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USING ARTIFICIAL INTELLIGENCE IN SAUDI ARABIAN HEALTHCARE SYSTEMS TO IMPROVE PATIENT OUTCOMES

***Abstract**: This paper aims to systematically review the status of using artificial intelligence (AI) in Saudi healthcare systems to improve patient outcomes. In the review, the status of Saudi Arabia was compared with those of some resource-poor, low-to-middle income and developing countries, using 20 papers each collected from Google Scholar. The review showed both similarities and differences in their approaches to using AI in healthcare systems. Saudi Arabia is a late-comer. However, it developed many innovative AI applications for the hajj season. These applications can be used for public health problems also. Being a resource-rich and high-income country, Saudi Arabia must only be willing to adopt AI in its healthcare system. There is a lot of scope for researching and developing more innovative AI applications to facilitate the building up of a healthy and productive population, as stipulated in its Vision 2030 goals. Six recommendations have been listed to indicate how to raise the level of AI adoption and integration into the Saudi healthcare systems to enhance patient outcomes.*

***Keywords:** artificial intelligence, Saudi Arabia, healthcare systems, patient outcomes, quality.*

1. Introduction

An artificial intelligence (AI) tool is a software application that uses artificial intelligence algorithms to perform specific tasks and solve problems. AI tools can be used in a variety of industries, from healthcare and finance to marketing and education, to automate tasks, analyse data, and improve decision-making. Many AI tools have been developed. Some like ChatGPT are free. Here, we consider AI tools used in the healthcare system only.

According to Statista, in 2021, the global size of the healthcare AI market was around 11 billion USD. It is forecast to grow to almost 188 billion USD by 2030, increasing at a compound annual growth rate of 37% from 2022 to 2030. According to a Markets & Markets report (Markets & Markets, 2023), AI in healthcare has a market size that will grow from 14.6 billion USD in 2023 to 102.7 billion USD in 2028 at a compound annual growth rate of 47.6%. Large volumes of data generated through many sources, the need to reduce costs, and the need for rapid development of drugs and vaccines are the growth drivers. Lack of AI skills is a restraint. The growing potential for AI in elderly care provides tremendous growth opportunities. The lack of curated AI data is a challenge. There are many other varying estimates of the global AI market size.

In healthcare systems, AI-based tools may improve prognosis, diagnostics, and care planning. Soon, AI may become an integral

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part of healthcare services. AI may be incorporated into several aspects of clinical care. High investments have been made by IT organisations to develop AI tools for healthcare systems (Vikas Mahandule et al. 2024). Patients will be the most important beneficiaries and users of AI-based applications. Therefore, their perceptions may affect the widespread use of AI-based tools. Patients should be assured about the safety of AI tools sufficiently. Although AI can enhance healthcare outcomes, some concerns and risks should be addressed before its integration with routine clinical care. In this context, Esmaeilzadeh (2020) proposed a research model for AI in healthcare (Fig 1).

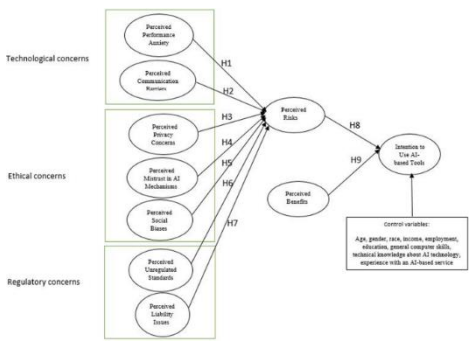

Figure 1. Research model of Esmaeilzadeh (2020)

Three concerns- technological, ethical, and regulatory- concerns form the basic elements of the framework. Performance anxiety and performance communication barriers are the two technological concerns. Privacy, trust levels and social biases are three ethical concerns. Unregulated standards and liability issues are the regulatory concerns. All these concerns together lead to perceived risks. However, the intention of using AI tools for healthcare is also driven by benefits. If benefits are more adoption of AI in healthcare systems will happen. If risks related to the concerns are more than benefits, AI adoption may not take place.

