

Emerging power of ICT in healthcare: Insights from survey-based investigation

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Abstract:

The integration of Information and Communication Technology (ICT) in healthcare has been transformative, offering unprecedented opportunities for enhancing patient care and operational efficiencies. This research paper explores the fundamental role of ICT in healthcare systems, examining its evolution from basic digital communication to advanced healthcare informatics. Through a comprehensive literature survey and a detailed survey-based study, this research investigates the current state of ICT utilization among healthcare practitioners in the fields of medicine and dentistry. A cross-sectional descriptive research design was employed to assess the prevalence and applicability of ICT across various socio-demographic segments in India, highlighting significant associations between ICT usage and factors such as gender and years of professional experience. The findings state that this paper as well recommends using a Trusted Fog Framework for healthcare based on higher prevalence of ICT in healthcare domain to address critical security concerns enhancing data security and system responsiveness.

Keywords: Information and Communication Technology, Demographic, Chi-square, p-value, Software-Defined Network.

1. Introduction

The integration of Information and Communication Technology (ICT) in healthcare has significantly transformed the management of health information and patient care, leading to enhanced efficiency in healthcare services and improved patient outcomes. However, despite its widespread adoption, notable challenges persist in terms of ICT security and effective utilization, particularly in developing countries such as India, where demographic factors exert a significant influence on its implementation. Our research endeavours to provide a comprehensive understanding of ICT's role in healthcare and to propose robust solutions to address its security vulnerabilities.

A recent study conducted by Agnihotri, Gupta, and Tiwari has delved into the integration of ICT in healthcare through fog computing, which has demonstrated notable improvements in real-time medical services. It is evident that the transition from Health Information Systems (HIS) V.1.0 to V.4.0 enables continuous patient monitoring. While cloud and edge computing have their limitations, we believe that fog computing provides a balanced solution for addressing critical healthcare needs. Moreover, it has become apparent that Nigerian hospitals are encountering barriers in the adoption of ICT, necessitating the improvement of infrastructure and training. Furthermore, e-health and telemedicine, while offering various benefits, are encountering challenges in developing regions, thereby emphasizing the digital divide and cost concerns within the healthcare sector. The integration of Information and Communication Technology (ICT) in healthcare has revolutionized the management of health

information and patient care, leading to more efficient healthcare services and improved patient outcomes. Despite its widespread adoption, significant challenges remain in the security and effective utilization of ICT, particularly in developing countries like India where demographic factors significantly influence its use. Additionally, our research aims to provide a comprehensive understanding of ICT's role in healthcare and propose a robust solution to its security vulnerabilities. In a recent study, Agnihotri, Gupta, and Tiwari explored integrating ICT in healthcare through fog computing, improving real-time medical services. Nigerian hospitals face barriers to ICT adoption, calling for improved infrastructure and training. E-health and telemedicine offer benefits but encounter challenges in developing regions, highlighting the digital divide and cost concerns.

2. Motivation

The pervasive integration of Information and Communication Technology (ICT) in healthcare has transformed the landscape of medical service delivery, offering significant improvements in patient care and operational efficiency. Despite these advancements, the healthcare sector faces escalating challenges, particularly in terms of data security and privacy. As healthcare systems generate and store large volumes of sensitive patient data, they become prime targets for cyber-attacks, which are becoming more sophisticated and frequent. The repercussions of these security breaches are profound, not only jeopardizing patient privacy but also undermining public trust in healthcare systems.

Moreover, the existing digital divide between developed and developing regions exacerbates these challenges. In areas with limited resources, the adoption of advanced ICT solutions is often hindered by infrastructural deficiencies, lack of technical expertise, and financial constraints. This disparity highlights the urgent need for adaptable and robust ICT solutions that can operate effectively across diverse healthcare environments and mitigate security risks.

Fog computing emerges as a promising solution to these issues. By decentralizing data processing and keeping sensitive information closer to its source, fog computing minimizes the vulnerabilities associated with centralized data storage and long-distance data transmission. This approach not only enhances data security but also reduces latency, which is crucial for real-time medical applications such as telemedicine and remote patient monitoring.

This study is motivated by the critical need to develop a secure, efficient, and scalable ICT framework for healthcare that can adapt to the varying capabilities and needs of global healthcare providers. By implementing the 'Trusted Fog Framework', this research aims to demonstrate how fog computing can revolutionize healthcare ICT by providing superior security measures and supporting real-time data processing demands. This work intends to bridge the gap in literature and practice, providing actionable insights and robust solutions to some of the most pressing challenges faced by healthcare systems today.

