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TECHNICIANS 4.0: ROLE OF PHARMACY TECHNICIANS IN SMART HOSPITALS IN PAKISTAN

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Abstract

Introduction: *Pakistan's evolving healthcare infrastructure makes the integration of smart technologies in hospital pharmacies both an opportunity and a challenge for the pharmacy workforce.*

Aims and objectives: *To review the dynamic role of pharmacy technicians within smart hospital settings in Pakistan and to present a conceptual framework, Pharmacy Technician 4.0*

Methodology: A cross-sectional survey was done quantitatively on pharmacy technicians in five governments, privately operated non-profit tertiary hospitals in Karachi, Pakistan. Descriptive statistics and Chi-square tests were used to analyze data based on 150 respondents and the statistical significance was set at $p < 0.05$.

Results: *The degree of automation was found to differ among the hospitals, with some having simple manual systems in place and others having partially automated dispensing and inventory management systems. Technicians in the partially automated hospitals showed a decrease in dispensing time (12 to 7 minutes per prescription), a decrease in medication errors (8–3%), and an improvement in patient adherence (65% to 78%). Mean scores demonstrated a moderately positive attitude towards automation, with the highest agreement that AI and robotics positively impact technician roles (mean = 3.81 ± 1.28). The Chi-square test showed a significant difference in the distribution of responses ($\chi^2 = 282.7$, $p < 0.0001$), which indicated overall acceptance of sophisticated technologies.*

Conclusion: *Pharmacy technicians in Pakistan are showing willingness to be transformed to a Technician 4.0 figure in smart hospital systems.*

1. INTRODUCTION

The Fourth Industrial Revolution, also known as Industry 4.0, is characterized by the integration of automation, robotics, artificial intelligence, and the Internet of Things (IoT) across various industries[1, 2]. Healthcare is undergoing a transformation as a result of smart hospitals, where interconnected systems improve safety, precision, and patient outcomes. During this transformation, the pharmacy technician role is now shifting from manual dispensing to technology-driven responsibilities that include robotic systems, automated dispensing cabinets,

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and AI-based medication management platforms[3].

Hospital pharmacy services in Pakistan are predominantly manual. There is limited incorporation of automation technologies; therefore, medication shortages and errors continue to exist[4]. Automation adoption is growing in wealthy nations, but its use is limited in developing countries like Pakistan, and the preparedness of technicians to work with these technologies is still not well understood.

A digitally skilled pharmacy technician 4.0 is someone who can bridge the gap between professional expertise and machine-based precision[5]. Technicians operating these systems oversee smart dispensing systems, provide telepharmacy assistance, data accuracy, and help contribute to medication safety analytics[6]. This research develops the concept of *Technician 4.0* and investigates its applicability to Pakistan's developing hospital pharmacy framework.

A research gap exists, as automated systems in hospital pharmacies, including robotic dispensing and intelligent inventory management, have been associated with decreased medication errors, improved workflow productivity, and maximized resource utilization [7]

Research in well-established healthcare systems shows that automation enables pharmacy technicians to concentrate on patient-centered and technical support tasks rather than repetitive manual duties [8, 9]

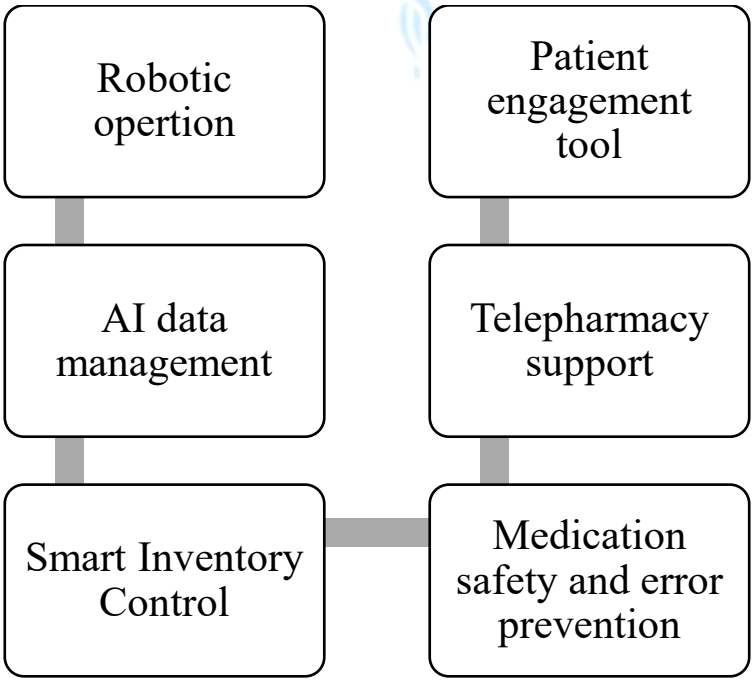
Globally, the pharmacy workforce is shifting from Technician 4.0 model that incorporates AI-enabled automation[10]. Countries such as Japan, Singapore, and the United States are at the forefront of adopting hospital robotics and intelligent dispensing systems[11] . Automation integration in Pakistan and South Asia is progressing slowly due to difficulties with infrastructure and staff training.