Thus, when implementing AI in healthcare systems, both the advantages and the above concerns need to be considered. Concerning the Saudi healthcare system, the question arises to what extent AI has been implemented in the country's hospitals and what are the patient outcomes. There is also a need to compare them with situations in other countries to know where Saudi Arabia stands in this respect and find out methods to raise its level. To answer these questions, a systematic review is done in this paper. The following are the aims and objectives-

Aim: A systematic review of the status and future scope for AI applications in Saudi healthcare systems for positive patient outcomes.

Objectives-

1. To evaluate the status of AI implementation in the Saudi healthcare system and its patient outcomes.
2. To compare AI implementation in the Saudi healthcare system with those in other countries and patient outcomes thereof.
3. To identify methods to raise the level of AI applications and patient outcomes in Saudi healthcare systems based on the comparison with other countries.

AI in the Saudi healthcare system

In the case of Saudi Arabia, although not directly mentioned, healthcare reforms are on the cards as an important component of its Vision 2030 goals (healthy and productive citizens) (Saudi Arabia, 2016).

It seems AI was considered only when the Covid-19 pandemic entered the country. Nasseef, Baabdullah, Alalwan, Lal, and Dwivedi (2022) note that during the Covid-19 pandemic, AI tools were used in the Saudi healthcare system for Government-to-Government (G2G) knowledge exchange, early diagnosis, intelligent observations, prediction of Covid spread, following up and communicating contacts of infected cases, and the analysis of rapidly accumulating large volumes of data for trends predictions. In Saudi Arabia, currently, AI is used only for interconnections among hospitals.

A schematic diagram of AI in mobile healthcare (m-health) was discussed by Khan and Alotaibi (2020) and presented in Fig 2.

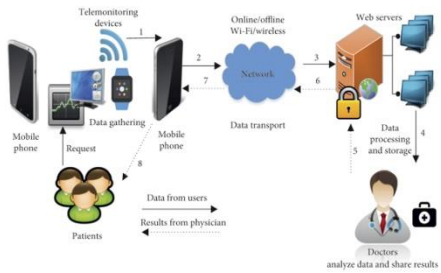

Figure 2. Schematic flow of AI-integrated mobile healthcare systems (Khan & Alotaibi, 2020)

A data-driven AI-based system called Musawah was tested by Alahmari, et al. (2022). It aimed to automatically discover healthcare services for co-creation and development by various stakeholders using social media analysis. A case study on cancer in Saudi Arabia was examined using Twitter data in the Arabic language. The authors discovered 17 services using machine learning and the Latent Dirichlet Allocation algorithm (LDA) on Twitter data. The 17 services were grouped into five macro-services Prevention, Treatment, Psychological Support, Socioeconomic Sustainability, and Information Availability. Subsequently, the authors discovered 42 additional services. They developed a software tool from scratch for this work for a complete machine-learning pipeline using a dataset containing over 1.35 million tweets curated from September to November 2021. Open service and value healthcare systems based on freely available information can revolutionize healthcare like the open-source revolution by using information made available by the public, the government, third and fourth sectors, or others, allowing new forms of prevention, cures, treatments, and support structures. The system architecture of Musawah is given in Fig 3. Data collected from Twitter are cleaned and an Arabic tweet database is created. The pre-processing steps involved removing irrelevant characters, punctuation, diacritics, tokenisation, and removing stop words. Services were discovered by detecting significant topics and merging and grouping them. Validation of the model was done internally and externally. For visualisation, inter-topic distance map and keywords visualisation were used. Taxonomies of cancer detection, diagnosis, and interventions were derived from the analysed Twitter data.

