

Industry 4.0 in Smart Hospital: A Scientometric Study

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Abstract

Background: Digital transformation through the use of technologies like blockchain, Artificial Intelligence (AI), and the Internet of Things (IoT) is the main focus of the 4th generation technology. In smart hospitals, the 4th generation technology boosts productivity while cutting expenses, permits monitoring and early diagnosis, and enhances the quality of medical services.

Objectives: This study was carried out with the intention of implementing the 4th generation technology tools in smart hospitals, given the current technological breakthroughs and the need for smart hospitals in Iran.

Methods: The current research is bibliometric in nature. All the papers published between 2000 and 2024 that had focused on the themes of smart hospitals and the 4th generation technologies which contained keywords like blockchain, AI, the IoT, and smart hospitals make up the study's population. Advanced searches in the citation ScienceDirect and PubMed databases were used to gather the data for this investigation. The citation network was visualized and examined using VOSviewer software.

Results: According to this survey, when it comes to the use of the 4th generation technology tools in smart hospitals, 40% of the articles mention improving patient care, 35% highlight operational efficiency, and 25% stress data driven decision making as important elements.

Conclusion: In addition to boosting patient safety, monitoring, early diagnosis, and the quality of medical services, the 4th generation technology tools are essential for converting a conventional hospital into a smart hospital and cutting expenses. These instruments are therefore crucial for enhancing patients' comfort and well-being in smart hospitals.

Keywords: Smart Hospital, Industry 4.0, Artificial Intelligence

1. Background

1.1. Industry 4.0

One of the primary forces behind the Fourth Industrial Revolution is Industry 4.0. Water and steam power marked the beginning of the first industrial revolution, which replaced manual labor with machine production. Electric power served as the foundation for mass production throughout the second industrial revolution. The third revolution automated production through the use of information technology and electronics. Smart automation is the foundation of the Fourth Industrial Revolution, and its use is crucial in the nowadays. The Internet of Things (IoT) links objects to one another, much like the Internet does by creating virtual relationships with humans. Intelligent products, machinery, networks, and systems that interact and work together autonomously throughout the production process with little assistance from humans are the foundation of Industry 4.0's smart production. Industry 4.0 describes the digital revolution of industries made possible by cutting edge technology like big data, AI, and the Internet of Things. Automation and smartization are two of the Industry 4.0's primary characteristics,¹ connectivity,² data analytics,³ and customized production.⁴ Businesses may better meet

market demands and become more competitive with the support of Industry 4.0. Industry 4.0 will have a significant and all-encompassing impact. With the help of global value chains, current manufacturing systems will become more adaptable, efficient, dynamic, and sustainable. They will also have a greater capacity for personalization and modification. The study's significance stems from the potential of Industry 4.0 technologies to enhance the standard of healthcare services, facilitate early diagnosis and monitoring, boost productivity, and lower expenses in smart hospitals. The use of Industry 4.0 tools in smart hospitals is the primary focus of this study. An initiative in Germany's High-Tech Strategy, which encourages the computerization of production, is where the term "Industry 4.0" first appeared. Specifically in areas like standardization and norms, security, legal frameworks, research, and workforce transformation, the German government created Industry 4.0 to assist small and medium sized German businesses in understanding and taking advantage of Industry 4.0 strategies and opportunities. Industry 4.0 is a comprehensive idea and a new trend in manufacturing (and associated industries) based on the integration of a range of technologies to decrease operational complexity and boost efficiency and effectiveness.

This makes it possible for integrated goods and services as well as ecosystems of intelligent, self-governing, and decentralized factories. When discussing upcoming technologies like the IoT, big data and data analytics, robotics, autonomous systems, and sensors, Industry 4.0 is frequently defined as digitalization or full

scale automation. Industry 4.0 was created by digitization, but because of convergence, it cannot be fully described from a technology standpoint alone. Organizational transformation through adjustments to business models, structure, and culture is also crucial. Industry 4.0 tools have been shown in Figure 1.