The challenges **arise from adapting** these global developments to LMIC settings—namely, how technicians can transition from manual dispensers to digital mediators within smart hospital environments

Pharmacy Technician 4.0: Conceptual Framework Model

Building on the principles **Industry 4.0**, the *Technician 4.0 framework* conceptualizes pharmacy technicians as hybrid professionals integrating automation, analytics, and patient interaction.

Core pillars of Technician 4.0



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Pharmacy technicians are increasingly taking on technology-based responsibilities. These include the management of robotic dispensing cabinets and automated compounding machines, as well as data management through electronic medication management systems. Technicians also oversee smart inventory control via IoT-enabled systems that provide real-time drug stock monitoring. Additionally, they support telepharmacy services by assisting patients with remote consultations and medication advice. Technicians are responsible for monitoring digital patient engagement tools such as medication adherence systems and smart pill dispensers, and for ensuring that AI-generated safety alerts are acted upon to maintain medication accuracy and prevent errors. This model emphasizes collaboration between humans and machines rather than substitution, recognizing technicians as vital team players in the delivery of accurate, patient-centered care.

Study aim and objectives

The aim of this study was to examine how pharmacy technicians in Pakistan can succeed in smart hospitals by working effectively with modern automated systems. The research highlights their changing role in a technology-driven healthcare environment, the influence of automated dispensing and robotics on daily responsibilities, and the new opportunities emerging in digital health and patient-focused medication services. A practical framework, "Pharmacy Technician 4.0," is proposed to guide future training and professional development.

Methodology

Study Design

A cross-sectional survey was administered to pharmacy technicians at selected government and private tertiary hospitals, including private non-profit hospitals in Karachi, Pakistan. The questionnaire assessed demographic data, level of experience, exposure to automation, perceived skill development, workflow productivity, and patient safety outcomes. The researchers evaluated exposure to automated dispensing systems, AI-based tools, workflow modifications, and perceptions toward the new Technician 4.0 model. One hundred and fifty (150) pharmacy technicians were contacted and consented to take part in the survey. This was found to be a sufficient sample size for descriptive and comparative quantitative analysis. The hospitals were chosen based on the presence or partial presence of automation in the form of automated dispensing cabinets (ADCs), barcode systems, or digital inventory tools.

Study Population

The target population included pharmacy technicians working in hospital pharmacy departments, particularly those involved in dispensing, inventory control, patient counseling, and electronic medication management.

Sampling Method

A purposive sampling technique was used to recruit participants. Five hospitals were included to ensure representation of varying automation levels within the city.

Inclusion and Exclusion Criteria

Inclusion criteria included: registered pharmacy technicians employed in hospital pharmacies, non-registered pharmacy technicians with a minimum of 6 months of work experience, those with direct involvement in dispensing, inventory management, and patient counselling, and those willing to provide informed consent. The exclusion criteria include Pharmacy students or interns, Technicians with less than 6 months of experience, Personnel not directly involved in medication management, Individuals unwilling to participate

Data Collection Tool

Data were collected using a structured self-administered questionnaire designed specifically for this study. Most questions were assessed on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The instrument included 25 items divided into five sections:

1. Demographic profile

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2. Exposure to automation and digital tools
3. Skill adaptation and training needs
4. Workflow efficiency and safety outcomes
5. Perceptions toward AI, robotics, and Technician 4.0 roles

Validity and Reliability

The questionnaire was reviewed by three subject experts (hospital pharmacists and academic faculty) to ensure content validity. Pilot testing was performed with 15 technicians, and internal consistency was established with a Cronbach's alpha of 0.82, indicating good reliability.

