

ARTIFICIAL INTELLIGENCE–AUGMENTED CLINICAL DECISION SUPPORT IN NURSING AND ALLIED HEALTH CARE: EXAMINING TECHNOLOGICAL POTENTIAL, PRACTICAL LIMITATIONS, AND ETHICAL RESPONSIBILITIES WITHIN THE PAKISTANI HEALTHCARE FRAMEWORK

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ABSTRACT

The integration of Artificial Intelligence–augmented Clinical Decision Support Systems (AI-CDSS) into nursing and allied health care offers considerable potential to bolster health systems in low- and middle-income countries, yet remains critically under examined in contexts such as Pakistan. Drawing on a cross-sectional quantitative study of 342 frontline health professionals across six tertiary hospitals, and corroborated by objective clinical data from a 12-month pre–post implementation period, this research demonstrates that AI-CDSS significantly improved diagnostic accuracy for high-acuity conditions (from 78.3% to 91.2%, $p < 0.001$) and enhanced both workflow efficiency ($\beta = 0.52$) and professional autonomy ($\beta = 0.38$). Nevertheless, these gains were consistently constrained by infrastructural fragilities, particularly unreliable connectivity and non-interoperable systems, and profound ethical uncertainties surrounding data privacy and algorithmic accountability. The findings affirm that effective AI adoption in Pakistan hinges not on technical prowess alone, but on context-sensitive design, foundational digital investment, workforce preparedness, and a robust national ethics framework. This study advances an integrated socio-technical-ethical model to guide equitable, sustainable AI deployment in LMIC frontline care, an imperative for global health equity

Keywords: Artificial Intelligence (AI), Clinical Decision Support Systems (CDSS), Nursing, Allied Health, Digital Health, Pakistan, low- and middle-income countries (LMICs), Ethics, Health Informatics.

Introduction:

The introduction of Artificial Intelligence (AI) in healthcare systems is turning clinical practice around the globe in a short period. One of the most promising uses is the implementation of AI - enhanced Clinical Decision Support Systems (CDSS), helping clinicians to get real-time,

evidence-based recommendations based on the most recent evidence base. Such systems are especially relevant to the nursing and allied health professionals, the roles of which often form the frontline of patient care but are constrained by vast time deficits, resource shortages, and cognitive load. Early symptom identification, risk

prioritization, administration of medications, and chronic disease management are among the tasks that can be accomplished with the help of AI-CDSS, thus, improving patient safety and operational efficiency (Buchanan et al., 2022; Kleib et al., 2021).

Although the high-income nations have achieved significant progress in integrating AI-based tools into the clinical workflow, low- and middle-income countries (LMICs) experience a unique set of threats and opportunities, against which Pakistan falls. The healthcare system of Pakistan is marked by disintegration, endemic lack of funds, and severe urban/rural inequalities. The Pakistan National Health Accounts (2022) reveals that there is insufficiently staffed primary healthcare facilities (only 30-percent), and electronic health records (EHRs) are predominantly unavailable in small cities without large urban hospitals. The AI-enhanced CDSS in this environment could be a clinician equalizer, providing nurses and other professionals in the healthcare field with the expert decision-making assistance in remote or understaffed locations (Labrique et al., 2018). Nonetheless, uncritical application of AI models developed in Western intellectual traditions can only result in either an ineffective or worse, dangerous solution to the population it is aimed at. When clinical decision-support systems have been trained mostly on datasets based on people of European origin, they tend to have lower performance when applied in ethnically and genetically homogenous groups of Pakistan, such as Punjabis, Sindhis, Pashtun, and Baloch. Groups of these people have varied susceptibility to the disease and social determinants of health, which Ahmed and Malik (2023) have carefully outlined. In addition, the clinical priorities that prevail in Pakistan include the need to mitigate high mortality of mothers, tuberculosis and polio, and face ever-growing diabetes and hypertension burden, which bear little relation to the ones predicted in high-income environments. As a result, the urgent need is the AI solutions sensitive to the local epidemiological environment (World Health Organization, 2023). This need is further demonstrated by the importance of nursing and allied health professionals in Pakistan. Nurses are

the most numerous group in the healthcare system of the country, but they often do not have access to relevant clinical guidelines or diagnostic tools in time. Allied workers such as laboratory technicians, physiotherapists, radiographers and community health workers are frequently working in rural areas with little supervision. Clinical decision-support based on AI may help to fill these knowledge gaps, reduce diagnostic uncertainty and normalise care delivery, especially in settings with limited presence of specialists (Khowaja et al., 2020). Pilot projects in neighbouring low- and middle-income nations, including India and Bangladesh, have shown that mobile-based AI solutions can be used to screen diabetic retinopathy and assess antenatal risks, and so provide transferable lessons to Pakistan (Prinja et al., 2022).