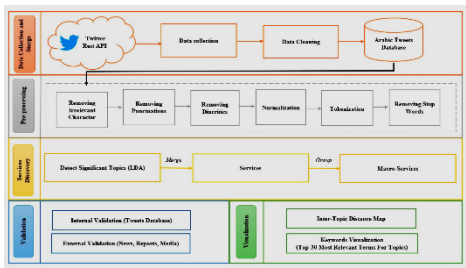

Figure 3. Flow diagram of the Twitter data analysis to identify and validate healthcare services which can be assisted by AI (Alahmari, et al., 2022)

Poor compliance with AI-integrated e-health system prescriptions among Saudi diabetic patients, especially on diet control and physical activities was noticed by Alanazi, Gay, and Alturki (2022). Non-compliance was positively correlated with education and income.

Thus, two problems are evident from the above papers-

a) The growing healthcare AI market provides many opportunities for its use. However, Saudi Arabia is relatively slow in taking advantage of these opportunities.
b) Saudi Arabia has no specific AI-integrated healthcare systems despite the reforms required to achieve its healthcare goals of Vision 2030, except perhaps some mobile applications for e-healthcare for specific health problems and some AI tools introduced during the Covid pandemic.

2. Methodology

Al The methodology used is summarised below:

1. First, the first three pages of Google Scholar were searched for AI applications in the Saudi healthcare system, the identified papers were screened and selected using the PRISMA flow diagram to finally select 20 papers.
2. In the second stage, the same process was repeated for other countries to finally select 20 papers.
3. The salient qualitative and quantitative points from the two types of papers were tabulated, analysed, and compared.
4. The above three steps led to understanding the status of AI applications in Saudi healthcare systems and patient outcomes and how it compares with other countries concerning these two aspects.
5. The comparison led to identifying methods to raise the Saudi level of AI applications and patient outcomes in its healthcare system.

2.1 The inclusion and exclusion criteria for screening and selection of papers

Inclusion criteria- Papers published in English, full texts preferred, but abstracts also included if they contain important information and all papers containing any one or all AI techniques, only those in which use of AI applications in healthcare systems are discussed.

Exclusion criteria- Papers in other languages, abstracts if they do not contain important information, books, book chapters, theses, citations only, repetitive papers published in different journals, and those not discussing any one or more of the AI techniques used in healthcare systems.

The results obtained for the first four stages above are described in the next section. In the subsequent sections, these results are discussed to draw comparisons and methods to raise the Saudi level of AI applications and patient outcomes are derived, leading to conclusions. Some limitations of this review are considered in the final section.

3. Results

3.1 Use of AI in Saudi healthcare systems

In an editorial, Saeed, Saeed, and AlAhmri (2023) opined that the adoption of AI solutions can transform the Saudi healthcare system. It can improve efficiency, reduce costs, and enhance the quality of care leading to better patient outcomes. However, there is a need for high-quality data and the development of regulations and guidelines.

3.2 Low level of acceptance and adoption

Fear of replacement of their jobs by AI, general lack of knowledge about AI, advantages and challenges were the basis for the low level of acceptance of AI by healthcare professionals, according to the results obtained by Abdullah and Fakieh (2020) from a survey of 250 healthcare professionals. The impact of AI was highest for technicians, as they had only limited human interactions. A tabulated summary of four related studies from Estonia, Netherlands, India, and South Korea showed positive attitudes towards AI in healthcare in the Netherlands and South Korea with little or no concern about losing their jobs due to AI. Attitudes varied in Estonia and most participants were aware of AI in India. Price and interface were the main problems in Estonia and the perception of the disadvantages of AI was the main problem in India.

In a survey of 186 participants from four main Saudi hospitals by Chikhaoui, Alajmi, and Larabi-Marie-Sainte (2022), most participants agreed that AI leads to better health, saves manpower, simplifies the

healthcare processes, helps reflect human intellectual competencies and pushes its limits. However, AI may not pass all ethical tests of fairness, reliability and safety, inclusiveness, transparency, and accountability. There are also legal challenges of regulation, insurance, indemnification, liability, risk allocation, privacy, and data protection.

Using an AHP technique on secondary data, Alharbe (2021) showed that the impacts of digital technologies (AI not mentioned, but can be included) on patients, doctors, hospital employees, insurance companies, and pharmaceutical companies were at an acceptable level. The impact factors ranged from 0.256 to 0.854.

