource constraints and workforce shortages. This overreliance on tertiary care highlights systemic gaps at the primary care level, where effective early management could reduce unnecessary referrals and patient burden. Moreover, Pakistan continues to face substantial healthcare workforce shortages. According to Shaheen and Shaheen [3], the doctor-patient ratio was approximately 1:1000 in 2022, below the World Health Organization recommendation of 1:400. Such workforce constraints increase the risk of diagnostic delays and medical errors, highlighting the potential value of AI-assisted clinical decision support. Diagnostic and medication errors remain major contributors to preventable adverse events in tertiary care settings. A study in Hyderabad found that 40.4% of outpatient prescriptions had an error, and this was particularly high in government hospitals [4]. Another study conducted in Karachi had a medication error rate of 5.5%, with the highest proportion being pharmacist errors [5]. Such challenges further emphasize the need for decision-support tools at the primary care level to improve accuracy and standardization of care. Some well-known institutions, such as Aga Khan University Hospital and Shaukat Khanum Memorial Cancer Hospital, have initiated pilots of AI-CDSS in discrete fields, including radiology and oncology; however, general implementation of AI-CDSS across the healthcare system remains a work in progress due to systemic challenges [6, 7]. Although these initiatives are based on tertiary care, they provide important insights for potential adaptation and scaling within primary healthcare settings.

This narrative review aims to identify knowledge gaps using existing literature and real-world evidence of AI-CDSS use in Pakistan's tertiary care hospitals. While the current evidence is derived from tertiary care settings,

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this review emphasizes its relevance and applicability to primary healthcare systems. Using the current state of awareness, compliance, and infrastructure in Pakistan's healthcare system as a foundation, this review outlines protocols for sustainable structural integration. Particular focus is placed on how such integration can strengthen primary care delivery and reduce the burden on higher-level facilities. This review aims to help hospital administrators and policymakers, as well as international stakeholders interested in investing in Pakistan's digital health transformation. This work can help eliminate gaps in access to the latest in care delivery, including improving accessibility, efficiency, and quality of care at the primary healthcare level.

METHODOLOGY

This narrative review was conducted to synthesize the available literature on the implementation of artificial intelligence-based clinical decision support systems (AI-CDSS) in Pakistan. A structured search of PubMed, Google Scholar, and Scopus was performed using combinations of the terms "artificial intelligence," "clinical decision support systems," "AI-CDSS," "Pakistan," and "healthcare." Literature published between 2015 and 2025 was considered.

Both local and international studies were reviewed, with emphasis on research describing AI-CDSS applications, pilot implementations, healthcare outcomes, clinician perceptions, and health system implications. Relevant grey literature and institutional reports were also considered where appropriate. Articles not published in English or lacking sufficient methodological information were excluded. The selected studies were reviewed and synthesized thematically to identify current applications, benefits, challenges, ethical considerations, and future opportunities for AI-CDSS in Pakistan, with particular attention to implications for primary healthcare practice.

GLOBAL CONTEXT OF AI-CDSS

On a global scale, the integration of artificial intelligence (AI) is further revolutionizing CDSS, with performance measured by three significant outcomes: diagnostic accuracy, workflow efficiency, and clinician satisfaction.

Evidence from various healthcare systems around the world has shown that the use of AI-based CDSS improves diagnostic accuracy across different medical specializations. In Taiwan, Juang *et al.* [8] implemented a CDSS based on the LSTM model to identify patients who require holistic healthcare (HHC) while hospitalized. In the study, the CDSS model showed remarkable improvements in the sensitivity (80.8% *vs.* 26.4%) and specificity (99.95% *vs.* 99.2%) compared to the conventional model, highlighting its potential for assisting clinical judgments.

Furthermore, oncology has been a focus area for trials of AI-CDSS systems [9]. In China, a guideline-driven CDSS called the Chinese Society of Clinical Oncology-Artificial Intelligence (CSCO AI), which showed excellent concordance with multidisciplinary tumor boards, was able to provide quick recommendations to doctors. It uses knowledge maps based on CSCO treatment guidelines and updates them in real-time to match the latest recommendations. The platform also includes medical records, insurance data, clinical trials, and pertinent literature, which helps ensure recommendations align with evidence-based medicine as well as the real-world healthcare situation in China [10].