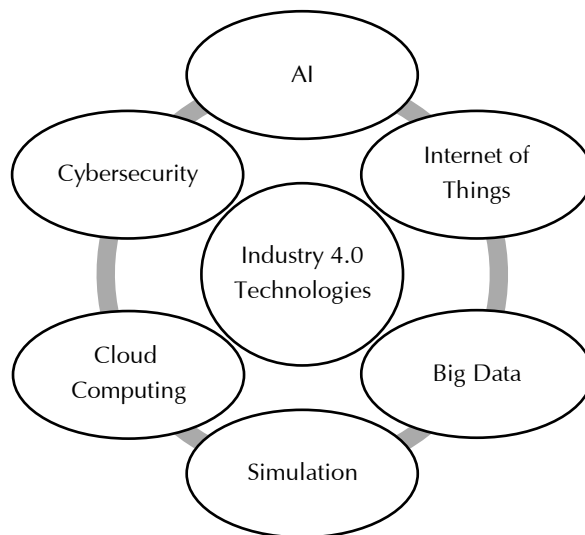


Figure 1. 4th Generation Technology Tools.⁵

Table 1. The Effects of the 4th Industrial Revolution on Various Industries

Industry	Positive effects	Negative effects	Ref
automobile manufacturing	Increasing the production of smart and connected cars	Need to develop new specialized skills	6
Health and treatment	Promote technology integration and improve care	Compatibility with new technologies	7
Energy production	Increasing efficiency in energy production	Negative environmental impacts	8
Education and research	Access to educational resources has become easier	Changing needs of the labor market and specializations	9
Financial and banking services	Simplifying financial and banking transactions	Competition from Fintech	10
Air and space industry	Increasing space exploration and satellite imaging	workforce	11

Despite starting with improved manufacturing, the Industry 4.0 eventually affects other industries, such as medical services and smart hospitals. In addition to developing information and communication technology infrastructure and structures, smart hospitals provide new information technology focused training and employment opportunities. Table 1 shows how the Fourth Industrial Revolution has affected different industries. In addition to highlighting the difficulties, this succinct analysis shows how notable advancements can be accomplished in specific areas.

1.2. Smart Hospital

Smart hospitals improve facility management and patient care by utilizing cutting edge technologies. To increase productivity and patient outcomes, these hospitals use technology including 5G networks, AI, and the IoT.¹² Key features of smart hospitals include:

- 1) Remote care: Using 5G and IoT, remote monitoring and treatment is possible.¹³
- 2) Medical data management: using AI to analyze

- medical data and improve diagnosis accuracy.¹⁴
- 3) Tracking and monitoring systems: using RFID and sensor networks to track and monitor patients.¹⁵
- 4) Location-based services: use of communication technologies to track and manage the location of patients and equipment.¹⁶

These technologies improve diagnostic accuracy while cutting down on treatment time and expenses.¹² Implementing state of the art technologies in all hospital departments, including radiology, intensive care units, operating rooms, emergency rooms, pharmacies, and other areas, is the aim of creating smart hospitals.¹⁷ By increasing efficiency, boosting care quality, streamlining current procedures, and raising patient happiness, smart hospitals have completely changed the way healthcare services are provided.¹⁸ Furthermore, it appears that overcoming these obstacles in the development of smart hospitals will require the use of new sciences, such as the Fourth Industrial Revolution technology.¹⁹ Despite the benefits of automating processes and using the Fourth Industrial Revolution technology, acceptance has been

extremely slow in a number of sectors, including healthcare.²⁰

But the truth is that technology is unavoidably maturing, and it is expected that the usage of new technologies in healthcare will increase in the near future.²¹ In addition to enhancing hospital service delivery and quality, smart hospitals can also be useful for delivering healthcare services in broader ecosystems, including smart cities.²² The Fourth Industrial Revolution technology is one of the ways that modern technologies and digital systems have affected many facets of our daily lives. One area that has seen notable progress as a result of the application of the Fourth Industrial Revolution technologies is healthcare.²³ Smart instruments, for

instance, are essential for diagnosing and treating a number of illnesses.²⁴ Thus, a new idea known as "smart hospitals" has emerged as a result of the development of such technologies as well as the knowledge, education, and attitudes of patients and medical personnel toward smart technology.²⁵ Remote control systems, Internet connected sensors, and other intelligent equipment are features of a smart hospital. Services including patient information registration and maintenance, patient request alerts, status monitoring, and more are offered by using this equipment for hospital automation. Due to the wide range of patient needs, these institutions provide a variety of services and specialties.²⁶ Figure 2 outlines the procedures for creating a smart hospital roadmap.

