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Health Services Promotion

Intelligent Routing Algorithm in the Vision of Futuristic Hospital

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Abstract

Background and Aim: Hospitals serve as vital pillars within the healthcare system, playing a unique and multidimensional role in maintaining and improving community health. Beyond providing treatment, hospitals significantly contribute to education, research, and social welfare. As lifestyle changes drive evolving health needs, hospitals face transformations in how services are delivered. To meet growing public expectations and improve healthcare outcomes, hospitals are increasingly adopting smart technologies and health navigation algorithms.

These intelligent models enable timely, efficient access to services and guide the healthcare system toward a future where hospitals function as smart, integrated centers, ultimately enhancing patient care and the overall effectiveness of health services. Therefore, the present review study aims to examine smart navigation algorithms in the vision of the hospital of the future.

Materials and Methods: This systematic review was conducted according to the PRISMA guidelines. The databases PubMed, Scopus, Web of Science, Google Scholar, SID, Magiran, and IranMedex, Up to Date, Embase ،were searched.And it includes Persian and English articles from 2011 to 2025.

Results: The findings show that intelligent routing algorithms play a key role in reducing waiting times, improving the quality of care, and increasing the efficiency of the health system by optimizing patient guidance and resource management processes.

Conclusion: The conclusion is that the integration of intelligent technologies and routing algorithms into the structure of new and future hospitals can lead to a fundamental transformation in service delivery, so that hospitals, as smart and automated centers, significantly improve the efficiency and effectiveness of the entire health system while enhancing the patient experience. Therefore, the development and implementation of such algorithms is a strategic necessity to achieve smart health goals.

Keywords: Smart Hospital, Futuristic Hospital, Routing Algorithm, Smart Routing.

Introduction

Health centers, clinics, health bases, and hospitals are recognized as the main centers of health service providers and meet the most important health needs of society. These centers play a significant role in improving individuals' health by offering a variety of services such as prevention, diagnosis, treatment, and post-treatment care. Each of these centers is categorized based on their facilities, specialties, and the level of services provided, enabling people to benefit from health and medical services according to their needs. Among the centers providing health and medical services Hospitals are one of the most important centers for providing health and medical services in countries. Hospitals, as vital pillars of the healthcare system, have an unparalleled, multidimensional, and influential role in maintaining and improving community health. The position of hospitals extends beyond merely providing treatment services; their impact also spans education, research, and even social issues, because Over time, with changes in lifestyle, health and medical needs have also evolved. These

changes have caused serious transformations in the method and nature of health service delivery. For example, with the introduction of Health Promoting Hospitals , the health system demonstrated that the concept of a hospital is not just about treating patients. Health Promoting Hospitals is a concept and movement—supported by the World Health Organization —that expands the traditional role of hospitals from merely treating illness to actively promoting health and preventing disease. These hospitals aim to enhance the well-being not only of their patients but also their staff and the broader community in which they operate (1).

Timely access to health and medical services, supported by smart technologies and health navigation algorithms, is crucial for guiding healthcare systems toward the future hospital vision. Major changes in healthcare delivery are expected soon, driven by increased public expectations and technological advancements like AI, the Internet of Things, and digital health. Hospitals play key roles beyond treatment so to optimize healthcare delivery; hospitals must modernize and adopt innovative approaches aligned with regional needs. Their effectiveness relies on quality management, technology upgrades, and evolving therapeutic methods, making them dynamic centers essential for sustaining community health and wellbeing, But what has forced hospitals to change rapidly and adapt to technology is artificial intelligence, which has accelerated the achievement of healthcare system goals.

Nowadays, the use of smart technologies and their application in electronic markets has become widespread across many fields, including finance, commerce, health, tourism, and other sectors.(2) The healthcare system has also prioritized the use of artificial intelligence in the current era. Therefore, all aspects of the use of artificial intelligence and somatization need to be examined and analyzed. Challenges and weaknesses must be carefully examined because hospitals are service centers that are directly related to the health of the community. Although the successful implementation of smart navigation algorithms in hospitals requires overcoming challenges through infrastructure development, data standardization, workforce training, information security assurance, and fostering a culture of technology acceptance within the healthcare system, these issues do not prevent implementation. This is because rapid and fundamental changes in hospital service delivery are expected in the near future, and ignoring them will lead to losing effective opportunities in healthcare services (3).