In spite of this promise a myriad of viable obstacles curtail the implementation of AI. This includes infrequent power supply, slow internet connections, poor digital literacy of health care providers and the lack of interoperable health information systems. A survey conducted by fifty district hospitals in Pakistan in 2023 has shown that less than fifteen percent of them use any type of digital clinical documentation (And no AI-ready data platform) (Ministry of National Health Services, 2023). Lack of a unified medical coding system (ICD10 or SNOMED CT) also creates more barriers to the development of structured datasets that would be required to train and test AI algorithms. Even the most advanced AI systems will probably be unaffordable without the basic investments in the health informatics infrastructure. In addition to these technical and logistical obstacles, there is the question of ethics looming large. The use of AI in clinical settings presents critical questions on transparency, responsibility, and fairness. In the event that an AI system makes a mistake in prescribing a therapy, who is liable, the clinician, the developer or the institution? What could be done to protect patient privacy of a country that does not have extensive laws to protect data privacy? And, more crucially, in what ways can AI be designed in a way that empowers and supports professional judgment and human dignity in care instead of disempowering

them? Reddy et al. (2020) argue that explainable AI and human-in-the-loop design are not extravagant necessities in low- and middle-income settings but ethical necessities. As a result, academic discourse on AI in Pakistani healthcare needs to be more than techno-optimism and develop a paradigm of innovation and integrity that is both nuanced and contextual. The paper examines the technological potential of the AI-enhanced clinical decision-support systems to support nursing and allied health professionals in Pakistan, and critically evaluates their real limitations and ethical obligations. It seeks to map a responsible, fair, and sustainable future of AI integration, in which nurses, allied health workers, and the patients they serve are at the centre of digital transformation.

Research Gap:

However, despite the increasing popularity of the application of artificial intelligence (AI) in healthcare, there are significant research and implementation gaps, primarily in low- and middle-income nations (LMICs) like Pakistan. Of special interest is how little of contextual relevance there is in extant AI-based clinical decision support systems (AI-CDSS), most models having been trained on Western datasets that do not reflect the demographic composition of Pakistan, its disease epidemiology, or local clinical workflow (Topol, 2019). This kind of mismatch obstructs generalization as well as creates a chance of breeding wrong or prejudiced suggestions in the event that these systems are implemented in Pakistani environments. Besides, the existing literature is characterized by a strong physician-centered focus, and the lack of attention is given to the unique role and decision-making situations and information requirements of nurses and other allied health workers, even though they play an irreplaceable role in the frontline of care delivery (Kleib et al., 2021). This asymmetry is an obstacle to a comprehensive view of the integration of AI into the multisectoral range of healthcare teams. To add to these problems, there is an impressive lack of empirical studies on the use of AI in the context of LMIC clinical settings. Research evidence on scalability, cost-efficiency, and practical acceptance of AI tools by users in health

systems constrained by resources is lacking (Scott et al., 2021). The information is critical in making informed policy and practice decisions.

The problem is also worsened by the regulatory environment in Pakistan. The nation does not have any detailed ethical and regulatory systems of health AI, such as effective data-protection laws or policies that regulate the transparency of algorithms, accountability, and patient consent. As a result, the key ethical risks are not addressed (Ahmed and Malik, 2023). Also, there is limited literature that has explored the technical issues of deploying modern AI-CDSS on the disjointed and frequently outdated Pakistani health information technology infrastructure. Other issues like interoperability, data standardization and sustainability of the system in the long-term should be subject to intense scrutiny. Collectively, these gaps prove the critical need to conduct research that is localized and multidisciplinary. This kind of scholarship should also help close the gap between global innovation and the practicalities and ethical realities of Pakistan so such that AI solutions become culturally relevant and also operationally feasible.

Literature Review:

The advent of Artificial Intelligence (AI) as a key to the modern decision-making in the global healthcare industry is the most prominent driver of the growing digitalization of the sector. The AI-enhanced Clinical Decision Support System (CDSS) are providing real-time, empirically based suggestions that improve the accuracy of the diagnosis, reduce errors, and optimize the use of resources in the domain of nursing and other allied health, which is the cornerstone of primary and secondary care (Buchanan et al., 2022). Whereas wealthy countries have made significant advances in deploying AI-mediated clinical solutions, low- and middle-income countries (LMICs) face different socio-technical, economic, and ethical challenges, as it is happening to Pakistan. The healthcare system in Pakistan is still disjointed, and access to healthcare services is uneven, there is a consistent lack of workforce, and digital maturity is low. However, the urgency of effective, scalable interventions; notably, in the

areas of infectious disease control, maternal and child health, and the growing burden of non-communicable diseases (NCDs) is acute. In such a setting, AI-enhanced CDSS may serve the purpose of a strategic multiplier by decreasing the load on overworked nurses and other health professionals. However, the unthinking application of such technologies in their translational form, without a thorough contextual adaptation, has a risk of enhancing the already existing inequities or undermining professional judgment and autonomy.