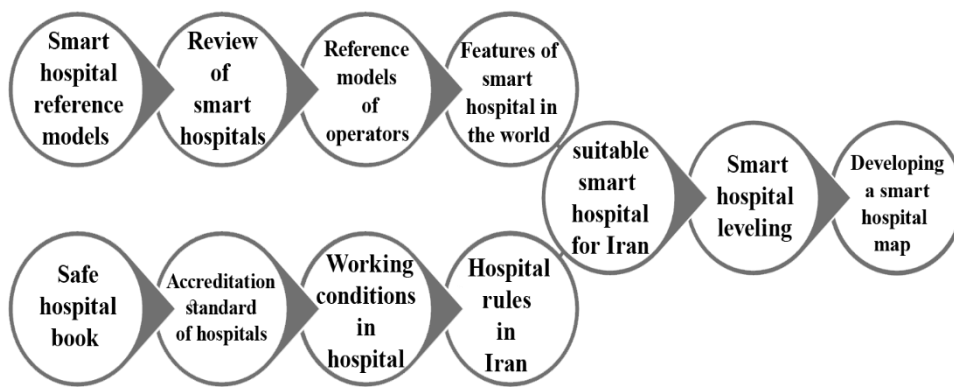


Figure 2. The Stages of Developing a Roadmap for a Smart Hospital.