In a survey by Alghamdi and Alashban (2023), out of 129 radiologists, 89 (69%) respondents had heard about AI and had a basic knowledge of artificial intelligence/deep learning/machine learning. While most of the participants had a positive outlook, 17% of participants indicated concern that AI will replace their jobs.

To assess the radiology community's attitude in Saudi Arabia toward the applications of AI, the responses from a survey of 714 radiologists were analysed by Alelyani, et al. (2021). The results showed that most participants (61.2%) had read or heard about the role of AI in radiology. The radiologists differed in their responses and seemed to read more about AI compared to all other specialists. About 82% of the participants wished AI to be included in the curriculum of medical and allied health colleges. About 86% of the participants agreed that AI would be essential in the future. About 89% of the participants thought that AI would never replace radiologists. Based on a survey of 224 radiologists, Qurashi, et al. (2021) observed a positive attitude, a reasonable understanding, and high levels of motivation to learn AI and incorporate it into clinical practice. Some participants felt their jobs were threatened by AI adaptation. This belief might change with good training and education programmes.

Results of a survey of 157 senior pharmacy students by Syed and Al-Rawi (2023) showed that pharmacy students had a good awareness of AI in Saudi Arabia. Most of the students had positive perceptions about the concepts, benefits, and implementation of AI. Most students indicated that there is a need for more education and training in the field of AI. Early exposure to AI in the curriculum of pharmacy will help in the wide use of these technologies in their future careers.

A survey of 1026 healthcare providers by Elnaggar (2023) showed that more than half (55.2%) of the providers had good knowledge of AI. About 48.1% of them were familiar with the application of AI in their speciality. About 57.9% of them knew at least one term to differentiate between machine learning and deep learning. About 69.9% of them had used speech recognition or transcription applications at least one time in their work. About 73.3% of them believed that they would lose their jobs due to AI. A vast majority (84.9%) of the participants agreed that collaboration between medical schools with engineering and computer science faculties could be a game changer to provide a road for incorporating AI into medical curricula. The mean perception of AI in this study was 37.6. Age, level of health, health profession, and working experience significantly impacted the positive perception score. However, there was no significant association between gender, nationality, and Saudi regions with a mean positive perception score.

3.3 AI models

Jadi (2020) proposed an AI-NN integrated mobile healthcare system for Saudi Arabia. This enables predictive data analytics for faster assessment of the reports and analysis of the current conditions. The tested systems have yielded 95% accuracy in risk prediction. Experiments with neural networks (NN) and AI have been done in many medical applications to design different types of risk

management systems. This can be adapted to mobile healthcare systems also. AI and NN-integrated mobile healthcare systems can lead to better patient outcomes and satisfaction. It will also help to avoid extreme situations with timely medical interventions.

In a systematic review, Khan and Alotaibi (2020) provided many examples of AI applications in mobile healthcare systems. A model of an AI-integrated mobile healthcare system provided by the authors is given in Fig 4.

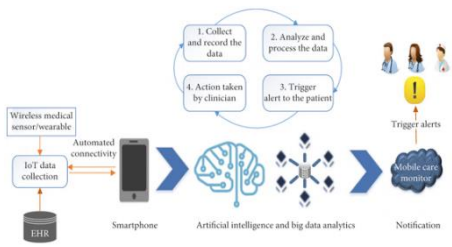

Figure 4. A model of AI and big data analytics-integrated mobile healthcare system (Khan & Alotaibi, 2020)

The authors proposed the architecture of AI and big data analytics integrated model as given in Fig 5.