AI-Augmented CDSS: Global Trends

Clinical Decision Support Systems (AI-CDSS) are artificial intelligence-based tools that use machine learning, natural language processing, and predictive analytics to help clinicians make evidence-based decisions. An example of this is IBM Watson for Oncology, Google Deep Mind to identify retinal diseases, and sepsis predictive models, which have been used in intensive care units (Davenport & Kalakota, 2019). It has been established that AI-CDSS could help decrease the number of diagnostic errors by up to 30 percent and improve compliance with clinical guidelines (Sharma et al., 2020). In contrast to the classical rule-based CDSS which are based on fixed rules, AI-CDSS is a multimodal system that dynamically queries large volumes of data such as electronic health records, medical imaging, genomic profiles, and social determinants of their health in order to produce predictive, personalized recommendations (Davenport & Kalakota, 2019). Systems are currently being implemented globally in a wide range of clinical settings: IBM Watson for Oncology cross-checks patient information with millions of medical publications to assist in cancer treatment planning; the Deep Mind division of Google has already managed to detect diabetic retinopathy and age-related macular degeneration based on retina scans with an ophthalmologist level of accuracy (De Fauw et al., 2018); and sepsis-predictive systems including the Deterioration Index provided by Epic use real These innovations highlight the ability of AI to support clinical judgments, decrease the time taken in diagnoses, and standard care of high quality.

The adoption of AI-CDSS is increasing most significantly in high-income nations which have developed digital health systems. The certification and clinical integration of validated AI tools in the United States and the European Union have been enabled by regulatory frameworks, such as the Software as a Medical Device (SaMD) pathway of the FDA and the EU Medical Device Regulation (MDR) (Benjamins et al., 2020). Academic hospitals like Johns Hopkins, Stanford, and Karolinska Institute are leading the AI use in the range of activities, including antimicrobial stewardship to mental-health risk stratification. In a 2022 meta-analysis, Sharma et al. found that 42 studies, most of which were based in North America and Europe, found AI-CDSS implementation was linked to a reduction of diagnostic errors by 27 per cent, an increase in guideline adherence by 19 per cent, and a reduction in hospital readmission rates by 15 per cent. Furthermore, AI platforms offered on the cloud can now be scaled, making them affordable by even smaller clinics, despite the required large on-site computing capabilities (Topol, 2019).

However, such developments are not devoid of sharp global inequalities. On the one hand, high income countries are enjoying integrated electronic health records, standardised data ontologies (e.g., SNOMED CT, LOINC), and strong broadband connectivity, on the other hand, low- and middle-income countries (LMICs) are facing fundamental barriers to the viability of AI. Most AI systems are trained using data of European or East Asian populations, which pose a threat to algorithmic bias and poor performance on more diverse ethnic groups (Obermeyer et al., 2019). The lack of transparency of many deep-learning systems, the black-box aspect, also contributes to a lack of trust and responsibility, particularly in the environment with clinicians that might have low levels of digital literacy (Reddy et al., 2020). Recognizing these disparities, health global programs such as the 2021 recommendations on Ethics and Governance of AI by the World Health Organization recommend inclusive design, contextual validation, and capacity building in LMICs. However, what is clear is that the trend today is that AI-enhanced CDSS are no longer experimental prototypes but

an integral aspect of modern, data-driven healthcare, as long as it is developed and implemented with equity, explain ability, and strong human oversight in the mainframe.

Role in Nursing and Allied Health

Nurses and other health care professionals often act as first responders and organizers of care. Triage, medication management, patient monitoring, and chronic disease education can be assisted with the help of artificial intelligence tools (Kleib et al., 2021). Indicatively, AI-based mobile apps have improved the screening of diabetic foot by community healthcare workers in India (Prinja et al., 2022).

The frontline healthcare delivery often involves the nursing and allied health personnel such as clinical nurses, midwives, physiotherapists, laboratory technicians, radiographers, community health workers, and other related personnel, whose contributions are mostly made in the primary and secondary care environments. Their duties include constant patient observation, early detection of clinical decline, medication, health education and coordination of care. AI-enhanced Clinical Decision Support Systems (AI-CDSS) have a potential to significantly enhance their clinical effectiveness as they can provide real-time and context-sensitive recommendations that supplement their knowledge. An example is that AI-driven mobile apps can assist community nurses to identify high-risk pregnancies through symptom-checking algorithms, and predictive analytics in bedside monitors can notify critical-care nurses about the early signs of sepsis or cardiac arrest (Kleib et al., 2021). In comparison with physician-focused AI tools that usually prioritize the complexity of the diagnosis, nursing-focused CDSS needs to be able to support the rapid triage, the smooth integration of workflows, and the focus on the psychosocial aspects of care, thus, requiring user-centered design and task-specific functionality (Nagel et al., 2022).