In South Korea and the United States, AI-CDSS has demonstrated significant potential to improve oral cancer screening and diagnosis. Current studies indicate that deep learning algorithms can effectively detect and diagnose oral cancer lesions with an effectiveness equal to that of expert clinicians and improve the reliability of oral cancer diagnosis by reducing inter-observer variability [11]. Together, these findings indicate that in high-resource settings, AI-CDSS not only enhances diagnostic correctness but also promises to minimize diagnostic delays in oral oncology [12].

Moreover, in a retrospective study from the emergency department of a tertiary care center in Monza, Italy, Ippolito *et al.* [13] assessed an AI system that can differentiate between COVID-19 pneumonia, standard bacterial pneumonia, and normal lungs based on chest X-rays. Using a multi-tasking Mask R-CNN architecture, the deep-learning model performed both classification and semantic segmentation of pathological features, such as consolidations and interstitial patterns. For detecting pneumonia due to COVID-19, the AI achieved a sensitivity of 94.7% and a specificity of 80.2%, compared with the radiologist's reported sensitivity of 96% and specificity of 79.8%. When differentiating between bacterial pneumonia and other conditions, the AI model achieved 97.5% sensitivity and 83.9% specificity, whereas human performance measured 97.9% and 88.0%, respectively. The inter-rater agreement between the AI system and the most senior radiologist was perfect, with Cohen's κ values of 0.822 for COVID-19 and 0.913 for bacterial pneumonia. These results demonstrate that well-trained AI-CDSS can reliably match the performance of expert radiologists in high-risk emergency settings. The study emphasizes that even in situations where standard CT imaging is unavailable, AI-supported CXR interpretation can reduce misclassification and support faster decision-making in resource-limited or high-patient-flow settings.

Moreover, systematic reviews on the treatment of stroke mention that AI-CDSS can reduce time-to-diagnosis and facilitate decision-making for thrombolysis or thrombectomy [14]. However, they also advise that various methodologies and a few real-world trials complicate the analysis of efficiency gains. The ongoing GOLDEN BRIDGE II trial in China is one of the few cluster-randomized evaluations of AI-CDSS, designed to measure not only diagnostic accuracy but also workflow and patient outcomes in acute stroke care [15]. This

study represents a critical step in transitioning from proof of concept to real-world evidence.

In addition to disease-specific use, other reviews have emphasized the benefits of AI-CDSS in reducing diagnostic uncertainty through the integration of multimodal data and context-dependent suggestions. A recent systematic review highlighted the potential of natural language processing–based clinical decision support systems to improve the accuracy of clinical decision-making by extracting and integrating information from electronic health records and other clinical data sources, thereby supporting diagnostic and treatment workflows [16]. Clinician acceptance is a key factor in the successful implementation of AI-CDSS. Systems that are easy to use, integrate smoothly with electronic health records, and fit into existing clinical workflows are more likely to be adopted. Trust in AI recommendations also depends on their transparency and explainability. However, concerns about alert fatigue, over-reliance on automation, and medico-legal responsibility continue to limit acceptance. These challenges are particularly important in primary care settings, where high patient volumes and limited specialist support require decision-support tools that are both efficient and easy to interpret.

CURRENT LANDSCAPE IN PAKISTAN

The adoption of AI-CDSS in Pakistan is still in its early stages. Unlike in high-income countries, where they are increasingly integrated into tertiary healthcare, in Pakistan, they are confined to a mix of small-scale pilot studies, retrospective analyses, and perception-based surveys.

A prominent Pakistan-based prospective cohort assessed supervised machine-learning risk models for cardiovascular events and integrated them into a real-time app. Two algorithms, logistic regression (LR) and random forest (RF), were trained on patient records (n=290). Myocardial infarctions declined from 28 to 19, and strokes from 18 to 9, along with decreases in ER visits (-26.9%) and admissions (-12.5%), as well as high patient acceptance, with approximately 81% expressing trust in AI recommendations. While single-center comparisons are susceptible to secular trends and unmeasured confounding, this is one of the only local studies that has reported both model performance metrics and patient perceptions in a tertiary institution [17].