Data Collection Procedure

Data were collected through in-person distribution of questionnaires during duty hours, with permission obtained from hospital administration. Participants were given sufficient time to complete the survey, and forms were collected anonymously.

Data Analysis

Data were entered and analyzed using Graph pad prism (version 8). Likert-scale responses were summarized using frequency distributions, and non-parametric tests (Chi-square goodness-of-fit) were applied to assess response patterns. A p-value of < 0.05 was considered statistically significant.

Ethical Considerations:

Ethical approval for this cross-sectional anonymous survey study was obtained retrospectively from the Institutional Review Board (IRB) of Ziauddin University, Karachi, Pakistan (Approval No:ZU-FoPPS/ERC-2025/018). The study involved voluntary participation of pharmacy technicians. Written informed consent was obtained from all participants prior to data collection. No patient data were collected, and anonymity and confidentiality were strictly maintained throughout the study.

Results

Karachi had five hospitals representing the government, private, and private non-profit sectors of healthcare. Hospitals were coded and anonymized to guarantee confidentiality. Table 1 presents an overview of institutional variables, size of workforce and level of automation of pharmacy technicians. The sizes of the pharmacy staff varied in the range of 4 to 22 with more staffing found in the non-profit-making privately operated hospitals. The extent of automation ranged between basic systems that were used in government hospitals and partially automated systems that were used in the private and non-profit hospitals. All the hospitals had pharmacy technicians, whose activity was associated with dispensing, stock management, and patient counseling, whereas automation-based tasks were documented only in those hospitals that were partly automated. Figure 1 also demonstrates these findings.

Table 1: Summary of Participating Hospitals and Pharmacy Technician Distribution

Hospital Name	Location	No. of Pharmacy Technicians	Type of Hospital	Automation Level	Use of AI / Robotics	Services Involving Technicians
Hospital G	Karachi	6	Government	Basic	No	Dispensing, inventory control, patient counseling
Hospital P1	Karachi	8	Private	Partial Automation	Yes	Dispensing, patient counseling

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Hospital P2	Karachi	15	Private	Partial Automation	Yes	Dispensing, inventory control, patient counseling
Hospital N1	Karachi	22	Private Non-Profit	Partial Automation	Yes	Dispensing, inventory control, patient counseling
Hospital N2	Karachi	04	Private Non-Profit	Partial Automation	Yes	Dispensing, inventory control, patient counseling

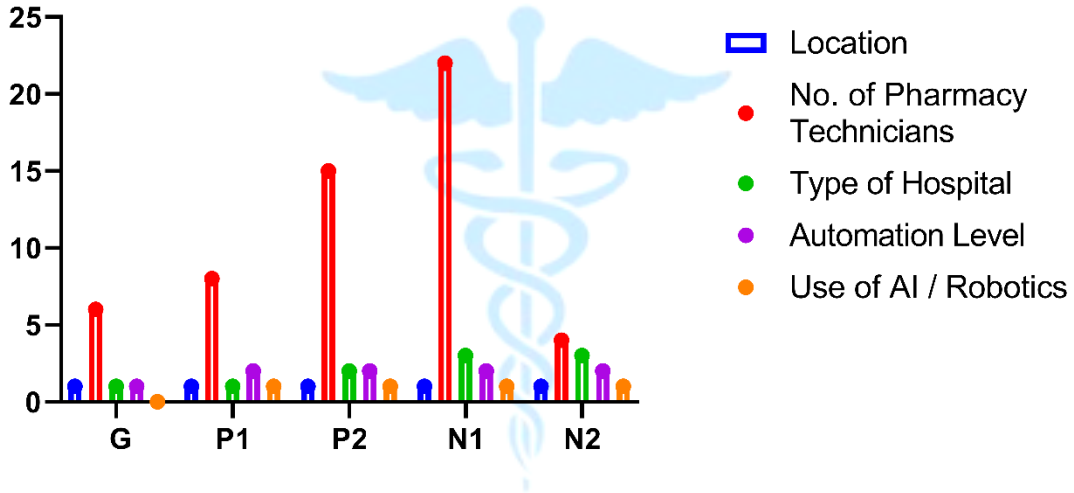

Figure 1: Overview of key operational parameters across hospitals in Karachi, Pakistan

Transition of Technician Responsibilities Before and After Automation

Automation significantly changed the nature of technician responsibilities (Table 2). The data illustrate a clear trend: as automation shifted from manual to partially automated systems Table 4, dispensing time decreased, error rates dropped, and both technician satisfaction and patient adherence improved.