The goal of the global "Digital Health" strategy in the "Global Digital Health Strategy 2020-2024" is stated as follows: to promote healthy lives and well-being for all, everywhere, and at every age, so that the realization of national or regional digital health plans and the utilization of their potential must be guided by a strong strategy that provides financial, organizational, human, and technological resources (4-5). Artificial intelligence plays a very important role in the digital health strategy. To achieve a desirable and healthy healthcare approach, all aspects must be carefully examined. The path to achieving goals in the future vision of hospitals is not possible without the use of artificial intelligence and digitalization. Because the medical and health industry is no exception to this rule, and the impact of transformative technologies on longer and healthier lives cannot be denied. The emergence of smart hospitals, smart devices, and surgical robots has brought about a major transformation in patient care and experience (5). So It is expected that the Internet of Things (including all internet-based, digital, and advanced technological applications) will reduce costs in quality-based healthcare services, enhance quality of life, and improve overall performance by enriching the user experience (6).

Although there is still information High costs and economic pressure of medical care, the aging population, increased prevalence of chronic diseases, and shortage of specialized personnel are reasons that indicate that the main trend to address these challenges is moving towards digitalization (5) and The healthcare sector has been reported as one of

the most benefited industries from the applications of IoT technology (7-9).

Ten years ago, the Future Hospital Programme was created following the publication of the Future Hospital Commission report, which made recommendations for providing patients with safe, high-quality, sustainable care that they deserve. There had been growing concerns about the standards of care and it was seen that change needed to occur (10). Changes that have occurred over time have jeopardized the health system, so adopting the use of artificial intelligence in hospitals is necessary and essential to achieve the desired level of health and medical services. This is more important in developing countries and public hospitals because these hospitals have significant referrals and need to update and make themselves more efficient. Public hospitals designed for the past are not changing rapidly enough to meet the needs of the future (11).

Currently, when treatment is concentrated in public hospitals and changes do not occur quickly, there is a need for short-term, medium-term, and long-term plans that have the power to be flexible and transformative. Urban travel, especially in Iran, really needs to equip and modernize the centers that provide health and medical services and hospitals to better meet the needs of the people.

The Iranian health system, like other health systems in the world, is exploring the process of digitalization and somatization. In Iran, there are also projects and initiatives underway to make hospitals smart, Smart and systematic routing helps patients and visitors in hospitals to achieve their health and treatment goals conveniently, quickly and accurately. Smart routing will be considered a health road in the future. Accordingly, the present study has been conducted with the aim of presenting a smart navigation algorithm in the vision of the forward-looking hospital.

Methodology

This systematic review was conducted according to the PRISMA guidelines. The databases PubMed, Scopus, Web of Science, Google Scholar, SID, Magiran, and IranMedex, Up to Date, Embase ،were searched. Keywords were selected according to Table 1 and searched using Boolean operators. And it includes Persian and English articles from Beginning of the year 2011 to 2025. In the initial search, the titles and abstracts of the articles were screened by researcher number one. Relevant articles were selected for full-text review. In the second stage, the content reading of the selected articles was carried out by researcher number two. After extracting the eligible articles, general data, study characteristics, and results were extracted from the articles and summarized in Table two. Data extraction was performed by researchers one and two together. The extracted data was subjected to content analysis. After reviewing and analyzing the extracted articles, the approach of utilizing smart hospitals was identified and extracted. Finally, the results obtained were categorized and presented in the form of this article.