A recent study by Hussain *et al.* [18] plays a significant role in providing evidence regarding the application of AI in predicting disease progression and treatment outcomes in Pakistan's tertiary care hospitals. The study enrolled 330 patients with type 2 diabetes, chronic kidney disease (CKD), and cardiovascular disease (CVD). Using supervised machine learning models such as Random Forest, Gradient Boosting Machines (GBM), and Support Vector Machines (SVM), the researchers achieved good prediction performance with 91.2% accuracy for diabetes, 88.5% for CKD, and 86.4% for CVD. Sensitivity and specificity were uniformly high, and AI-assisted care was better than standard care, with greater declines in HbA1c (1.4% *vs* 0.8%), a slower rate of decline in GFR in CKD patients (24.9% *vs* 16.5%), and greater LDL reduction in CVD patients (27.1 mg/dL *vs* 18.3 mg/dL). Overall, the results show the relevance of applying AI-CDSS in the context of Pakistan's tertiary health facilities, not only in terms of its accuracy but also in its potential to tailor treatment plans for individual patients.

In the field of hematology, the research achieved over 90% accuracy by employing Naïve Bayes and other classifiers to predict thalassemia risk, based on data from the hematology department, demonstrating the value proposition of the proposed AI-CDSS in low-resource laboratories [19].

Simultaneously, cross-sectional studies surveying practicing cardiologists and physicians working in tertiary healthcare facilities have shown general awareness, albeit with varying levels of confidence, of the use and effectiveness of AI-CDSS. For example, a 2024 cardiology survey reported that although 73% of respondents agreed that AI technology has the potential to reduce diagnostic errors, only a fraction felt comfortable using it independently, citing lack of training and legal uncertainty as reasons [20].

Hospital-based reports indicate that clinicians find AI-CDSS beneficial for enhanced decision accuracy and efficiency but emphasize the need for proper training and ethical measures [21]. In contrast, Siddiqui *et al.* [22] focus on natural language processing (NLP) within electronic health records (EHRs), demonstrating how automated documentation can enhance the quality and consistency of clinical data available to CDSS. Various cross-sectional studies based on perceptions indicate a positive trend towards the integration of AI systems, despite concerns about privacy, dependency, and the absence of national guidelines [23].

Collectively, these studies provide vital background, illustrating that although the application of AI-CDSS is in its early stages in Pakistan, there is academic interest in exploring the long-term integration of this tool into tertiary care, as well as clinician recognition. Despite encouraging findings, the current evidence base remains limited. Most available studies originate from single-center tertiary institutions, involve small sample sizes, and frequently rely on observational or perception-based designs. In contrast, few studies have evaluated long-term clinical outcomes, cost-effectiveness, or implementation feasibility across diverse healthcare settings. Furthermore, the absence of randomized controlled trials and multicenter data limits the generalizability of existing findings. Consequently, while early results support the potential value of AI-CDSS in Pakistan, stronger and more methodologically

Table 1: Summary of AI-CDSS and AI-enabled healthcare studies conducted in Pakistan.

Study	Clinical Setting	AI Model / Approach	Sample Size	Key Outcomes/ Findings	Limitations
Khan *et al.* [17]	Cardiovascular disease management in tertiary care	Logistic Regression and Random Forest predictive models	290 patients	Reduced myocardial infarctions, strokes, ER visits, and hospital admissions; high patient trust in AI recommendations	Single-center study; limited generalizability
Hussain *et al.* [18]	Nursing practice in healthcare settings	AI-assisted decision support	146 nurses	AI demonstrated potential to support nursing decision-making and clinical efficiency.	Limited contextual and implementation data
Ali & Saqib [19]	Hematology laboratory	Data mining classifiers, including Naïve Bayes	301 records of CBC reports	>90% accuracy in predicting thalassemia risk	Requires external validation using larger datasets
Nawaz & Ali [20]	Breast cancer screening	AI-based imaging techniques	380 malignant and 620 benign cases	Demonstrated potential for earlier breast cancer detection through AI-assisted imaging	Limited information regarding real-world implementation
Shahid *et al.* [21]	Hospital settings	Survey of AI integration in healthcare	104 health practitioners	Reported growing interest in AI-supported clinical decision-making and healthcare delivery	Self-reported responses; cross-sectional design
Siddiqui *et al.* [22]	Electronic Health Records	Natural Language Processing (NLP)	500 participants	Improved clinical documentation and quality of health records for decision support systems	Early-stage implementation evidence
Zahra *et al.* [23]	Clinical and healthcare applications	AI-based predictive analytics	330 patients	AI demonstrated potential for predicting disease progression and treatment outcomes.	Limited implementation and validation data