Table 2: Comparison of Technician Tasks Before and After Automation

Indicator	Manual system	Partial Automation system
Average Dispensing Time (per prescription)	12 min	7 min
Medication Error Rate	8 %	3 %
Technician Job Satisfaction Score (out of 10)	6	7.5

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Patient Adherence (Self-reported %)	65%	78%

Quantitative Outcomes Across Different Automation Levels

Comparative Workflow Outcomes of Pharmacy Technicians Before and After Automation Implementation in Hospital Settings.

Table 3. Key Quantitative Outcomes by Automation Level

Technician Task	**Manual (Before Automation)**	**Automated (After Automation)**
Medication Dispensing	Manual work flow	Managed via barcode verification
Inventory Management	Physical stock-taking	IoT-linked real-time tracking
Record Keeping	Paper-worked logs	Integrated Electronic Health Records (EHR)
Quality Assurance	Pharmacist-led	Technician-AI collaboration via error detection system
Patient Support	Minimal	Enhanced via telepharmacy and adherence apps
Error Rate (%)	10-12%	<3-4%

**Error rate ranges are indicative of general automation trends; study-specific figures are reported in Table 2.*

Automation allowed technicians to focus on data interpretation, telepharmacy, and AI alert management, resulting in reduced error rates and enhanced workflow efficiency.

Pharmacy Technicians' Perceptions of Automation: Frequency distributions of 5-point Likert-scale responses indicated an overall positive perception toward automation and Technician 4.0 roles from 150 pharmacy technicians across hospitals with varying levels of automation. Items measured on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree) as shown in Table 4 and Figure 2.

Table 4: Pharmacy Technicians' Perceptions of Automation (Survey Responses, n = 150)

Item / Perception Statement	Mean Score	**SD**
AI and robotics positively transform pharmacy technician roles	3.81	1.28
Technicians should evolve toward Technician 4.0 competencies	2.74	1.47
Confident in working with AI-supported systems	3.13	1.39
Automation enhances job satisfaction rather than replacing jobs	2.66	1.17
Support integration of AI and robotics into hospital pharmacy settings	3.07	1.42

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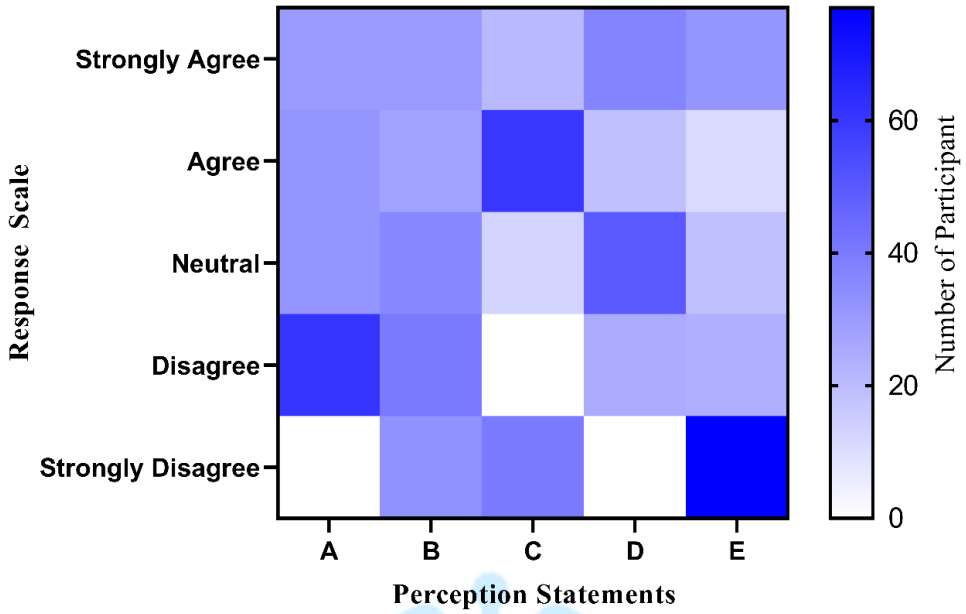