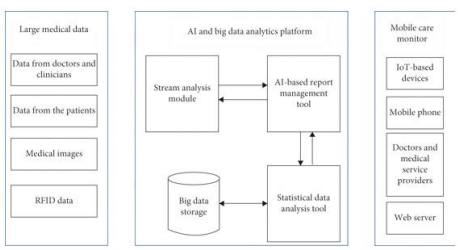

Figure 5. Architecture of the proposed AI and big data analytics integrated mobile healthcare system (Khan & Alotaibi, 2020)

Fig 5 provides a better idea of the AI integration. AI is specifically used for report management in this model. It includes risk predictions also since it is a report. Ensuring access to a large population and complying with ethical requirements are important when implementing the model.

3.5 Covid-19

Given the gaps revealed by the 2020 Covid-19 pandemic in healthcare systems, Nasseef, Baabdullah, Alalwan, Lal, and Dwivedi (2022) investigated the effects of using an AI-driven public healthcare framework to improve the decision-making process using an extended model of Shaft and Vessey's (2006) cognitive fit model in Saudi healthcare organizations. A survey of healthcare CEOs, senior managers/managers, doctors, nurses, and other relevant healthcare practitioners under the MoH, who were involved in the decision-making process relating to Covid-19 (N=362), was done. The survey results revealed a positive influence of internal AI-based Covid-19 problem domain representations on G2G knowledge-based exchange and AI-based Covid-19 diagnoses. G2G knowledge-based exchange had a positive influence on internal AI-based Covid-19 problem domain representations and AI-based Covid-19 diagnosis. Usage of AI-based healthcare technologies had a positive influence on AI-based Covid-19 diagnosis and AI-enabled Covid-19 problem-solving performance. AI-enabled Covid-19 problem-solving performance had a positive influence on the AI-enabled Covid-19 decision-making process. Experience-based decision-making moderated the impact of an AI-enabled Covid-19 decision-making process on G2G knowledge-based exchange.

The difference between AI-based and non-AI-based approaches towards Covid-19 patients was shown by Vaishya, Khan, and Haleem (2020) through a diagram, as given in Fig 6. The diagram explains the involvement of AI in the critical steps of treatment with high accuracy and reduced complexity and duration. The physician is focused on the treatment of the patient and at the same time, controls the disease with the AI application. Major symptoms and test analyses are done using AI with the highest accuracy. The total number of steps in the whole process is reduced making it more procurable.

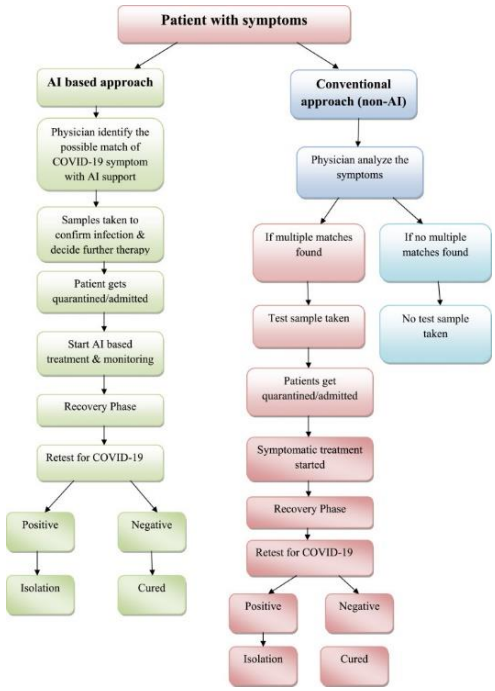

Figure 6. AI and non-AI approaches towards Covid patient (Vaishya, Khan, & Haleem, 2020)

Some AI-based techniques to combat Covid-19 infection and spread were reviewed by Jamshidi, et al. (2020). Some Deep Learning (DL) methods were illustrated to reach this goal. They included Generative Adversarial Networks (GANs), Extreme Learning Machine (ELM), and Long /Short Term Memory (LSTM). An integrated bioinformatics approach was used. In this approach, different aspects of information from a continuum of structured and unstructured data sources were integrated. It helped to form user-friendly platforms for physicians and researchers. These AI-based platforms can accelerate the process of diagnosis and treatment of the Covid-19 disease.