rigorous research before widespread implementation is vital. A summary of major AI-related studies conducted in Pakistan, including their methodologies, findings, and limitations, is presented (**Table 1**).

AWARENESS AND ACCEPTABILITY AMONG HEALTHCARE PROFESSIONALS IN PAKISTAN

Awareness is a subjective and nuanced characteristic, so to understand the current standing in Pakistan, it is vital to consider data from different groups of healthcare professionals. One study designed with the same goal of assessing the attitude of physicians towards AI incorporation into the healthcare system in Pakistan, based on the General Attitude towards AI Scale (GAAIS) and some added questions, shows an ambivalent response, with doctors accepting the advantages that AI brings. Many wantwant to use it in their daily work life, but at the same time, ethical principles of AI have been highly questioned. Interestingly, despite these concerns, physicians seemed to have come to terms with the fact that AI eventually may start replacing humans in their jobs, with more than half the participants tilting toward the agreeing side. A similar trend of understanding is seen among medical students too, who one would hope to be more in touch with the advances of modern times. Still, despite the lack of knowledge, the majority have an optimistic approach, with demands for the integration of AI in Pakistan's healthcare [24].

This raises the question of whether this polarized approach is due to insufficient knowledge, cultural conditioning, or legitimate concerns regarding the framework and strategies used for AI-CDSS. One study inquiring into the readiness of Peshawar-based undergraduate medical students and physicians towards AI observed a similar difference to that mentioned before, where males were considerably more open to it than females. An overall less optimistic approach was seen in that demographic, which strengthens the influence of culture on awareness and acceptability of AI-CDSS in Pakistan [25]. Another similar study in the same demographic found a clear demand for AI-focused education to improve undergraduate medical students' understanding [26]. On the other hand, a forward-looking approach is evident among undergraduate medical students based in Lahore, who were observed to have intermediate computer literacy and used technology consistently for learning [27].

Despite the ethical and legal concerns observed among some of the healthcare professionals, others have accepted and started to incorporate it into their work as well. Data mining classification algorithms, AI-integrated predictive analytics, and AI-driven healthcare frameworks are already being used in Pakistan [2, 17, 19], which suggests higher awareness and acceptability among certain groups. However, this adoption remains highly uneven, highlighting the need for standardization.

In general, healthcare professionals in Pakistan, when asked about their understanding of AI, showed below-par knowledge. Still, despite this, they were seen to have a positive approach towards AI incorporation [28]. In limited spaces where it is implemented on a small scale, a positive response is measured from the healthcare professionals [20]. This proves that with just the right education, the barrier of acceptability may not be hard to overcome.

BENEFITS OF AI CDSS IN PAKISTAN

Pakistan's healthcare system faces persistent challenges, including workforce shortages, limited resources, and unequal access to healthcare services, particularly in rural and underserved areas. In this context, AI-based clinical decision support systems (AI-CDSS) offer a promising approach to strengthening clinical practice

by supporting more accurate diagnoses, reducing the likelihood of errors, and promoting evidence-based decision-making. By providing timely recommendations, these systems can assist healthcare professionals in making informed clinical decisions, especially in settings where access to specialist expertise is limited and patient volumes are high.