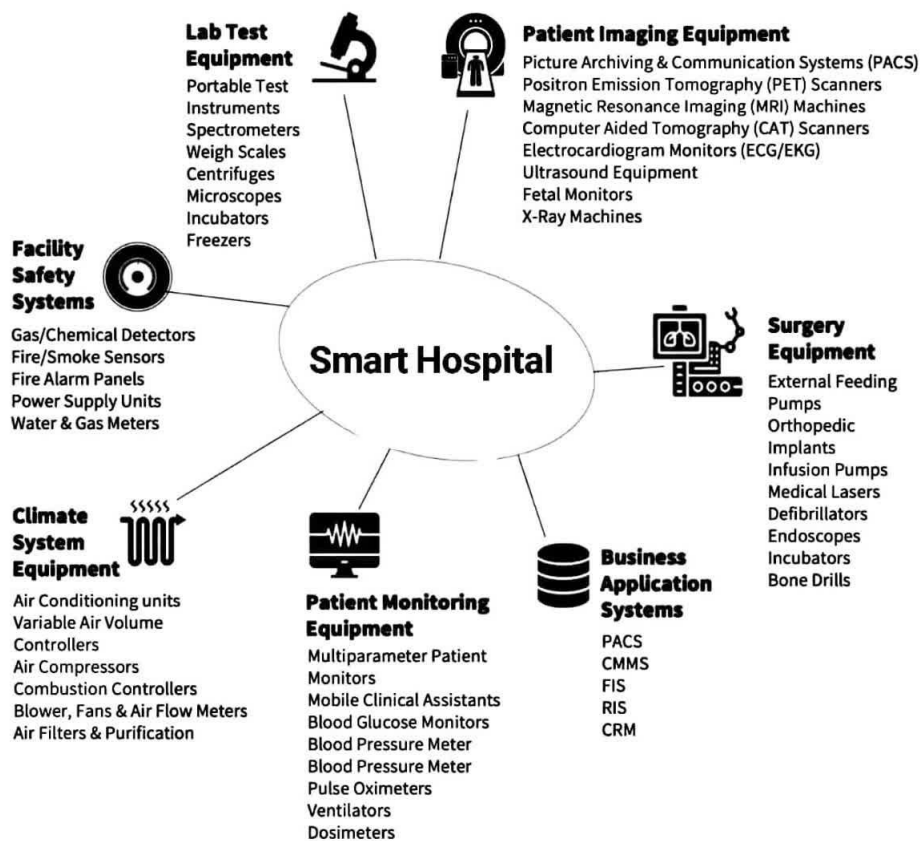


Figure 3. Smart Hospitals Vision.²⁷

Table 2. Existing Background related to the 4th Generation Technology Tools

N	The title of the article under study	Objective	Ref
1	Impact of IoT on Inventory Management	To explore how IoT technologies enhance inventory management in supply chains, identifying research gaps and potential opportunities in the Industry 4.0 era	28
2	Investigating the Impact of 4th-Generation (4G) Mobile Technologies on Student Academic Performance	This study examines how 4G mobile technologies affect university students' academic performance, focusing on improvements in mobility, internet quality, and communication among students	29
3	Built Environment Professionals' Perspective on Digital Technology Skills	This research investigates the adoption and utilization of 4th-generation digital technologies in the construction industry, particularly from the perspective of Black, Asian, and Minority Ethnic (BAME) professionals. It aims to identify barriers to technology adoption and provide recommendations for improvement	30
4	Development of 4th Generation ECR Ion Source	To present advancements in the FECR ion source, focusing on high power ECR plasma heating and intense beam production	31
5	Cybernetic Technologies in Industry 4.0	To analyze the role of cybernetic technologies, such as AI and smart automation, in transforming industrial practices and enhancing real-time monitoring	32
6	Understanding 6G Network Requirements	To outline the transition from 5G to 6G, focusing on the evolving requirements and performance indicators for future communication systems	33
7	RMS Delay Spread in 5G Indoor Channels	To study the propagation properties of microwaves in 5G networks, providing insights for network planners on bandwidth and delay spread	34
8	Condition-Based Maintenance Evolution	To assess the developments in maintenance strategies focusing on condition-based approaches to reduce equipment failure rates	35

Delays in collecting and processing patient data at traditional hospitals can have a negative impact on patients who are in critical condition. Smart hospitals steer clear of these issues by promoting intelligent and effective communication between doctors, patients, and equipment.

Hospital asset and equipment systems today remain a shabby assemblage of outdated architectures and technology that fail to handle the most fundamental issues with data integration, administration, and cooperation. Healthcare organizations' capacity to effectively and efficiently control costs and provide a smooth patient experience is being weakened by these issues. Users, equipment makers, and third party service providers won't be able to fully appreciate the value of their machine and operational data without sophisticated data management solutions. Figure 3 depicts the smart hospital's vision.

The realization of tomorrow's smart hospitals will depend more and more on data innovation and orchestration, which will open up new collaborative partnerships throughout the healthcare delivery system.

While several studies have looked at certain aspects

of 4G technology and smart hospitals, no study has taken a comprehensive approach to using 4G tools in a smart hospital, according to a thorough survey of previous research. Background information on the the 4th generation of technology tools is given in Table 2, followed by the smart hospital's context in Table 3 and the context of the smart hospital's use of the 4th generation technological tools in Table 4.

When smart technology is integrated into public health and healthcare systems, efficiency, accuracy, and patient happiness are greatly increased. By enabling improved communication between patients and doctors, these technologies like smart infusion pumps and mobile health applications improve healthcare delivery and lower human error. Smart infusion pumps, for instance, reduce medication errors, while mobile health apps improve users' quality of life and chronic illness management.⁴⁹ Furthermore, it has been demonstrated that the use of smart card technology in public health enhances patient outcomes and service delivery.⁵⁰ All things considered, the advancement of public health programs and the maintenance of an efficient healthcare system depend on the acceptance of these technologies.