Although they play a central role, nurses and allied health professionals are still under-represented in the designing and testing of AI-CDSS. In a scoping review study, Kleib et al. (2021) found that less than 12.0 percent of AI-health studies published

in 2015-2020 expressly covered nursing workflows or decision-making settings. This gap is especially concerning in low-resource environments, like those in Pakistan, where nurses and other health workers are often left to work with little supervision by doctors and who have limited access to current clinical practices. Cognitive load could be reduced and quality of care improved with AI tools tailored to their scope of practice such as image-based diagnostics of diabetic foot ulcers used by community health workers or voice-assisted documentation systems used by overwhelmed nurses (Prinja et al., 2022). However, the effectiveness of the integration depends on the reduction of usability concerns, cultural relevance, and the development of trust based on the transparent and explainable AI results. The evolution of the AI in nursing as described by Buchanan et al. (2022) needs to focus more on augmentation, rather than automation, and this should be applied to protect professional autonomy while enabling frontline providers with intelligent and ethically sound support.

Challenges in LMICs

The research studies based in sub-Saharan Africa and Southeast Asia shed some light on a cluster of issues that impede digital implementation of health-related solutions in the resources-constrained environment: unreliable electricity, lack of access to broadband, digital illiteracy, and deficit in high-quality data (Labrique et al., 2018). In Pakistan, the situation is particularly bleak: just 28 percent of health institutions have functional electronic medical records (EMRs) which is an absence that directly compromises the implementation and deployment of artificial-intelligence (AI) models (Pakistan Bureau of Statistics, 2022).

Introduction of Artificial Intelligence-enhanced Clinical Decision Support Systems (AI-CDSS) in low- and middle-income countries (LMICs) is facing tremendous structural and operational burdens that go beyond the technological limitations. One of the key barriers is that there is no underlying digital-health infrastructure. Most LMICs, such as Pakistan, do not have adequate electronic health record (EHR) systems,

standardized clinical codes like ICD-10 or SNOMED CT, and interoperable data platforms; these factors are among the preconditions of training and implementing powerful AI models (Labrique et al., 2018). Without the availability of organized, high-quality data, AI systems cannot learn effectively and generalize to different clinical settings. In addition, power cuts, low broadband coverage, and outdated hardware of rural and semi-urban health care facilities is a significant impediment to the viability of real-time AI applications. Because AI does not exist in the siloed, paper-based, or non-existent data as some of them note, which are predominant in the LMICs healthcare context, this reality does not bode well with AI (Scott et al. 2021).

On top of these infrastructural shortfalls are employee related obstacles. Professionals working within the LMICs receive very little training in healthcare informatics or digital literacy, which hampers their capacity to interpret, trust, or make good use of AI-based recommendations (World Health Organization, 2021). The particularly vulnerable group of frontline workers can be nurses and allied health workers, who represent the largest percentage of the workforce, as they might be apt to either succumb to the automation bias (overreliance on AI), or to resist on the grounds of potential loss of professional autonomy. Also, the lack of local AI skills, including data scientists and clinical informaticians, would mean that, despite the introduction of pilot projects, they are often undertechnically supported during maintenance, adaptation, or scaled. Prinja et al. (2022) emphasize this fact by concluding that, even though an AI-based diabetic foot screening tool showed promising results in rural India, the lack of local capacity to troubleshoot software issues or to train new models with new data impeded sustainability. Lastly, there are ethical and governance lapses, which are major systemic risks. The majority of LMICs such as Pakistan do not have an elaborate data-protection law, defined regulatory avenues of AI approval, and a system of algorithmic responsibility (Ahmed and Malik, 2023). Such a legal gap raises some serious doubts about patient privacy, informed consent, and liability in case of AI-related mistakes. In addition,

AI models that have been trained on data of high-income countries are likely to be biased and therefore make a misdiagnosis or provide suboptimal care to the populations of different genetic, environmental, or sociocultural profiles (Obermeyer et al., 2019). Without the principles of inclusive data collection, community engagement, and context-sensitive design, AI-CDSS can contribute to the existing disparities in health and not alleviate them. Unless equity, transparency, and local ownership are central to implementation, as the WHO (2021) warns, the promise of AI in global health will not be met.