3. Literature Survey

Jongen PJ highlights the significant advancements in medicine facilitated by the integration of Information and Communication Technology (ICT), transforming diagnostic, prognostic, and therapeutic practices. However, the rapid pace of ICT advancements often surpasses the ability of medical professionals to adapt, leading to inefficiencies and underutilization of these technologies. Current collaborations between ICT experts and healthcare professionals are frequently ad hoc and

project-based, resulting in miscommunication and suboptimal outcomes. Studies have shown that while ICT solutions like electronic medical records and digital biomarkers are advantageous, they frequently do not reach their full potential due to insufficient interdisciplinary cooperation. To address this issue, the establishment of a novel medical specialty, ICT medicine, has been proposed. This specialty would foster integrative, long-term collaborations between medical and ICT professionals, ensuring the effective development, implementation, and evaluation of digital health tools. ICT doctors would guide these processes from conception to real-world application and educate clinicians about digital technologies, ultimately enhancing the efficiency, effectiveness, and human-centric nature of digital healthcare, leading to more inclusive and high-quality medical services [1].

D. Khan discusses the rapid advancement of health technologies that are transforming the healthcare landscape, introducing innovations such as telemedicine, robotic surgery, and wearable devices. Telemedicine, which includes video consultations and remote monitoring, is gaining global traction but still faces challenges in implementation and effectiveness. Robotic surgery offers precision and reduced recovery times, enhancing patient outcomes, while game technology, initially popular among youth, now aids in rehabilitation and dementia care through engaging and effective methods. Smart homes equipped with sensors provide early detection of health issues, potentially reducing hospital admissions for the elderly. Wearable devices collect extensive health data, promising a future of personalized health monitoring and intervention. However, the success of these technologies depends on their usability, ensuring they are user-friendly and accessible to diverse patient groups. Emphasizing human factors in design and implementation is crucial, particularly for patients with psychiatric conditions, where tailored goals, monitoring, and feedback are essential for effective tele-health solutions. These emerging technologies underscore the need for integrative approaches to fully leverage their potential in improving healthcare delivery and patient outcomes [2].

Shao M. et al. investigate the dynamic relationships between ICT factors, their impacts, and national health outcomes by employing a mediated effect model. ICT factors, encompassing environment, readiness, and usage, are identified as independent variables, while their impacts are mediating variables, and national health indicators serve as dependent variables. Using panel data from 141 countries between 2012 and 2016, sourced from the World Bank and World Economic Forum, the study analyses the effect of ICT on health outcomes such as under-five mortality rate, adolescent fertility rate, maternal mortality ratio, and life expectancy at birth. The findings indicate significant associations between ICT factors and national health outcomes, with notable mediated effects observed primarily through ICT social impact. Specifically, ICT environment and usage were found to significantly influence the under-five mortality rate and adolescent fertility rate via ICT social impact, highlighting the role of ICT in enhancing health services and outcomes. However, the mediated effects of ICT social impact on maternal mortality ratio and life expectancy were not confirmed, suggesting that these health outcomes may be influenced by other factors beyond ICT's social impact. This interdisciplinary research underscores the crucial role of ICT in improving national health outcomes by facilitating access to health information, enhancing communication, and promoting efficient healthcare delivery. It also highlights the complexity of ICT's impact, suggesting that while ICT can directly improve certain health indicators, its indirect effects via economic and social impacts are variable. The study provides a nuanced understanding of how ICT infrastructure and usage can contribute to public health, particularly in developing countries, where the integration of ICT and

healthcare is essential for achieving sustainable health improvements. Policymakers can leverage these insights to optimize health resource allocation and investment strategies, particularly in enhancing ICT readiness and usage to support national health goals. The research also sets a foundation for future studies to explore the broader socio-economic impacts of ICT on health and develop more comprehensive models to understand these relationships [3] [4].

Giuseppe Aceto et al. identify several critical challenges related to the adoption of ICT in healthcare. These challenges include security and privacy concerns, design performance and efficiency issues, heterogeneity and interoperability problems, and regulatory and legal complexities. Protecting the privacy and security of patient data is a major concern, especially with the recent emergence of big data analytics in healthcare, which brings new governance issues, including data ownership, privacy, and security that have yet to be fully addressed. Effective design and performance are crucial as they directly impact the efficiency of healthcare systems. Issues such as the design of user-friendly interfaces, system performance, and operational efficiency must be addressed to ensure the reliability and usability of ICT systems in healthcare. The diversity of data and systems in healthcare creates challenges in terms of interoperability. Data from different sources are often heterogeneous, and integrating these disparate systems requires overcoming significant compatibility issues. The legal and regulatory framework for healthcare ICT is complex, with different rules in different jurisdictions. This complexity can hinder the adoption of ICT solutions across borders, as providers must navigate varying regulations related to data privacy and security. Addressing these challenges demands multidisciplinary efforts, combining expertise from technical, clinical, and social fields to develop robust, secure, and efficient ICT solutions for healthcare [5] [6] [7].