Table 3. Background Related to Smart Hospital

N	The title of the article under study	Objective	Ref
1	BCGeo: Blockchain-Assisted Geospatial Web Service for Smart Healthcare System	To develop a decentralized blockchain-enabled geospatial service architecture for smart healthcare, enhancing patient prioritization and data privacy.	36
2	Role of AI, Big Data in Smart Healthcare System	To analyze the application of AI and big data analytics in improving healthcare systems and providing insights for better planning	37
3	Using Medical Data and Clustering Techniques for a Smart Healthcare System	To design a smart healthcare system that utilizes clustering techniques to analyze patient risks and trends for personalized services	38
4	Trends in Smart Healthcare Systems for Smart Cities Applications	To systematically study technological trends in smart healthcare systems, focusing on AI and big data contributions	39
5	IoT-Based Smart Healthcare System: A Review on Constituent Technologies	To provide a comprehensive review of IoT-based smart healthcare systems and their constituent technologies, addressing challenges and future research directions.	40
6	A Novel Medical Image Data Protection Scheme for Smart Healthcare System	To present a lightweight encryption scheme for medical images in smart healthcare systems, addressing security and latency issues.	41

Table 4. The Existing Background related to the Application of the 4th Generation Technology Tools in the Smart Hospital

N	The title of the article under study	Objective	Ref
1	5G-based smart healthcare network architecture and challenges	Architecture, classification, challenges and 5G-based smart healthcare network research paths	42
2	Comprehensive analysis of smart hospital technologies and their impact on patient care	A comprehensive analysis of the applications and impact of smart hospital technology in addressing the challenges of the Indian healthcare system is to focus on patient-centered care and reduce errors and operational efficiency	43
3	Network slicing for smart hospital applications	Using fifth generation networks in smart hospitals	44
4	Model for assessing smart hospital readiness within the Industry 4.0 paradigm	Explaining the smart components and providing a model to evaluate the readiness of the smart hospital	45
5	Quality of Service-driven edge computing in smart hospitals	Using the Internet of Things in improving the smart hospital	46
6	The role of AI and IoT in enhancing operational efficiency in smart hospitals	Investigating the potential impact and rationale of user participation and automation on pre-use attitude and behavioral intention towards information technology for workflows based on smart barcode scanners	47
7	The impact of telemedicine and remote monitoring in smart healthcare environments	The development of a smart hospital in Ch	48

2. Objectives

The 4th generation technology tools improve patient care and outcomes through the use of AI, data mining for medical data analysis, better disease prediction and diagnostic accuracy,⁵¹ increased efficiency, and cost reduction through the IoT and connected devices. They make it easier for medical data to be automatically collected and analyzed. Improved treatment outcomes and lower costs are the results of the 4th generation technological instruments.⁴² Improvements in hospital management through digital technologies to improve resource management and reduce operational errors,⁴³ as well as improvements in communication and collaboration among healthcare providers and the ability to diagnose and treat patients remotely,¹³ are made possible by the use of 4G and 5G networks.

In addition to showing how these technologies can enhance the standard of care and efficiency in smart hospitals, this study explores the prospects and constraints of implementing the 4th generation technological tools in these settings. Thus, the purpose of this study was to employ the 4th generation technological instruments in smart hospitals. It highlights how using the 4th generation technology tools may enhance data driven decision making, operational effectiveness, and patient care. These technologies include sophisticated communication networks like 4G and 5G, blockchain, AI, and the IoT.

3. Methods

This study falls under the category of scientometric research since it was carried out with VOSviewer software for drawing and the co-citation analysis technique. The research community for this study consists of all articles in the fields of smart hospitals and the 4th generation technology published between 2000 and 2024. The keywords included in this community are blockchain, AI, IoT, and the 4th generation technology.

Using an extensive search in the PubMed ScienceDirect citation databases, data were gathered for this investigation. The publications' full text accessibility, currentness, and

emphasis on the 4th generation technological instruments in the smart hospital were among the inclusion criteria. Cases like the papers' incompleteness in describing the goals of this study were also included in the exclusion criteria. Following a review of the abstracts of the papers that were found through the search, the full texts of relevant publications and those with the potential for a thematic connection were downloaded and saved. A few studies that did not fit the review's input or output criteria were not included. Subsequently, pertinent papers and studies with questionable relevance were examined. In order to further analyze and interpret the data, key themes and ideas related to the smart hospital's 4th generation technology tools were extracted from qualitative articles. The findings were then grouped based on these themes and concepts. At the end of the study, the desired points were retrieved along with the full texts of the articles. Among the research's strong aspects were the exhaustive search of trustworthy information sources, the application of strict entry and exit criteria for selecting articles, and the accurate and qualitative data analysis. The work was eventually published in 67 journals.