The potential benefits of AI-CDSS extend beyond diagnostic support. These systems can also improve medication management by assisting with prescribing decisions, identifying potential drug interactions, and simplifying complex treatment regimens [29]. Such capabilities may enhance patient safety, improve adherence to clinical guidelines, and contribute to more efficient healthcare delivery. Pilot initiatives supported through Pakistan's National Center of Artificial Intelligence have demonstrated the feasibility of AI-assisted tuberculosis detection and mammographic image interpretation, contributing to improved screening efficiency and diagnostic support [30]. These experiences provide early evidence that AI-enabled decision support tools can be adapted to strengthen healthcare delivery in resource-limited settings. Their potential extends beyond individual patient care, particularly when integrated with electronic health records and broader public health systems. Such integration may support disease surveillance, outbreak prediction, vaccination planning, and the management of chronic conditions, thereby improving the continuity and coordination of care [31]. In the long term, these applications could help reduce disparities in healthcare access and outcomes between urban and rural populations in Pakistan.

CHALLENGES OF AI CDSS IN PAKISTAN

Despite their potential benefits, the implementation of AI-CDSS in Pakistan faces several challenges. Limited digital infrastructure and the lack of comprehensive electronic health records in many healthcare facilities restrict the effective use of these systems. Even where electronic records exist, issues related to data quality and completeness may affect the accuracy of AI-generated recommendations [32]. In addition, evidence from other healthcare settings suggests that poorly designed decision support systems can increase workload rather than improve efficiency [33]. This concern may be particularly relevant in Pakistan, where healthcare professionals often work under significant time and resource constraints.

Furthermore, AI models developed using data from other populations may not always perform optimally in the local context, highlighting the need for validation using representative Pakistani datasets.

Furthermore, AI-CDSS models developed using datasets from high-income countries may not accurately reflect the demographic, epidemiological, and socioeconomic characteristics of Pakistan's population. As a result, algorithmic bias and reduced predictive accuracy may occur when these systems are applied in local clinical settings. Such limitations highlight the importance of developing and validating AI-CDSS using representative local datasets before large-scale implementation.

ETHICAL CONSIDERATIONS

Ethical considerations will play a crucial role in the successful adoption of AI-CDSS in Pakistan [34]. One of the main concerns is the limited transparency of many AI systems, which may make healthcare professionals hesitant to rely on recommendations that are not easily explained or interpreted. Data privacy and security are equally important, particularly given the absence of comprehensive regulations governing the use of AI in healthcare. Currently, there are limited mechanisms to ensure accountability, evaluate system performance, or safeguard patient information. To support the responsible use of AI-CDSS, measures such as data anonymization, informed consent, and robust data protection frameworks must be prioritized [35]. Clear regulatory guidelines are also needed to address questions of liability and build trust among healthcare professionals. Furthermore, the implementation of AI in healthcare should remain sensitive to the cultural and social context of Pakistan to ensure its acceptance and equitable use.

SUPPORT FROM THE HEALTH DEPARTMENT AND POLICYMAKERS

For AI-CDSS to be meaningfully implemented, there needs to be significant policy direction and commitment of resources within the healthcare system in Pakistan. However, current initiatives reveal that there is no actual policy targeting this area; the development and application of AI-CDSS are entirely lacking a national policy, a regulatory framework, and concrete government financial support. Support remains predominantly conceptual and is discussed under the umbrella of digital health rather than through specialized, healthcare-specific regulations.

Published evidence describing large-scale public-sector AI-CDSS initiatives remains limited; instead, provincial health ministries, like the Punjab Health Initiative Management Company, have concentrated their digital efforts on telemedicine and basic health information systems.

The absence of a defined policy framework is a significant barrier to advancement. For developers and hospitals, uncertainty around evaluation criteria for the algorithm, data privacy, and responsibility for any harm has deterred investment and innovation. Moreover, until there is national coordination, funding, and an implementation plan for AI-CDSS, adoption will remain stagnant and even opportunistic at individual private institutions, rather than a collective national focus on quality of life.