Methodology:

Research Design:

This study employed a cross-sectional quantitative research design to examine the technological potential, practical limitations, and ethical responsibilities associated with Artificial Intelligence-augmented Clinical Decision Support Systems (AI-CDSS) in nursing and allied health care within Pakistan's low-resource healthcare settings. The design enabled the systematic assessment of healthcare professionals' perceptions, workflow impacts, and ethical concerns through structured survey instruments, while also integrating objective clinical performance indicators. Structural Equation Modeling using Partial Least Squares (PLS-SEM) was used to test hypothesized relationships among AI-CDSS adoption, perceived improvements in clinical decision-making and workflow efficiency, and the moderating effects of infrastructural constraints, digital literacy, and ethical apprehensions. This approach is particularly suited for theory development and prediction in complex, real-world health systems with limited prior empirical models (Hair et al., 2019).

Population and sample:

The study was conducted across six public-sector tertiary care hospitals located in four provinces of Pakistan (Punjab, Sindh, Khyber Pakhtunkhwa, and Balochistan), selected to represent geographically and economically diverse low-resource environments with high patient loads and

recent pilot implementations of AI-enabled health tools. The target population included:

- Registered nurses and clinical nurse specialists involved in triage, monitoring, and patient education;
- Allied health professionals, including radiographers, laboratory technologists, physiotherapists, and community health workers;
- Mid-level hospital administrators are responsible for health information systems and digital health initiatives. Eligibility criteria required participants to have at least 1 year of clinical or operational experience in their respective roles and to have had direct exposure, either through training or daily practice, to AI-CDSS or digital clinical support tools within the past 12 months.

Sampling Technique

A stratified random sampling technique was applied to ensure proportional representation across professional categories and geographic regions. Based on PLS-SEM guidelines, a minimum sample size of 10 times the largest number of structural paths directed at any latent construct was targeted (Hair et al., 2019). Given the model included 12 key constructs, a minimum of 120 responses was required; however, anticipating a 30% non-response rate and to enhance statistical power (effect size $f^2 = 0.15$, $\alpha = 0.05$, power = 0.80), the final target sample was set at 360 participants: 150 nurses, 150 allied health professionals, and 60 administrators. Stratification ensured balanced inclusion across urban and semi-urban facilities.

Data Collection Method

A validated, structured questionnaire was developed through a two-phase process:

1. **Content Validity:** A panel of seven experts, comprising three senior nursing educators, two allied health leaders, and two health informatics researchers, reviewed item relevance, clarity, and domain coverage using the Content Validity Index (CVI > 0.80).
2. **Pilot Testing:** The instrument was pre-tested with 40 healthcare workers across two non-study hospitals to evaluate internal consistency

(Cronbach's $\alpha > 0.85$) and construct validity via exploratory factor analysis.

The final instrument included five multi-item scales measured on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree):

- **Perceived Technological Potential** (e.g., "AI-CDSS improves my diagnostic confidence")
- **Practical Limitations** (e.g., "Unreliable internet disrupts AI tool functionality")
- **Ethical Responsibilities** (e.g., "I am concerned about patient data privacy with AI systems")
- **Workflow Integration** (e.g., "AI tools reduce my time spent on routine tasks")
- **Professional Autonomy** (e.g., "AI recommendations sometimes conflict with my clinical judgment")

In addition to survey data, anonymized secondary clinical metrics, including average patient throughput time, diagnostic error rates (via retrospective case audits), and AI system uptime—were extracted from hospital records over a 6-month period preceding data collection to provide objective correlates of self-reported outcomes.

Variables and Measurement

This study operationalized five core latent constructs, drawn from the Technology Acceptance Model (TAM), the Socio-Technical Systems framework, and AI ethics literature, to examine the multidimensional impact of AI-augmented Clinical Decision Support Systems (AI-CDSS) in nursing and allied health contexts in Pakistan. Each construct was measured using multi-item, validated scales adapted to the local clinical environment, with all items rated on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). The variables and their measurement indicators are detailed below.

1. **Technological Potential (TP)**
This construct captures the perceived clinical and operational benefits of AI-CDSS. It reflects respondents' beliefs that AI tools enhance diagnostic accuracy, decision confidence, and care quality (Kleib et al., 2021; Davenport & Kalakota, 2019).
2. **Practical Limitations (PL)**
This variable assesses infrastructural, technical, and

human-resource barriers that hinder AI-CDSS implementation in low-resource settings (Labrique et al., 2018; Scott et al., 2021):

3. **Ethical Responsibilities (ER)**
This construct gauges awareness of and concern regarding ethical implications of AI deployment, including privacy, bias, transparency, and accountability (Ahmed & Malik, 2023).
4. **Workflow Efficiency (WE)**
This variable measures the perceived impact of AI-CDSS on task completion time, coordination, and resource utilization among nurses and allied health staff.
Measurement items (adapted from Nagel et al., 2022; Sharma et al., 2022).
5. **Professional Autonomy (PA)**
This construct evaluates the extent to which AI-CDSS is perceived as supporting or undermining clinical independence and professional judgment (Buchanan et al., 2022; Reddy et al., 2020).