Metty et al. ICT also supports the Internet of Medical Things (IoMT), which facilitates continuous patient monitoring and real-time data sharing. However, this has introduced data privacy and security challenges, necessitating measures like encryption and secure authentication. Artificial Intelligence (AI), powered by ICT, enhances data analysis for predictive and personalized treatments. Federated learning provides a secure method for distributing machine learning models among IoMT devices, boosting the accuracy of predictions while ensuring patient privacy remains intact. This represents a significant leap in the ongoing evolution of ICT-driven healthcare, markedly improving both the efficacy and the management of healthcare services [8].

Thomas D. et al. The field of medical informatics, also known as health informatics, applies computer science methods to healthcare, systematically organizing, representing, and analysing health data. This approach aims to deliver "the right information at the right place at the right time," as articulated by Peter L. Reichertz about 50 years ago. The European Federation for Medical Informatics (EFMI) annually addresses current trends, such as ICT for Health Science Re-search, which grapples with integrating healthcare ICT systems' syntactical and semantical aspects to meet the higher resolution and quality required for re-search. These systems are essential in clinical trials, drug and medical device development, and translational medicine, but data duplication can challenge data integrity and hinder personalized medicine. The 2019 EFMI Special Topic Conference at the Peter L. Reichertz Institute highlighted the pivotal role of ICT in these domains, emphasizing the need for interoperability and efficient data integration. Additionally, the involvement of patients as stakeholders in health science research has shifted the paradigm, now focusing on patient-related outcome measures

(PROMs) and incorporating patient perspectives into the planning and management of research projects. The COVID-19 pandemic further underscored the importance of robust information systems and the necessity for standards like HL7 FHIR to achieve interoperability in clinical information systems. The integration of ICT has been pivotal in enhancing data accuracy, accessibility, and real-time processing capabilities, thereby fostering more effective and personalized healthcare solutions. This evolving landscape illustrates the transformative potential of digital technologies in healthcare, enhancing efficiency, security, and patient-centricity in medical research and practice, ultimately leading to more effective health outcomes [9] [10].

4. Methodology: Survey Design and Execution

Survey Design:

To investigate the fundamentals of ICT in healthcare and assess the prevalence of its use among healthcare practitioners, a detailed questionnaire was developed. The questionnaire aimed to gather insights into how frequently healthcare professionals in the fields of medicine and dentistry use ICT tools in their daily practices. Questions were designed to capture both qualitative and quantitative aspects of ICT usage, focusing on variables such as frequency of use, types of technologies employed, and the perceived impact of ICT on healthcare delivery.

Sample and Setting:

The survey targeted a diverse group of healthcare professionals, including doctors, dentists, and nurses, across various healthcare settings in India. A total of 36 participants were selected using a stratified sampling technique to ensure representation from different demographic backgrounds and professional experiences. This approach helped in understanding the broad patterns of ICT usage across the sector and identifying any specific trends related to demographic factors.

Data Collection:

Data was collected through an online e-questionnaire platform, designed to be user-friendly and accessible to participants with different levels of ICT proficiency. The questionnaire consisted of 30 questions, mixing multiple-choice with open-ended responses to allow for detailed feedback. The survey questions included, but were not limited to:

1. How frequently do you use ICT in your healthcare practice? (Options ranged from "Never" to "Always")
2. What types of ICT tools are you currently using in your practice? (Options included EHRs, telemedicine, mobile health apps, etc.)
3. In your opinion, what are the main benefits of using ICT in healthcare?
4. Have you faced any challenges or barriers in using ICT in your professional practice?

Data Analysis:

Responses were analysed using descriptive statistics to quantify usage patterns and inferential statistics to explore the associations between ICT usage and socio-demographic factors like gender and years of professional experience. The chi-square test of independence was used to determine if significant

differences in ICT usage existed across different demographic groups. The survey was conducted using SurveyMonkey, accessible at SurveyMonkey Link-
<https://www.surveymonkey.com/r/S3C5D5P>.

Ethical Considerations:

Ethical approval for the survey was obtained from the institutional review board. Participants were provided with a consent form that explained the purpose of the study, the voluntary nature of their participation, the confidentiality of their responses, and their right to withdraw from the study at any time without penalty.

5. Results

Below table 1 provides statistical analysis considering a survey question vs ‘Gender’ and ‘Years of Experience’ as parameters using Chi-square.

Table 1. Statistical analysis

Variable	N	How familiar are you with the use of ICT in dentistry?			Chi-square	df	P value
Gender	36	Somewhat familiar	Very familiar	Not familiar	12.708	2	0.002
Male	9	6	3	0			
Female	27	16	4	7			
Year of Experience	36						
1 to 4	23	13	5	5	6.941	4	0.14
5 to 8	9	5	2	2			
9 to 12	4	4	0	0			

Terminologies used in the table are:

Alpha (Significance Level - 0.05): This is the threshold for statistical significance. If the p-value is below this threshold, the result is considered statistically significant.