Thus, the transition from high-level policy statements to practical, healthcare-specific instructions is the most

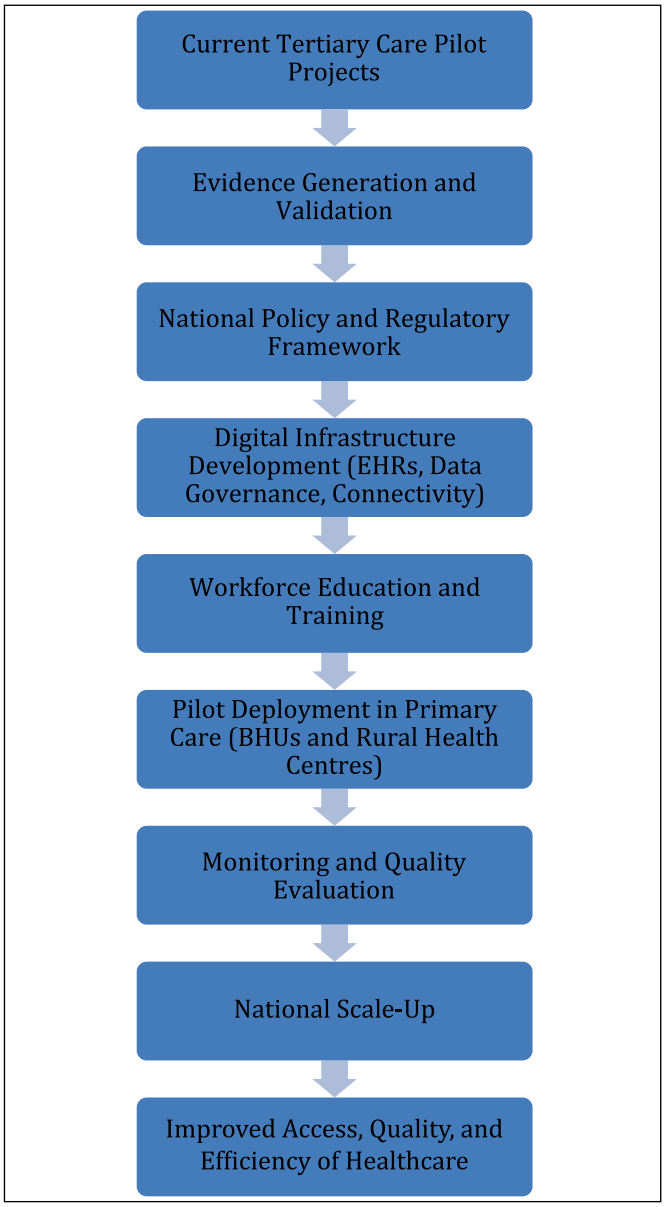


Fig. (1): Proposed framework for sustainable integration of Artificial Intelligence-Driven Clinical Decision Support Systems (AI-CDSS) into Pakistan's healthcare system.

significant support needed. The Ministry of National Health Services, Regulations and Coordination (NHSRC) and provincial health departments are responsible for formulating the national AI vision into actionable policies that enable clinical validation, ethically deploy AI-CDSS, and provide sustainable funding for AI-CDSS in the public health system. Based on the opportunities, challenges, and policy considerations identified in the literature, a conceptual framework for the sustainable integration of AI-CDSS into Pakistan's healthcare system is proposed (**Fig. 1**).

The framework illustrates a phased pathway for implementing AI-CDSS in Pakistan. Beginning with evidence generated through tertiary care pilot projects, the process progresses through validation, policy and regulatory development, digital infrastructure strengthening, workforce training, implementation in primary healthcare settings such as Basic Health Units (BHUs) and Rural Health Centers (RHCs), continuous monitoring and evaluation, and eventual national scale-up. The framework highlights the interconnected requirements necessary for sustainable and equitable AI-CDSS adoption across the healthcare system.