Results

Demographics Participant:

A total of 342 healthcare professionals completed the survey, yielding a response rate of 85.5% (out of 400 distributed questionnaires). The sample closely aligned with the intended stratification: 148 (43.3%) nurses, 142 (41.5%) allied health professionals (including radiographers, laboratory technologists, physiotherapists, and emergency medical technicians), and 52 (15.2%)

administrative staff involved in digital health coordination or ED operations.

In terms of gender, 68.7% (n = 235) of respondents identified as female, reflecting the gender composition of the nursing workforce in Pakistan, while 31.3% (n = 107) were male, predominantly among allied health and administrative roles. The mean age was 32.4 years (SD = 6.8), with the majority (61.4%) aged 25-35 years. Professional experience ranged from 1 to 18 years, with a mean of 6.3 years (SD = 4.1). Notably, 74.3% (n = 254) reported having used or observed an AI-assisted clinical tool (e.g., AI triage apps, image interpretation aids, or predictive analytics dashboards) within the past year, primarily in pilot projects supported by hospital partnerships or donor-funded digital health initiatives.

Geographically, participants were drawn from six tertiary hospitals: two each in Punjab and Sindh, and one each in Khyber Pakhtunkhwa and Balochistan. Facilities in urban centers (e.g., Lahore, Karachi) reported higher AI system availability (89%) than those in semi-urban sites (52%), underscoring infrastructural disparities.

Descriptive Statistic:

Descriptive analysis of the five latent constructs revealed nuanced perceptions of AI-CDSS across professional groups (Table 1). All scale reliabilities were satisfactory (Cronbach's α : 0.84–0.91; Composite Reliability: 0.86–0.93), supporting internal consistency.

Table: 01

Variables	Mean(SD)	Max	Min	Explanation
Technological Potential (TP)	3.82 (0.76)	1.50	5.00	Highest among nurses (M = 3.94); allied health staff expressed moderate optimism.
Workflow Efficiency (WE)	3.41 (0.82)	1.25	4.75	Nurses reported greater time savings; administrative staff rated integration lower (M = 3.12).

Professional Autonomy (PA)	3.65 (0.79)	1.75	5.00	Majority (68%) agreed AI "augments rather than replaces" their judgment.
Practical Limitations (PL)	4.18 (0.69)	2.00	5.00	Highest-rated barrier: "Unreliable internet" (M = 4.42); "Excessive data entry" (M = 4.05).
Ethical Responsibilities (ER)	4.03 (0.73)	2.25	5.00	Strong concern about data privacy (M = 4.31) and lack of error accountability protocols (M = 4.17).

Measurement Model Assessment

The reflective measurement model met all required psychometric thresholds:

- Factor loadings for all indicators exceeded the recommended threshold of 0.70 (range: 0.74–0.92).
- Cronbach's alpha (0.84–0.91) and composite reliability (0.86–0.93) confirmed internal consistency.
- Average Variance Extracted (AVE) values ranged from 0.58 to 0.72, satisfying the convergent validity criterion (AVE > 0.50).
- Discriminant validity was established via the heterotrait-monotrait (HTMT) ratio, with all values below the conservative threshold of 0.85 (max HTMT = 0.79 between Workflow Efficiency and Technological Potential).

Moderator and Group Analysis

A multi-group analysis (MGA) comparing nurses (n = 148) and allied health professionals (n = 142) revealed significant differences: First the path from TP → WE was stronger for nurses ($\beta = 0.61$) than allied health staff ($\beta = 0.43$) ($p < 0.05$), likely because AI tools in the study (e.g., vital sign alerts, triage classifiers) aligned more closely with nursing tasks. Second Ethical Responsibilities had a stronger negative effect on PA among allied health professionals ($\beta = -0.37$ vs. -0.22 for nurses), possibly due to their greater involvement in data generation (e.g., lab/radiology) and heightened sensitivity to data misuse.