Al-Jehani, Hawsawi, Radwan, and Farouk (2021) outlined how AI techniques helped reduce the burden of Covid-19 on health workers to provide faster diagnostic tests and forecast the epidemic's outbreaks. The authors cited six papers, out of which, three described AI applications in healthcare. In one, the role of AI in the prevention of Covid-19 spread was demonstrated. In the second, AI helped rapid diagnosis of Covid-19. In the third, clinical and diagnostic applications of AI in dental and maxillofacial radiology were explored. A few AI applications for tackling issues related to Covid-19 were developed and used by Saudi MoH. AI can be applied to cover almost the entire range of activities in healthcare. A medical robot was created by Al-Muammar Information Systems Company "MIS".

The idea of this robot was created during the Hajj season of the year 1440 H (2018), and it contributed significantly to dealing with emergency cases to which pilgrims were exposed in places far from doctors. Smart pharmacy robots to distribute medicines, Nala, an AI medical application in Arabic, and the SAIR robot of Aramco to detect leakage of dangerous liquids and gases are some healthcare-related AI applications developed in Saudi Arabia. AI was used widely to detect Covid-19 through imaging processing. Other AI applications relevant to Covid-19 include those useful for contact tracing, drug discovery and development, optimising disease management to reduce fatality and forecasting. Other AI applications like Doctor B2 Robot, Tawakkalna, and Tabaoid were also developed during the Covid-19 period. According to Alghamdi, Alsulayyim, Alqahtani, and Aldhahir (2021), AI was used during the Covid-19 period to screen people using machines in large public places, provide fast diagnosis, and detect infected people with fever. This was especially useful during the Hajj season 2021, which ended in zero cases.

3.6 ChatGPT

The impact of ChatGPT on teleconsultants in managing their operations and services was investigated by Alanzi (2023). Focus groups were done with 54 participants (11 physicians, 24 nurses, eight dieticians, six pharmacists, and five physiotherapists) with

varying degrees of experience using AI such as ChatGPT in healthcare. Twelve themes were identified which positively influenced their use of ChatGPT for teleconsultations. They were informational support, diagnostic assistance, communication, enhancing efficiency, cost and time saving, personalizing care, multilingual support, assisting in medical research, decision-making, documentation, continuing education, and enhanced team collaboration. Six themes of negative influence identified were misdiagnosis and errors, issues in personalized care, ethical and legal issues, limited medical context/knowledge, communication challenges, and increased dependency.

3.7 Clinical decision support system

Alqahtani, Alshahri, Almaleh, and Nadeem (2016) categorised AI as a non-knowledge-based technique when used in clinical decision support systems (CDSS). AI technologies like genetic algorithms and ANN may be used in such cases. However, patients and doctors may not favour CDSS due to concerns about privacy and confidentiality issues. Physicians may be apprehensive of their relationship with patients in the presence of a third party. Despite some challenges, CDSS reduces medical errors and therefore, is a welcome tool in healthcare systems. The authors provided some successful examples of CDSS in Saudi Arabia.

Based on a literature review, Alowais, et al. (2023) concluded that AI is useful to diagnose diseases, develop personalized treatment plans, and assist clinicians with decision-making. However, it should not be used for automation of tasks. AI should be used for developing technologies that can enhance patient outcomes across healthcare settings. However, there are challenges related to data privacy, bias, and the need for human expertise that must be addressed for the responsible and effective implementation of AI in healthcare.

Findings related to some negative aspects of current methods to detect and prevent adverse drug reactions prompted Kassem, Alhabib, Alzunaydi, and Farooqui (2021) to suggest the use of AI to be integrated in the Saudi healthcare system to develop smartphone applications for improving both patient safety and signal detection of ADRs. These observations were based on semi-structured interviews with 15 healthcare professionals.

3.8 Use of AI in healthcare systems of other countries

Panch, Szolovits, and Atun (2018) discussed various AI applications in healthcare systems, their limitations, and possible solutions. The immediately possible step is the creation of narrow and targeted machine learning systems. This is aimed at tackling core information processing problems across a health system. It is to be used to support the capabilities of human decision-makers and establish new standards of effectiveness and efficiency in clinical and management operations.