Table NO 1: Search strategy

Variable	Keywords
Smart Hospital	"Smart Health Center*" OR "Smart Medical Center*" OR "Smart Clinic*" OR " Smart Health and Medical Center *" OR "Smart Emergency Room*"
Futuristic Hospital	"New hospital*" OR " future hospital *" OR " AI hospital *"
Routing Algorithm	" Health Algorithm *" OR " Health Routing Algorithm" OR " Routing Algorithm" OR " Network *" OR "Cause*" OR " Optimal Route *"
Smart Routing	"Artificial Intelligence*" OR "Route Optimization*" OR "Spatial Data Analysis*" OR "Automatic Routing*" OR "Smart Routing*" OR "Systematic Routing".

Results

The search and screening results were 8 articles, which are mentioned in the table of findings below.

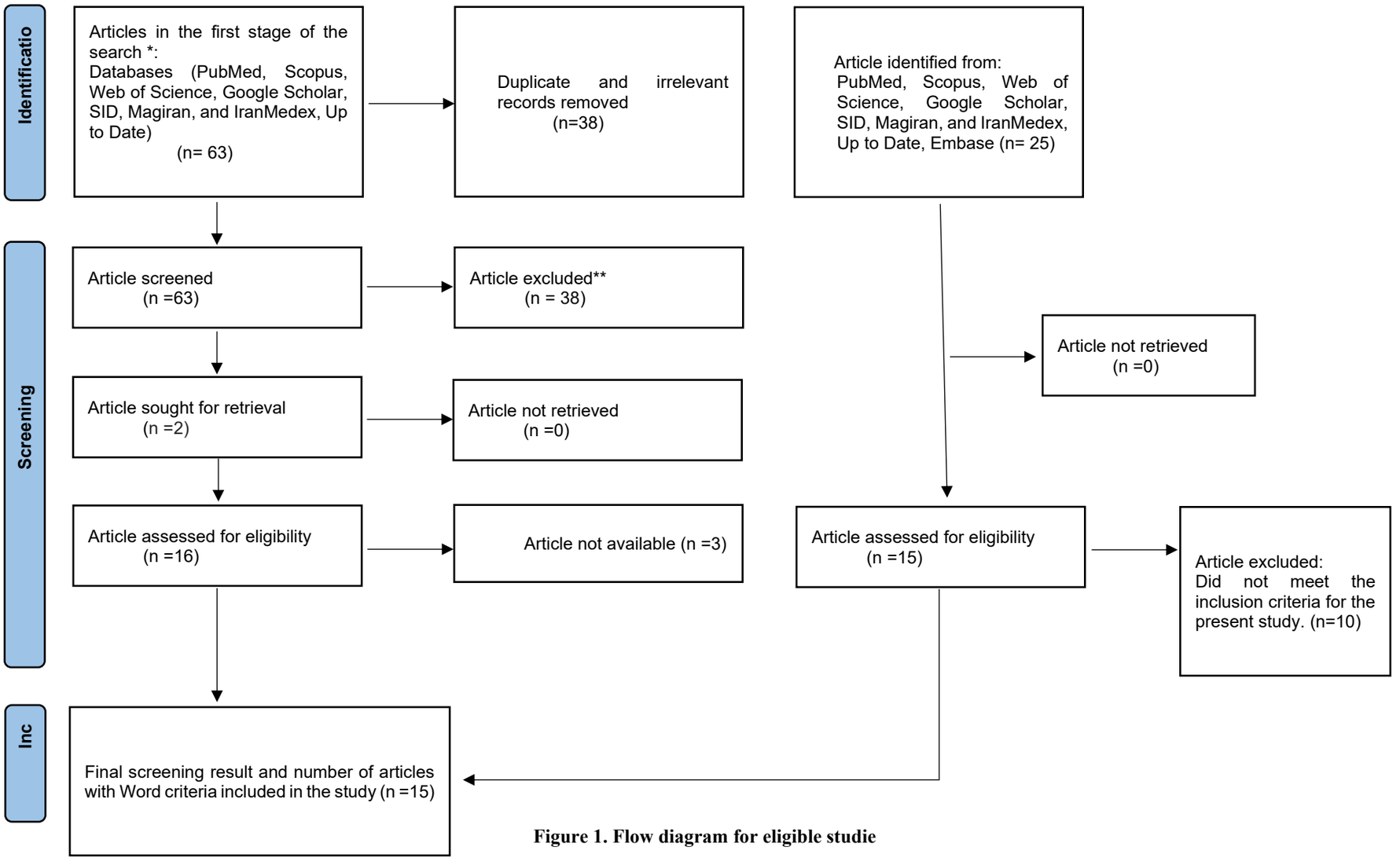

Figure 1. Flow diagram for eligible studie

Table 2: The Eligible Studies Characteristics

Study	Year	Title	Main findings
Jovy-Klein F, et el.(12)	2024	Forecasting the future of smart hospitals: findings from a real-time delphi study	Jovy-Klein and colleagues' study, "Forecasting the future of smart hospitals," concludes that smart hospitals are likely to become a reality within the next 20 years. Advances in artificial intelligence will improve operational efficiency, patient-centered care, sustainability, and collaboration in healthcare. However, overcoming challenges such as staff shortages, ethical issues, and the demand for strong digital skills is crucial. A combination of expert healthcare professionals, clear ethical guidelines, and robust digital competencies is essential to fully achieve the smart hospital vision and meet future healthcare delivery needs.
Pascale F, Achour N.(13)	2024	Envisioning the sustainable and climate resilient hospital of the future	The healthcare system is undergoing transformative changes due to evolving healthcare delivery, patient expectations, emerging technologies, climate change, and sustainability. However, current hospital strategies often fail to consider the interrelationship between the hospital estate and its socio-environmental context. Policymakers, healthcare system leaders, and hospital leaders need a clear vision of the hospital of the future to implement transformational strategies.
Bhagat SV, Kanyal D.(10)	2024	Navigating the Future: The Transformative Impact of Artificial Intelligence on Hospital Management- A Comprehensive Review	Integrating AI in administrative functions, clinical operations, and patient engagement holds significant promise for enhancing efficiency, optimizing resource allocation, and revolutionizing patient care. However, this evolution is accompanied by ethical, legal, and operational considerations that necessitate careful navigation.