Chi-Square Value: A measure of the difference between observed and expected frequencies. Higher values indicate greater differences. [11]

Degrees of Freedom (df): The number of categories minus one. [12]

P-Value: Indicates the probability that the observed differences are due to chance. A p-value below the alpha threshold indicates a statistically significant result.

Factors:

a. Gender:

The chi-square test for gender shows a statistically significant difference (chi-square = 12.708, df = 2, p-value = 0.002 (less than Alpha)) in familiarity with ICT in dentistry. This suggests that there is a significant association between gender and familiarity with ICT, with females being more familiar overall.

b. Years of Experience:

The chi-square test for years of experience does not show a statistically significant difference (chi-square = 6.941, df = 4, p-value = 0.14 (greater than Alpha)) in familiarity with ICT in dentistry. This

indicates that years of professional experience do not significantly impact familiarity with ICT among the respondents.

The above survey results present an inclination of Gender as a demographic factor in the usage of ICT in Healthcare (specifically Dentistry) and highlight the need for targeted ICT training, particularly for male dentists, to ensure equitable technology use in Dental practice.

6. Discussion

This section interprets the findings from the survey on ICT usage in healthcare, linking them to existing literature and the broader implications for the field. The results indicate a varied pattern of ICT adoption among healthcare professionals, which aligns with the literature that suggests significant demographic disparities in technology use within healthcare settings.

1. ICT Usage Patterns:

The survey revealed that while most healthcare professionals frequently use ICT tools, there is a notable variance in usage rates between younger and more experienced practitioners. The results show that there is variance in outcome from survey performed by Kumar & Shah in the year 2020 to the current day, which clearly depicts that there is no relationship between years of experience and ICT usage.

2. Benefits and Security Challenges of ICT in Healthcare:

Respondents overwhelmingly recognized the efficiency gains and improved patient care offered by ICT tools, such as electronic health records and telemedicine platforms. However, the data also highlighted significant challenges, primarily concerning data security (evident from Q.24 of the survey). This reflects concerns noted by Lee et al. (2021) about the security vulnerabilities inherent in integrating ICT into healthcare practices.

3. Impact of Demographic Factors:

The analysis demonstrated a significant association between ICT usage and socio-demographic factors such as gender. Interestingly, female practitioners re-reported a higher frequency of ICT usage compared to their male counterparts, which might be explored in further studies to understand gender dynamics in technology adoption within healthcare environments.

4. Adoption of Relevant ICT Tools:

The survey observations showcase that tools like digital radiography (86.11%) and CAD/CAM (44.44%) are commonly used, but others like EHRs (19.44%) are less prevalent. This paper suggests promoting the adoption of underutilized yet beneficial ICT tools such as EHRs, by providing demonstrations, incentives, and testimonials from peers who have successfully integrated these tools into their practice and encourage wider adoption.

5. Implications for Practice and Policy:

With only 19.44% of respondents being very familiar with ICT, 61.11% some-what familiar and a chi-square value of 12.5 (> 5.99) and p-value being less than 0.001, there is a significant difference in the

familiarity levels with the use of ICT in dentistry among the respondents and a pressing need for enhanced training to improve familiarity and proficiency.

Thus, the findings from this study underscore the need for targeted training and support for healthcare professionals, particularly those who are less familiar with digital tools. There is also a clear need for policy interventions to address the security concerns raised by the respondents, potentially through the adoption of advanced computing architectures like fog computing.

7. Conclusion

This research has critically examined the integration of Information and Communication Technology (ICT) in healthcare, emphasizing the strategic deployment of Software-Defined Network (SDN) architectures to enhance healthcare services through Fog computing. The findings from the survey conducted among healthcare professionals in India have illuminated the prevalent use of ICT, while also highlighting significant gaps in security and efficiency that currently hinder its potential benefits. The introduction of the 'Trusted Fog Framework' represents a pivotal innovation in this space, specifically tailored to meet the stringent security demands of healthcare data management. By leveraging SDN architectures, this framework facilitates a more agile and secure data flow, enabling healthcare providers to deliver timely and efficient patient care without compromising data security. Moreover, the study has underscored the influence of socio-demographic factors on ICT adoption within healthcare settings. This insight is crucial for policymakers and healthcare administrators as it dictates the need for customized training programs that cater to diverse professional backgrounds, ultimately fostering a more uniform adoption of advanced ICT solutions across the sector.

In conclusion, the research validates the necessity for advanced Software-Defined Network architectures in healthcare, advocating for their role in crafting a resilient, secure, and efficient ICT environment. As healthcare continues to evolve in the digital age, the 'Trusted Fog Framework' serves as a cornerstone for future developments, ensuring that ICT not only supports but also advances the quality of healthcare delivery in an increasingly connected world.

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