RECOMMENDATIONS FOR SUSTAINABLE INTEGRATION

Although the current evidence base for AI-CDSS in Pakistan originates from tertiary care institutions, its potential impact may be greatest at the primary healthcare level. Basic Health Units (BHUs), Rural Health Centers (RHCs), and secondary-level facilities frequently operate with limited specialist availability, variable diagnostic support, and high patient volumes. In such settings, AI-CDSS could assist frontline healthcare providers through guideline-based recommendations, early disease detection, medication safety alerts, and referral support. Therefore, lessons learned from tertiary care pilot projects should be viewed as foundational evidence for the future adaptation and scale-up of AI-CDSS within Pakistan's primary healthcare system. The following practical suggestions are put forth to ensure the effective and fair deployment of AI-driven Clinical Decision Support Systems (AI-CDSS) throughout Pakistan's healthcare system:

Policy and Regulatory Reforms

For the safe and effective implementation of AI-CDSS in Pakistan, a strong policy and regulatory infrastructure is required. In Pakistan, national guidelines for AI-CDSS should be developed to ensure stability in how algorithms are validated, how clinical inputs and feedback are used, and how performance is monitored, all according to international best practices. Accurate testing of clinical tools to be used in the ecosystem must be established before deployment. At the same time, strengthen data governance, preventive measures, and other applicable laws prohibiting ethical violations against individuals, including the use of AI-based systems. National Data Protection legislation would be a start, like the EU's General Data Protection Regulation (GDPR), which would embed patient confidentiality and informed consent regarding data usage. Currently, residents lack protection against unauthorized access to their own data. As we see more AI technologies being used in healthcare, without appropriate regulations to protect health-related data, there is a real risk that Pakistan could subject its citizens to the unregulated use of AI in their healthcare system. In addition to damaging trust with patients, standards of care may vary, which could lead to uneven care for patient sub-groups. Developing a coordinated national approach for AI-CDSS will develop trust and clinical confidence in using AI-CDSS in Pakistan, while managing the vulnerabilities involved in using AI systems. Pakistan has a good possibility of being seen as a responsible health AI adopter, receiving

national sanctions, and aligning with international health sector standards if it creates a coordinated national approach to AI system adoption.

Strengthening Healthcare Infrastructure

For AI-enabled clinical decision support systems (AI-CDSS) to be sustainably integrated within Pakistan's healthcare system, the country will have to prioritize modernizing its underlying infrastructure in a coordinated fashion by making direct investments from both the public and private sectors. The public health sector's investment includes additional funding from the federal and provincial health budgets to improve public health facilities' IT infrastructures through interoperable electronic health records, reliable connectivity, and secure data storage to facilitate their access to AI. On the private sector side, the government must incentivize participation through tax breaks and grants regarding language-based AI applications that are contextually relevant and have been developed locally. For additional resources and expertise, the government can establish collaborative relationships between the healthcare systems in its own country and those funded by international bodies, such as the World Health Organization and/or the World Bank, thus creating more opportunities for funding and training. An integrated approach will help to close the knowledge gap between public and private health facilities. With the required technology, the equitable AI-CDSS can now reach all healthcare facilities in the country.

Capacity Building and Workforce Training

Comprehensive education reforms are necessary to prepare Pakistan's healthcare workforce for AI-enabled clinical decision support. Pakistan's Higher Education Commission (HEC) and Pakistan Medical and Dental Council (PMDC) should incorporate artificial intelligence and clinical decision support systems (AI-CDSS) into their curricula to guarantee that future doctors and nurses are digitally literate and competent. Current clinicians also require training in utilizing and interpreting AI technology; this should be achieved through continuous professional development CPD programs. This should also coincide with the development of specialized residency and fellowship programs for clinical informatics to train a new generation of clinical professionals who will bridge the gap between clinical care and AI.

Phased Implementation and Pilot Scaling

The initial implementation of AI-CDSS in Pakistan should be done in phases to identify where the highest impact can occur in the development and deployment of AI for healthcare and to identify the timeliest opportunity for clinical benefit. The initial rollout locations should target high-impact areas of clinical care that will use AI as part of the diagnostic process, such as radiology and pathology. Leading teaching hospitals in Pakistan (*e.g.*, Aga Khan University) that have successfully implemented AI in their diagnostic process should provide templates for how AI will be implemented in government hospitals. Further, to enable rapid adoption of AI by clinicians and to build confidence in its use for healthcare, demonstration hubs will be developed at strategically selected "model" hospitals within each province in Pakistan. Stakeholders will be educated about how an AI-CDSS system can be integrated into everyday clinical practice, receive training in the use of AI-CDSS systems, and conduct live experimental trials to assess their functionality and clinical output before a wider rollout. Engaging stakeholders directly can build confidence, trust, and support for using AI-assisted tools to implement new practices and evaluate modern technologies.