A few examples of AI applications were categorised and tabulated by Iliashenko, Bikkulova, and Dubgorn (2019). They include fitness applications in smartphones and smartwatches. Various applications, opportunities, and challenges of AI in healthcare, already discussed above, were discussed by the authors.

Joshi, et al. (2022) aimed to determine and propose an MCDM for the crucial AI implementation barriers in public healthcare from the viewpoint of society, the economy, and the infrastructure. The benefits of AI in healthcare are early diagnosis, empowering patients, data-driven decision-making, assistance in surgery and telesurgery, support for mental health, use of natural language processing and cost reduction. The barriers identified were the same as those described above. The proposed model was not validated by the authors.

Huang, et al. (2018) developed a solution, "Smart Wireless Interactive Healthcare System" (SWITCHes) to facilitate objective data (related to obesity and overweight) reception and transmission in a real-time manner. Based on the user data acquired from the SWITCHes app and the auxiliary data from medical instruments, the SWITCHes app can engage users with tailored feedback in an interactive way through an artificial intelligence-powered health chatbot. The healthcare professional can provide more accurate medical advice to users. The SWITCHes app was developed based on the energy balance equation, to support and facilitate users to keep track of weight, dietary intake, and physical activity daily easily and conveniently.

3.9 Resource-poor, low- and middle-income and developing countries

Kaur, Garg, and Gupta (2021) noted that resource-poor countries do not benefit from the best practices of healthcare due to the lack of educated healthcare providers, infrastructure, financial and technical issues, etc. The data are in various formats and the quality of data is suspect. Challenges of development, regulations, and sustainability of business models. Data privacy and ethics, healthcare integration, scanty evidence for using AI, and lack of trust at all levels also exist. Healthcare systems in resource-poor countries face many challenges like increased healthcare costs, patient safety, overtreatment, and failure to adopt best practices for healthcare. Thus, the use of AI applications also is very limited in these countries. The use of robots for surgery and virtual assistants for nursing might overcome human resource limitations in these countries. Some methods of using AI applications in resource-poor countries were proposed by Wahl, Cossy-Gantner, Germann, and Schwalbe (2018).

The basic principle of this is to use AI for building intelligence into existing systems and institutions rather than starting from scratch or hoping to replace existing systems, even if broken. Expert systems can replace physicians, as there is a shortage of qualified physicians in resource-poor countries. Some examples of AI applications which can be used in resource-poor countries include predicting the need for resuscitation for a newborn child diagnosed with British Asphyxia; prediction of dengue fever incidence and spread; use of Global Health Monitor for surveillance and outbreak predictions of infectious diseases; support for clinical decision-making systems, to guide cancer treatment, planning and improving primary healthcare systems; and signal processing to predict birth asphyxia from the first cry of the baby. However, the main challenge is to build large volumes of high-quality data required for these purposes.

Based on a review, Guo and Li (2018) concluded that the promotion of medical AI technology in rural areas of developing countries might be one means of alleviating the inequality between urban and rural health services. The establishment of a multilevel medical AI service network system may be a solution. Earlier, computer-assisted medical technology was the term used for medical AI technology. In 1998, a computer-assisted diagnostic system, the Early Detection and Prevention System (EDPS), was developed in India for rural clinics without a physician. The system provided guidance and recommendations for nurses or experienced paramedical personnel. A study conducted by Kempegowda Institute of Medical Science in Bangalore, India showed significant consistency between the EDPS and physicians of 94% for 933 patients. Patient responses were positive, they believed the computer system was more accurate and had more in-depth interaction with them than health personnel they had met. The village nurses were interested in using this system in their practice. Wearable devices and portable testing equipment connected to hospitals via the cloud are also useful in rural areas.