Sukin DF, et al.(14)	2024	Building the smart hospital of the future with technology bets	Central to this Houston Methodist, a leading hospital system, is the 'Smart Hospital DNA', a framework that marries technological innovation with collaboration. Within this structure, the institution has incorporated predictive artificial intelligence, integrated ambient intelligence for heightened patient safety, leveraged service robots for diverse operations, and initiated remote monitoring through advanced wearables.
Golpira R, et el.(3)	2023	Prerequisites of Implementing Smart Hospitals in Iran.	Implementing a smart hospital in Iran requires providing infrastructure and technological prerequisites and overcoming existing challenges. Given the current situation, it is suggested that this should be started gradually and with a focus on some specific areas or processes. It is also necessary to carry out detailed strategic planning with the participation of all stakeholders.
Hosseini SH, et al.(15)	2023	Design and Standardization of Smart Hospital Evaluation Checklist	Smart hospitals try to reduce costs and increase the speed and accuracy by creating connection among service provider, care giver and equipment. Due to the lack of related tools for evaluating the level of smartness in hospitals, we presented this checklist.
Mirsaeidi Farahani Sh M, et al.(16)	2021	Providing the Model of Deployment of Smart Services in Iranian Health Sector: A Qualitative Study	Providing the model for deploying smart health care and use of these technologies help to significantly improve the quality of health services, improve access to these services, reduce costs and thus improve health of society.
Hosseinpour M, et al.(17)	2021	Identify and Prioritize Internet of Things Technological Applications on Hospital Quality Management Using a Structural Interpretive Approach	Applications of controlling the vital signs of the patient, caring for patients without the need for the presence of the person on site, checking the inventory of equipment and essentials, tracking and monitoring the performance of staff, patients and inventory, intelligent monitoring and regulation of environmental conditions of patient care and medication, road visits patient turnover in acute and special times, reduction of hospital waste, monitoring of physical activity of the elderly and launching online communities and online medical consulting were identified as the key factors
Mahmoodi S, et al.(18)	2020	Modeling a Smart Hospital Information Architecture Based on Internet of Things and Recommender Agent	Utilizing the IoT in medical processes reduces errors, although the extent of its effectiveness varies at different stages of treating various diseases. Since some disease-specific IoT devices overlap in their functions, and given the limited number of these devices in hospitals, it is recommended that a recommender agent be used to ensure maximum effectiveness. Recommender agents make informed decisions as to how IoT devices can be efficiently allocated to patients at each stage of their treatment.