Diagnostic Accuracy: The Strongest Evidence of Technological Potential

Table 02:

Metric	Pre-AI-CDSS	Post-AI-CDSS	Change	Improvement%	P-Value
Overall Diagnostic Accuracy	78.3%	91.2%	+12.9%	16.5%	<0.001
Sepsis Detection Accuracy	74.1%	89.6%	+15.5%	20.9%	<0.001
Stroke Recognition Accuracy	76.8%	90.3%	+13.5%	17.6%	<0.001
Fracture Identification	81.2%	93.4%	+12.2%	15.0%	<0.001

(X-ray)					
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In table 2, the implementation of AI-CDSS in six tertiary emergency departments led to a statistically and clinically significant improvement in diagnostic accuracy for high-acuity conditions:

- Pre-AI accuracy: 78.3%
- Post-AI accuracy: 91.2%
- $p < 0.001$ ($t = 12.54$)

Gains were highest for sepsis detection (+15.5%) and stroke recognition (+13.5%). This is the most compelling evidence of AI's value in the Pakistani context. It demonstrates that even in a resource-limited setting, AI-CDSS can enhance frontline clinical judgment, especially when integrated into nursing and allied health workflows (e.g., vital sign monitoring, triage checklists, image pre-screening). The improvement was statistically

significant across all categories (paired t-test: $t = 12.54$, $p < 0.001$). Notably, the greatest gains were observed in sepsis detection, where AI-CDSS integrated real-time vital signs, lactate levels, and nursing observations into a predictive score, enabling earlier escalation by triage nurses.

Structural Model and Hypothesis Testing

The PLS-SEM structural model explained substantial variance in key outcome variables:

- Workflow Efficiency (WE): $R^2 = 0.48$ (48% of variance explained)
- Professional Autonomy (PA): $R^2 = 0.36$
- Perceived Technological Potential (TP): $R^2 = 0.41$

Key path coefficients and hypothesis tests are summarized below

Variable Relationships	β	t-value	p-value
TP & WE	0.52	8.74	<0.001
TP & PA	0.38	5.92	<0.001
PL & WE	-0.31	4.63	<0.001
ER & PA	-0.29	4.18	<0.001

Interpretation:

Following data collection from 342 participants (95% of the target sample of 360), the structural model was analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). The analysis confirmed the validity of both the measurement and structural models, with all constructs demonstrating strong reliability and predictive validity. Technological Potential strongly drives Workflow Efficiency ($\beta = 0.52$, $p < 0.001$), indicating that when nurses and allied health workers believe AI-CDSS improves diagnostic confidence and care quality, they report greater time savings and smoother task execution. Practical Limitations significantly undermine both TP and WE, confirming that infrastructural barriers (e.g., internet instability, poor integration) directly erode

perceived benefits and operational gains. Ethical Concerns negatively impact Professional Autonomy ($\beta = -0.29$, $p < 0.001$), suggesting that unresolved issues around data privacy and algorithmic transparency make clinicians feel less in control of their decisions. Professional Autonomy is positively associated with TP ($\beta = 0.38$), reinforcing that AI tools are most valued when override, clinical judgment.

Conclusion:

The integration of Artificial Intelligence-augmented Clinical Decision Support Systems (AI-CDSS) into nursing and allied health care in Pakistan presents a transformative opportunity to address longstanding challenges in diagnostic accuracy, workforce strain, and care equity.

Empirical findings from this study demonstrate that AI-CDSS implementation in tertiary emergency departments significantly improved diagnostic precision, from 78.3% to 91.2%, for critical conditions such as sepsis, stroke, and fractures. These gains were not merely technical but deeply human: nurses and allied health professionals reported enhanced clinical confidence, reduced cognitive load, and more timely patient interventions. As Topol (2019) asserts, the convergence of human expertise and artificial intelligence can elevate “high-touch” care through “high-tech” support, provided it is implemented with purpose and partnership.

However, the promise of AI is not self-fulfilling. This study reveals that practical limitations, particularly unstable infrastructure, limited digital literacy, and fragmented health information systems, remain the most formidable barriers to scalable adoption in Pakistan. Even the most accurate AI tool becomes inert without reliable electricity, broad band, or interoperable data standards. These findings align with global evidence from low- and middle-income countries (LMICs), where Labrique et al. (2018) emphasize that “digital health innovations fail not from lack of ingenuity, but from misalignment with system realities.” In Pakistan, where only a fraction of district hospitals maintain functional electronic records, AI must be designed for low-bandwidth, mobile-first, and offline-capable environments to be truly inclusive.

Equally critical are the ethical responsibilities that accompany AI deployment. Frontline health workers expressed profound concerns about patient data privacy, algorithmic transparency, and accountability, issues that remain unaddressed in the absence of comprehensive data protection legislation or AI-specific health regulations in Pakistan (Ahmed & Malik, 2023). Without clear governance frameworks, AI risks eroding trust rather than building it. The World Health Organization (2021) rightly cautions that AI in health must be “guided by principles of equity, transparency, and human rights.” In the Pakistani context, this means co-developing AI systems with clinicians, patients, and ethicists to ensure they

reflect local values and safeguard professional autonomy.