Figure 2: **Pharmacy Technicians' Perceptions of Automation**

Pharmacy technicians demonstrated moderately positive perceptions of automation overall. The highest agreement was recorded for the statement that AI and robotics positively impact technician roles (mean = 3.81 ± 1.28). Moderate confidence in working with AI-supported systems was also noted (mean = 3.13 ± 1.39). However, perceptions of job satisfaction and readiness for Technician 4.0 competencies were more variable across hospitals. Since the Likert scale is ordinal, a Chi-square goodness-of-fit test was performed on each item to assess whether the distribution of responses differed significantly from equal proportions. The Chi-square test indicated a statistically significant deviation in response distributions ($\chi^2 = 282.7$, df = 16, $p < 0.0001$), suggesting that most pharmacy technicians responded positively or strongly to perception statements regarding AI, robotics, and Technician 4.0 competencies. These findings indicate a positive perception and acceptance of advanced technologies in hospital pharmacy settings.

Discussion

As smart hospitals expand their digital health infrastructure, pharmacy technicians trained in robotics, automation, and AI systems will become indispensable. The transition to Pharmacy Technician 4.0 is a necessary evolution in Pakistan's healthcare setting. The global literature confirms that automation increases efficiency and safety while redefining technician competencies as manual dispensing systems shift to digital management systems[12]. But in Pakistan, the obstacles like inadequate training initiatives, high cost of implementation, and unavailability of regulatory frameworks are impeding this transition. Deploying formalized digital training modules and revising the pharmacy technician curriculum in academia, hospital systems, and technology providers can hasten this change. Finally, Technician 4.0 is a concept that combines human empathy with digital precision, where automation supplements human professional judgment but does not replace it[13].

Medication dispensing has transitioned from manual drug counting to automated dispensing cabinets (ADCs) and barcode verification systems, which assist in enhancing accuracy and reducing errors[14]. To improve medication availability, inventory management has evolved

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from traditional physical stock-taking to real-time monitoring systems through IoT[15]. The use of paper-based logs has been replaced by the Electronic Health Record (EHR) integrated with record-keeping [16]. When it comes to quality assurance, AI-generated warnings and automated systems designed to detect mistakes have been implemented [17]. Moreover, patient interaction and follow-ups have improved with the incorporation of telepharmacy services and mobile medication-adherence applications [18]. The highest level of agreement was expressed by technicians regarding the perception that AI and robotics can transform pharmacy technician roles in a positive manner. This aligns with the literature from developed healthcare systems, where automation has been shown to reduce manual workload and allow technicians to focus on more valuable technical and patient-support tasks[19]. These findings have also been documented in automated dispensing settings, where technicians are involved in medication verification, inventory analytics, and safety monitoring rather than routine manual tasks.

The scores of overall perception indicated that Technician 4.0 responsibilities were well accepted. Technicians in partially automated hospitals reported participating in various systems, such as controlling barcode systems, AI-generated safety alerts, and supportive telepharmacy systems. Technicians in automated settings felt that AI tools served as helpful features that alleviated cognitive load, particularly during peak periods. The results are consistent with the previously documented increase in medication safety and workflow efficiency related to automated dispensing systems because additional improvements toward a Technician 4.0 model can bring extra benefits[20].

In practical terms, the results highlight the necessity of targeted digital training, updates to the pharmacy technician education curriculum, and institutional policies that reflect the expanded role of technicians in an official capacity. Skill development and gradual implementation of automation could enhance acceptance, confidence, and effectiveness of the Technician 4.0 role in Pakistan. The evidence suggests that through automation, pharmacy technicians can transition from manual and repetitive duties to more sophisticated, technology-driven, and meaningful activities, including: data interpretation, AI-assisted medication checking, telepharmacy support, digital patient communication, and smart inventory monitoring. More than 70% of respondents affirmed that automation expanded their professional scope and improved confidence in technical activities.

Conclusion

Pharmacy Technician 4.0 represents the future of pharmacy support practice. A workforce that is well-trained and skilled in automation, robotics, and AI-driven systems within smart hospitals. This paradigm shift emphasizes the enhancement of medication safety, reduced errors, and improved patient outcomes through synergistic collaboration between the human intelligence and modern technology. For Pakistan, investing in technician training, digital infrastructure, and policy frameworks is quite essential to realizing the promise of a truly smart healthcare ecosystem.

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