Table 2: The Eligible Studies Characteristics

Study	Year	Title	Main findings
Jamil F, et al.(19)	2020	Towards a Remote Monitoring of Patient Vital Signs Based on IoT-Based Blockchain Integrity Management Platforms in Smart Hospitals	propose a novel platform for monitoring patient vital signs using smart contracts based on blockchain. The proposed system is designed and developed using hyperledger fabric, which is an enterprise-distributed ledger framework for developing blockchain-based applications. This approach provides several benefits to the patients, such as an extensive, immutable history log, and global access to medical information from anywhere at any time.
Ronaghi MH.(20)	2020	A Conceptual Framework for Smart Hospital towards Industry 4.0	According to research results the main components of smart hospital are eight technologies: Internet of things technology, robotic, blockchain technology, cloud computing, big data, augmented and virtual reality technology, additive manufacturing and artificial intelligence.
Helmy Elhefnawy M.(21)	2020	A Proposed Methodology for Integrated Architectural Design of Smart Hospitals	The research conceived a proposed methodology for the architectural design of smart hospitals and identified mechanisms for utilizing smart materials and systems in developing hospital designs
Fischer G, et al.(22)	2019	Towards evaluating proactive and reactive approaches on reorganizing human resources in IoT-based smart hospitals	ElHealth was simulated on a hospital environment using data from a Brazilian polyclinic, and obtained promising results, decreasing the waiting time by up to 96.4% and 96.73% in reactive and proactive approaches, respectively.
Amidi M, et al.(23)	2014	Intelligent scheduling for emergency room(ER) personnel to improve productivity	Objective of this research is to design an intelligent schedule for ER personnel in order that waiting time is reduced and hospital management constraints are fully considered. First , patient flow in ER is simulated. Secondly, Gentic Algorithm(an Intelligent approach) is applied to solve the multi objective problem. Results show that average and standard deviation of patients waiting time for first visit is reduced by 74% and 53% respectively.
Darvish N, et al.(24)	2011	Modeling and scheduling intelligent method's application in increasing hospitals' efficiency	Research various models can be used as a suitable tool for scheduling and determination staffs optimized number needed in several parts of a hospital which has a vital role. In case that the designed system in the current project is limited to the achieved and collected data from educational center of Booali attached to Tehran Islamic Azad university, it is need to make changes in programming based on data for generalizing it and optimized utilization in other hospitals. So it is recommended to make the prepared program close to the real world for make these systems utilizable in other hospitals and increasing restrictions.

Discussion

Domestic and international research shows that the successful implementation of intelligent routing algorithms will bring about a remarkable transformation in the management of healthcare service centers, productivity, and the quality of services in forward-looking hospitals. However, it should be noted that this field still requires practical research, precise simulations, and field tests to correctly identify and address the specific challenges of healthcare environments. Moreover, paying attention to both human factors and information technology together can ensure the acceptance and sustainable impact of healthcare systems. Continuous interaction among researchers, hospital managers, and IT experts is essential so that routing algorithms are optimized not only technically but also from a usability perspective, thereby creating a smarter and more efficient healthcare environment. This process can significantly contribute to improving the quality of services for patients, reducing hospitals' operational costs, enhancing the satisfaction of patients, their companions, and visitors, and lay the groundwork for a novel, attractive, and effective transformation in the healthcare system.