Monitoring, Evaluation, and Feedback Mechanisms

Monitoring and assessing AI-CDSS (Clinical Decision Support Systems) is essential to ensure clinical credibility and trustworthiness. Components of monitoring and evaluation shall include conducting audits of AI performance standards, assessing bias and unintended consequences on patient outcomes, and creating an accessible, transparent decision log that allows clinicians to verify AI-generated recommendations. Documentation capturing the steps of algorithm interpretation is critical in maintaining physician credibility. In addition, continuous enhancement of AI capabilities requires a set of ways for collecting ongoing feedback for improvement. A simple reporting mechanism will support the sustainability of AI algorithms through ongoing updates to healthcare providers following the reporting of algorithm errors or workflow disruptions. The elements of monitoring and evaluating AI performance lead to a feedback loop of deploying AI, assessing AI performance, and then utilizing performance assessment to drive ongoing development. Together, these processes would build the confidence needed to facilitate an AI-CDSS that is trusted and reflexive while supporting patient care rather than interrupting it.

PROSPECTS

Several studies have explored healthcare professionals' perceptions of AI using technology acceptance models and survey-based assessments. Overall, findings suggest a generally positive attitude toward AI-assisted diagnostics and decision support, with many clinicians recognizing their potential to enhance clinical practice and improve patient care [20,30].

Evidence from local initiatives has also been encouraging. Applications such as data-mining classifiers for thalassemia risk prediction, predictive analytics for cardiovascular disease management, and locally developed platforms such as Darcheeni have demonstrated AI's potential to support clinical decision-making, reduce physician workload, and promote more patient-centered care [2, 17, 19].

Looking ahead, AI-CDSS has the potential to support healthcare delivery across multiple levels of Pakistan's health system, particularly in underserved primary care

settings where access to specialist expertise is limited. Integration with telemedicine platforms, electronic health records, and national health information systems may improve diagnostic support, chronic disease management, and referral pathways. However, achieving these benefits will require investment in digital infrastructure, workforce training, regulatory oversight, and locally validated AI models. Continued collaboration among policymakers, healthcare institutions, and technology developers will be essential to ensure sustainable and equitable implementation. These strategies are particularly relevant to primary care settings, where AI-CDSS can enhance early diagnosis, triage, and referral decisions.

CONCLUSION

Evidence from healthcare systems worldwide suggests that AI-driven Clinical Decision Support Systems (AI-CDSS) can improve diagnostic accuracy, support clinical decision-making, and enhance workflow efficiency across a range of specialties and practice settings. Although the adoption of AI-CDSS in Pakistan remains at an early stage, growing interest from researchers and healthcare institutions highlights its potential role in strengthening healthcare delivery.

However, several challenges continue to limit widespread implementation, including the absence of comprehensive regulatory frameworks, limited digital infrastructure, and disparities in resource availability across healthcare settings. Despite these barriers, AI-CDSS offers promising opportunities to improve the quality and accessibility of care. Realizing this potential will require coordinated efforts focused on policy development, infrastructure strengthening, workforce training, and phased pilot implementation to support the sustainable integration of AI-CDSS within Pakistan's healthcare system. Benefits may be realized at the primary healthcare level, where AI-CDSS could support frontline clinicians, strengthen referral decisions, and improve access to evidence-based care in underserved communities throughout Pakistan.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

The authors declare that an artificial intelligence (AI) tool (ChatGPT) was used during the preparation of this manuscript. The tool was used solely for language editing, grammar correction, and improving the text's clarity and organization.

No AI tools were used for data collection, data analysis, interpretation of results, or generation of original scientific content. The AI tool did not contribute to authorship.

All content generated or assisted by the AI tool has been critically reviewed, verified, and approved by the authors. The authors take full responsibility for the accuracy, integrity, and originality of the manuscript and are accountable for all aspects of the work, including any portions supported by AI tools.

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