3.1. Introduction of VOSviewer Software

It is a piece of software used to create and display bibliometric networks. Maps based on network data, which can include journals, researchers, or scientific papers, are frequently created using this program. A variety of display options, including network, overlap, and density visualizations, are available for these maps. Important characteristics consist of: bibliometric mapping,⁵² data sources,⁵³ and visualization types. Types of visualization are: network visualization, overlapping visualization, and density visualization.⁵⁴

3.2. The Main Programs of the VOSviewer Software

- 1) Exploratory research: used for preliminary studies in order to develop research questions and new hypotheses.⁵⁵
- 2) Trend Analysis: Helps to identify emerging trends and

research hotspots in various areas, such as mobile banking and corporate tax avoidance.

- 3) Scientific collaboration: Analyzes coauthorship networks to understand patterns of collaboration among researchers.⁵⁶

Several map types are supported by VOSviewer, including:

- 1) Network Map: This kind of map shows the connections between things, including bibliographic coupling, co-authorship, and co-citation. By demonstrating the connections between various elements, it aids in understanding the structure of a research domain. In

this investigation, a network map was utilized.

- 2) Overlay Map: This kind of map enables the presentation of extra data on a base map. It is helpful for displaying patterns across time or group differences, like the activities of researchers in different fields of study.
- 3) Density Map: This visualization gives a heatmap like depiction of the data and highlights regions with a high concentration of objects. Finding hot areas or clusters within a research domain is made easier with the help of this map.

The study method flowchart is described in Figure 4.

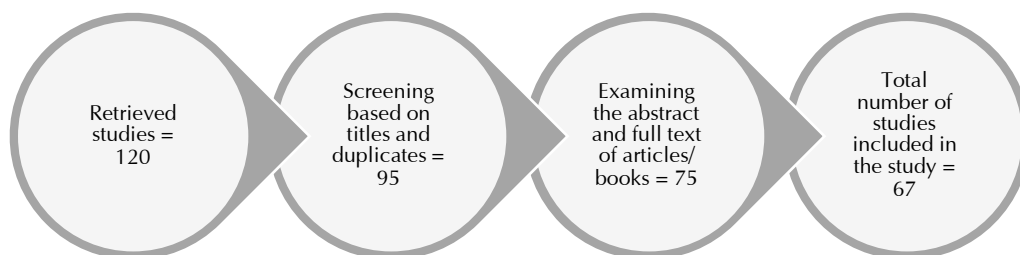


Figure 4. Research Flowchart.

4. Results

The data's of this study showed that 5,420 documents about smart hospitals and the 4th generation technology were indexed in the ScienceDirect and PubMed databases between 2000 and 2024. Following data extraction using VOSviewer software, the co-citation technique was used to create a scientific map of research on smart hospitals and the 4th generation technology throughout the designated time frame. In the first place, a scientific map

of the smart hospital domain was made. This was followed by maps of the 4th generation technology and smart hospitals, which each have two or three thematic clusters that are identified by distinct colors. The general topics of these clusters were determined by looking at the authors and papers of each cluster. The thematic map of the 4th generation technology and smart hospitals is created by representing each author's articles with a line connecting them if they are co cited with another document.