But why is the routing algorithm important in hospitals?

The intelligent routing algorithm is a computational method that determines the optimal path for transferring data or goods from the source to the destination by analyzing traffic data. These algorithms, by employing artificial intelligence technologies, evolutionary algorithms such as genetic algorithms, ant colony optimization, game theory, and adaptive methods, are capable of simultaneously and intelligently considering multiple factors such as time, cost, traffic, obstacles, and network conditions, and providing the best possible path in real-time (25).

Because hospitals have multiple sources and destinations for providing health and medical services, intelligent routing for accessing services is a critical necessity for patients. Intelligent routing in hospitals means utilizing modern technologies to improve the routing process, traffic management, and enhance the quality of health and medical services. Since hospitals have various sources (patient entries, companions, staff, and equipment) and multiple destinations (inpatient wards, operating rooms, laboratories, emergency departments, etc.), smart management of routing in these centers holds special importance so,

Smart health system, by providing healthcare professionals with real-time access to medical data, these systems can help improve patient outcomes and reduce the risk of medical errors. However, it seems indispensable to ensure that patient data is protected and that healthcare professionals receive proper training in the use of these systems. With these considerations in mind, interactive intelligent health information systems have the potential to revolutionize the way healthcare is delivered, improving the lives of patients around the world (26).

Hospitals, as the most important centers for delivering health services, have been influenced by generational revolutions, and significant advancements have also occurred in hospital management and clinical care (27). As a result, today the concept of a smart hospital is recognized as one of the key foundations in the health revolution and is globally considered an important area in the health sector. Considering the current situation of the country, the establishment of fully smart hospitals in Iran in the short term and all at once is impossible. However, with proper planning and a gradual, phased approach, effective and safe steps can be taken toward a progressive path (18, 20).

The search results have shown that some experts in some fields are against the use of new technology, artificial intelligence, and smartization, and some other experts are in favor of the introduction of new technology in the field of health. For example, Davari (28) in his study mentioned the model of integrating the Internet of Things and smart vehicle routing, as well as Sangeetha (29) et al, Fallah (30) et al, Ma (31) et al, Masmoudi(32) et al, Bahadori-Chinibelagh (33) et al. In this regard, the Amidi M, et al study the data for research was collected from the ED of Show-Chwan Memorial Hospital in Central Taiwan utilizing simulation and a genetic algorithm (GA) that by making appropriate adjustments to the nurses' schedules, the patients' queue time is shortened, thereby raising the quality of patient-care and patient-satisfaction. This shows that health-oriented intelligent routing can be of great help both in transporting patients to the hospital and in providing healthcare services (34).

In this regard, some studies have been conducted on machine learning algorithms and intelligent routing using real-time data (such as hospital status and traffic) to optimize ambulance routing (35). Studies Nahata et al, Indoria, Abdeen et al, Karkar, also point to this issue (36-39). For example, in the study Shaban and Golshannavaz, The conducted study concludes a promising potential of AI-based machine learning algorithms in devising predictive healthcare systems capable of initial diagnosis and preliminary decision makings to be relied upon by the clinician. What is more, the availability of biometric data and the features of the proposed system significantly contributed to primary care assessments (40). Some other studies also point to similar results (41-42).

In the health routing algorithm, some studies refer to automatic routing of hospital service robots (43), while path planning for hospital robots is also approved and used in several studies (44-45).

These sources have introduced and analyzed various methods and algorithms, with an emphasis on optimizing and intelligentizing routing in hospitals and health-related environments. Based on the type of application (health logistics, robotics, EMS, etc.), there are different algorithms and models.

Smart hospitals can influence health and medical policies and create new medical value by defining and quantitatively measuring detailed indicators based on data collected from existing hospitals. Simultaneously, appropriate government incentives, consolidated interdisciplinary research, and active participation by industry are required to foster and facilitate smart hospitals (27).