Moreover, the study underscores a pivotal insight: AI’s impact is role-dependent. Nurses derived greater workflow and diagnostic benefits from current AI tools than allied health professionals, whose complex, specialty-specific tasks, such as interpreting nuanced lab results or radiographic anomalies, remain underserved by generic algorithms. This disparity highlights the need for participatory design that engages diverse frontline roles from the outset. As Kleib et al. (2021) dispute nursing and allied health perspectives have been historically marginalized in AI development; reversing this trend is essential for building tools that are not only intelligent but also clinically meaningful and socially just.

In conclusion, AI-augmented CDSS can be a powerful catalyst for strengthening Pakistan’s overburdened health system, but only if implementation is grounded in local context, ethical integrity, and human-centered design. The path forward requires coordinated action: policymakers must prioritize digital infrastructure and regulatory frameworks; educators must integrate AI literacy into nursing and allied health curricula; and developers must partner with frontline workers to co-create contextually appropriate solutions. As Reddy et al. (2020) remind us, “The goal of AI in healthcare is not to replace clinicians, but to restore time, reduce error, and refocus care on the patient.” In Pakistan, where human resources are scarce but dedication is abundant, AI, when wisely deployed, can help nurses and allied health professionals do more of what they do best: deliver compassionate, competent, and timely care.

Future Recommendation:

Based on empirical findings and contextual analysis of AI-augmented Clinical Decision Support Systems (AI-CDSS) within Pakistan’s nursing and allied health landscape, a set of integrated, evidence-based recommendations is proposed to ensure ethical, sustainable, and equitable AI integration. First, AI tools must be deliberately designed for Pakistan’s infrastructural constraints, prioritizing mobile-first, lightweight

applications that function reliably offline or on low-bandwidth networks while minimizing data entry burdens. Seamless integration with existing national platforms, such as the Sehat Sahulat Program or District Health Information Systems (DHIS), can enhance interoperability, and a modular design should allow health facilities to activate only the features aligned with their technical capacity, such as triage support, without requiring full electronic health record (EHR) implementation.

Second, Pakistan urgently requires a robust national regulatory and ethical framework for health AI. This includes enacting legally binding data protection legislation and developing AI-specific health guidelines aligned with the World Health Organization's 2021 Ethics Guidance. A multi-stakeholder National AI in Health Ethics Board—comprising nurses, allied health professionals, physicians, data scientists, ethicists, and patient representatives—should be established to oversee algorithm validation, conduct regular bias audits, and manage incident reporting. Clear accountability protocols must affirm that clinicians retain ultimate decision-making authority, especially when AI recommendations contribute to adverse outcomes.

Third, workforce readiness must be strengthened through comprehensive AI literacy initiatives. AI and digital health competencies should be embedded into undergraduate and postgraduate curricula across nursing, medical laboratory technology, physiotherapy, and radiography programs. Continuing professional development (CPD) modules—delivered via accessible mobile learning platforms—can train frontline workers to interpret AI outputs critically, recognize limitations, and navigate ethical dilemmas. Critically, nurses and allied health staff must be included in co-design workshops during the development and testing phases of AI tools to ensure clinical relevance, usability, and trust (Kleib et al., 2021).

Fourth, future efforts should shift from physician-centric models toward role-specific AI solutions tailored to the distinct workflows of different frontline professionals. For nurses, real-time early warning systems for sepsis or obstetric

complications could significantly improve outcomes; for radiographers, explainable AI with visual heatmaps could enhance fracture or tuberculosis detection; and for laboratory technologists, AI-guided test ordering and anomaly flagging could reduce waste and errors. Successful pilots should be scaled through strategic public-private partnerships with local health-tech innovators—such as Sehat Kahani and Doctory—and supported by international agencies like WHO and UNICEF, using a phased rollout that begins in urban tertiary centers and gradually adapts for rural and resource-limited settings.

Finally, sustainable AI adoption depends on parallel investment in foundational digital health infrastructure. Federal and provincial governments must prioritize standardizing clinical terminologies (e.g., ICD-11, SNOMED CT) across public facilities, deploying secure yet locally hosted data repositories with explicit patient consent mechanisms, and guaranteeing universal access to reliable electricity and internet connectivity in all public health facilities—treating digital infrastructure not as an optional enhancement but as a core public health utility. Together, these recommendations advocate for a human-centered, systems-aware approach that positions nurses and allied health professionals not as passive recipients of technology, but as active co-creators and stewards of AI-enabled care. By holistically addressing technological, practical, and ethical dimensions, Pakistan can harness AI as a catalyst for a more resilient, responsive, and equitable healthcare system.

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