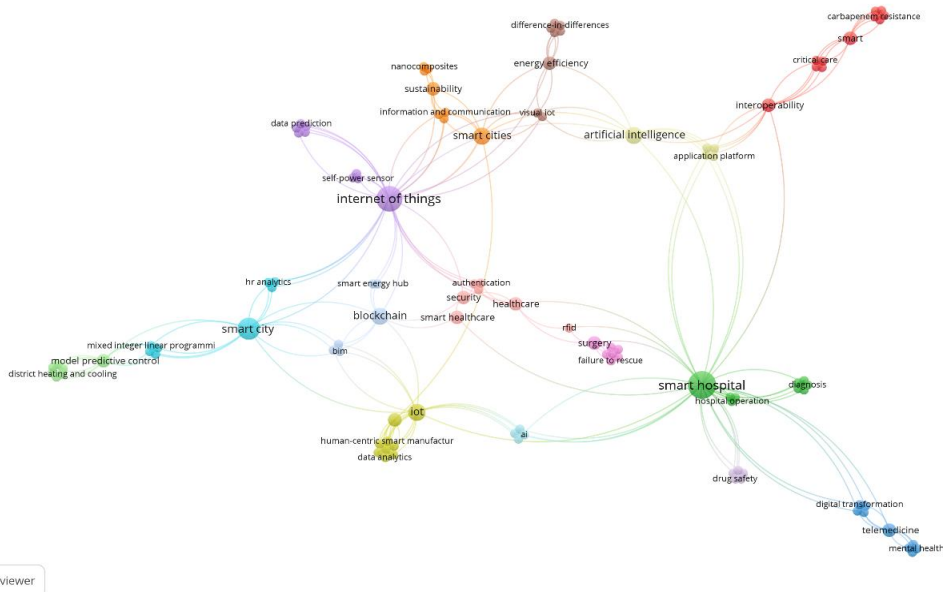


Figure 5. Scientific Map of Smart Hospital Research in ScienceDirect and PubMed Database during the Years 2000 to 2024.

2000 and 2024. Table 5 displays seven terms that are frequently used in this context.

The co-citation technique was used in this work to create a scientific map of research on the 4th generation technology and smart hospitals. High frequency keywords

in this field were found in this context. The benefits and difficulties of implementing the 4th generation technology in smart hospitals were investigated after reading through earlier publications. Table 6 provides an overview of these benefits and drawbacks.

Table 5. Most Frequent Words used in Articles in the Field of the 4th Generation Technology and Smart Hospital Indexed in ScienceDirect and PubMed Database during the Years 2000 to 2024

Rank	Word	Number of repetitions
1	Internet of things	53
2	Industry 4.0	48
3	Artificial intelligence	33
4	Big data	28
5	Cloud computing	25
6	Smart hospital	23
7	Machine learning	19

Table 6. Benefits and Challenges of using the 4th Generation Technology in Smart Hospitals

Agent	Sub agent	Description	Ref
benefits	Personalized Education	Smart patient rooms enhance patient education by providing engaging, customized content, which is particularly beneficial for rehabilitation	57
	Operational Efficiency	The integration of 5G technology facilitates seamless communication among healthcare providers, leading to more efficient diagnosis and treatment processes	13
	DataDriven Decision Making	Advanced analytics and digital twin technologies allow for better resource management and predictive analytics, enhancing overall healthcare delivery	58
Challenges	Staff Trainingand Adaptation	Healthcare professionals may face challenges in adapting to new technologies, necessitating ongoing training and support	59
	Integration Complexity	Implementing advanced technologies requires significant changes to existing systems, which can be resource-intensive and complex	60
	Integration Complexity	Implementing smart technologies requires overcoming interoperability challenges among various systems and devices	61

Regarding the utilization of the 4th generation technology tools in smart hospitals, an analysis of papers reveals that 35% of the articles focus on improving operational efficiency, 25% on data-based decision making, and 40% on enhancing patient care. To improve the comfort and well-being of hospital patients, 4th generation technological tools can be crucial in converting a conventional hospital into a smart hospital.

5. Discussion

The IoT, blockchain, and AI are acknowledged as crucial instruments for enhancing hospital performance, according to this study's co citation analysis in the area of the 4th generation technology in smart hospitals. These results unequivocally show that these technologies may help improve patient care quality, boost operational effectiveness, and support data driven decision making. The study's conclusions show how the 4th generation technological tools can significantly enhance patient care, operational effectiveness, and data driven decision making in smart hospitals. The findings are in line with the body of research that highlights how these technologies have the ability to revolutionize healthcare settings.