The above is only a part of the existing findings in the field of routing methods and algorithms in the health field, but the future outlook is very broad and vast, and the hospital environment itself can have many health routes, each of which will have its own separate and specific algorithm.

The future outlook of forward-looking hospitals in providing health and medical services

In the very near future, some of the world's health systems will rapidly rush towards smart hospitals. Smart hospitals provide health and medical services in an organized and systematic framework. The rate of errors in providing health and medical services in these hospitals will be very low. Although nothing can replace human-based health and medical services, in order to optimally deliver services in the present era, a serious reconsideration of the health system is necessary. Intelligent and accurate examinations and history-taking, smart patient monitoring, precise consultation for patients and their companions, data management and electronic archiving, monitoring patient conditions, alerting patients based on disease symptoms, electronic health records, remote patient care, remote visits and consultations, telemedicine, disease follow-up, timely and smart care, creation of digital infrastructures, cybersecurity, etc. are among the approaches of smart hospitals. For the future outlook of smart hospitals, special attention must also be paid to market growth, as the health system is one of the cost-intensive systems and the optimal integration of new technologies greatly helps in achieving the operational goals of the health system. Paying attention to market growth in parallel with the rapid advancement of technology, moving toward patient-centered treatment and home care, distancing from collective and hospital-centered treatment, developing an ecosystem and intersectoral collaboration that enables effective communication between physicians and other health centers are key points on this path (12, 46).

The future outlook of smart hospitals is their transformation into fully digital and intelligent centers that utilize modern technologies to provide high-quality preventive, therapeutic, and managerial care. In the coming decade, smart hospitals will be the focal point of healthcare system transformation, relying on technologies such as artificial intelligence, the Internet of Things (IoT), automation, and communication infrastructures. These centers will not only improve the quality and efficiency of services but also play a decisive role in reducing costs, increasing safety, and enhancing sustainability in the health sector (12). Smart routing algorithms will play a key role in the evolution of hospitals and future service delivery centers. By leveraging advanced technologies such as artificial intelligence, intelligent electronic machines, and an effective and efficient workforce, these algorithms can determine the optimal routes for transferring patients, medical equipment, and personnel within the complex hospital environments.

Conclusion

The health system in developing countries is more important because these countries face serious challenges such as poverty, lack of financial resources, weak infrastructure, educational and gender inequalities in health, infectious diseases, maternal and child health problems, and malnutrition. Poor public health hinders economic growth, and economic development alone cannot improve health indicators. Therefore, the health system in these countries plays a vital role in disease prevention and control, improving maternal and child health, reducing poverty, and supporting sustainable development.

In contrast, developed countries, due to stronger infrastructure and greater financial resources, assign less importance to the health system in terms of basic needs and widespread diseases. Overall, the importance of the health system in developing countries stems from its key role in addressing fundamental and infrastructural health challenges, which form the foundation of their social and economic progress and development

Therefore, developing countries need to adopt modern technology to advance their goals, as technology, in some cases, accelerates the achievement of objectives. One of the modern technologies is the smartification of hospitals. In developing countries, future hospital planning must be based on realistic and attainable goals to improve the quality of healthcare services, increase equitable access to medical care, develop infrastructure, and maintain financial sustainability. Hospitals with a modern and smart technology approach are one of the important goals in the future outlook of these countries.

Smart and technology-driven hospitals can play a very important role in strengthening the health system of developing countries. These types of hospitals, by utilizing technologies such as advanced databases, intelligent resource management systems, the Internet of Things (IoT), artificial intelligence (AI), and telemedicine systems, are capable of improving the quality of healthcare services, increasing the accuracy of diagnosis and treatment, reducing medical errors, and facilitating patients' access to specialized services even in remote areas.

The use of intelligent routing algorithms in forward-looking hospitals not only enhances the level of healthcare services and improves patient experience but also significantly increases operational efficiency and resource management. These technologies constitute an essential infrastructure for smart and forward-looking hospitals and play a vital role in realizing the vision of digital health.

Conflict of Interest

The authors declare no competing interests

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