Given that 40% of the articles discuss how to improve patient care, it can be said that the 4th generation technologies especially the IoT offer the chance for the best possible patient monitoring and care. By gathering real time data on patients' situations, these technologies help medical personnel make better judgments, improving the standard of healthcare services. Real time monitoring and individualized treatment plans are made possible by

the integration of cutting-edge technology like AI and the IoT, which improves patient care and results in better patient outcomes. Sacker (2021), who addresses how data driven insights might improve healthcare delivery, supports this.⁶²

It can be stated that operational efficiency is emphasized in 35% of the publications. Blockchain technology and AI help streamline internal hospital operations, such as resource management, wait time reduction, and departmental cooperation. In addition to helping patients, these enhancements also lower expenses and boost employee happiness. According to this study's operational efficiency factor, implementing the 4th generation technologies improves hospital operations and cuts down on wait times. Big data analytics can greatly improve operational procedures in healthcare settings, according to Osman (2021).⁶³

The importance of data driven decision making is mentioned in 25% of the publications. Strategic decision making and better clinical outcomes can result from the use of AI and data analytics to find significant patterns and trends in hospital data. Health managers may make better judgments and improve strategic planning and resource management by analyzing vast amounts of data thanks to the data driven decision making factor. The work of Kadok (2015), which explores the significance of data analysis in supporting efficient decision making in intelligent environments, also places emphasis on this subject. These results demonstrate how hospitals must implement the 4th generation technologies in order to stay competitive and enhance the quality of healthcare

services they provide.⁶⁴ Lastly, this study suggests that more investigation is required into new technologies and how they affect health systems. Future research can be used to find new prospects and enhance healthcare services even more.

6. Conclusion

According to the data study, 5,420 papers were indexed in the ScienceDirect and PubMed databases between 2000 and 2024. This study analyzed citations from the ScienceDirect and PubMed citation databases pertaining to smart hospitals and the 4th generation technology research. The IoT, blockchain, and AI are the powerful 4th generation technological instruments in smart hospitals, according to the scientific mapping of this sector using co citation analysis. According to this report, implementing the 4th generation technology solutions in smart hospitals is crucial for enhancing patient care, operational effectiveness, and data driven decision making. The centrality index, which measures the authors' connectivity, shows that the authors in this discipline are extremely close to one another. This closeness is probably the result of numerous academics working together and the fact that the 4th generation technology problem in smart hospitals is still in its infancy. The terms "Internet of Things", "Industry 4.0", "Artificial Intelligence", "Big Data", "Cloud Computing", "Smart Hospital", and "Machine Learning" were most commonly used in stories about the 4th generation technology research and smart hospitals. A revolutionary strategy for enhancing patient care and operational effectiveness in smart hospitals is the combination of blockchain, the IoT, and AI. Together, these technologies improve patient monitoring, streamline healthcare procedures, and support data driven decision making.

Blockchain solves important issues with patient privacy and data management by guaranteeing the confidentiality and integrity of data.⁶⁵ IoT devices improve patient convenience and individualized care by enabling remote monitoring and real time data collecting.⁶⁶ In the meantime, enormous volumes of data are analyzed by AI algorithms to aid in clinical decision making, which eventually improves health outcomes.⁶⁷ When these technologies are used in a concert, they improve operational procedures and foster a patient centered, responsive environment. In order to overcome current obstacles and optimize the advantages of the 4th generation technology, continuous research and development in these areas will be crucial as smart hospitals continue to develop. Several avenues for further research can be suggested in light of current findings about the use of the 4th generation technology in smart hospitals:

1. Integration Challenges: Examining the difficulties of integrating blockchain, IoT, and AI in healthcare systems at the same time, with an emphasis on cost

effectiveness, data standardization, and interoperability.

2. Personalized Healthcare: Investigating how emerging technologies, especially wearables based on the IoT and AI analytics, may improve the provision of individualized healthcare services.

Research Highlights

What Is Already Known?

Smart tools, Internet-connected sensors, and remote control systems are all part of the smart hospital's production technology.

What Does This Study Add?

The 4th generation technological tools are crucial in converting a conventional hospital into a smart hospital and enhancing patient safety, early monitoring and diagnosis, medical service quality, efficiency, and cost reduction. Therefore, in smart hospitals, the 4th generation technological instruments are essential for improving patient comfort and wellbeing.

Author Contributions

Authors contributed equally to this work.

Conflict of Interest Disclosures

All authors declared that they have no conflict of interest.

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