AI-powered chatbots can directly communicate with patients, offer treatment

suggestions, and train health workers in rural areas. A low-cost swallowable endoscopic capsule with AI analysis technology can be used to screen for upper gastrointestinal cancers. It can replace expensive or difficult traditional screening equipment. This device is highly suitable for rural areas of developing countries, where most gastric cancer cases occur. The authors proposed a multilevel medical AI technology designed specifically for rural areas of developing countries. It contains a basic level, a middle level, and a top level to handle various processes of patient care, keeping and using records and management. However, financial, technical, training, infrastructure, professional, and relationship with patients are some challenges related to the implementation of medical AI in rural areas. The lack of appropriate medical AI technology for resource-poor developing countries was highlighted by King and Beck (1990).

Since AI-based health applications are recent in low and middle-income countries (LMICs), few robust and contextualized evaluations can guide informed decision-making in these contexts. There is a significant risk of unintentional adverse consequences. Their use in health care services remains poorly documented. It is possible to identify many risks and challenges specific to LMICs, like those of resource-poor countries identified above. To address these issues, Alami, et al. (2020) proposed five building blocks to guide the development and implementation of more responsible, sustainable, and inclusive AI healthcare technologies in low and middle-income countries. They are training in AI for all stakeholders, a robust monitoring system, a system-based approach, social policies, and responsible leadership.

With AI, health systems can be made more predictive by detecting risk factors and helping health professionals respond faster to prevent disease. To address some common challenges faced in adopting AI in healthcare in developing countries, the working group of the Broadband Commission for Sustainable Development proposes six building blocks for digital health systems (Ikram Ahida et al 2023). These were: formulate and execute a national digital health strategy; create policy and regulatory frameworks to support innovation with the protection of security and privacy; ensure access to digital infrastructure; ensure interoperability of digital health system components; establish effective partnerships; and provide adequate funding. Case studies from Tanzania, the USA, Chile, Brazil, Kenya, and Senegal to support these proposals. Digital health systems can be used as forerunners of AI technology (Aerts & Bogdan-Martin, 2021).

AI can help respond to the Covid-19 pandemic in many ways. They include integrating different types of data from different sources, determining the most effective treatment for each patient, insights into differences among policies for consistent decisions at all levels, recruiting samples for clinical trials with targeted treatment to some subgroups if needed, and transfer learning experiences. AI is suitable when there are resource limitations. However, the currently available AI-based support systems for chronic diseases are unsuitable for Covid-19 because the former is an individual health problem, and the pandemic is a public health problem. Using the large volume of EHR data, it is possible to predict individual-level risks to the pandemic if AI methods are applied. AI can help in determining the different diagnostic and treatment policies, policy priorities, possible improvements in the current policies and increasing the level of confidence in the policies.

Thus, the use of AI-based methods at individual, hospital and national levels can solve many problems associated with dealing with pandemics like Covid-19. The authors cited the UK healthcare system to explain various aspects (van der Schaar, et al., 2021). Senbekov, et al. (2020) noted that digital healthcare technologies were highly useful during the recent pandemics, including Covid-19. The disastrous dissemination of Covid-19 through all continents necessitated

fast and effective solutions to localize, manage, and treat the viral infection. The use of telemedicine and other e-health technologies supported by AI helped to lessen the pressure on healthcare systems. According to McCall (2020) AI is causing a paradigm shift in healthcare with its applications in the Covid-19 outbreak, including predicting the location of the next outbreak. This application was effectively demonstrated by the Canadian company, Blue Dot. It was the first organisation to reveal news of the outbreak in late December. Another application was that of Benevolent AI of Imperial College London, which reported that a drug approved for rheumatoid arthritis, baricitinib, might be effective against the virus. Insilco Medicine based in Hong Kong announced that its AI algorithms designed six new molecules effective against viral replication. The authors discussed many AI-used collections and the application of data to protect healthcare workers and predict the spread behaviour of Covid-19. AI was used to analyse CT images of lungs for rapid diagnosis of Covid-19 among patients. Blockchain combats pandemics like Covid-19 by enabling decentralized healthcare data sharing, protecting users' privacy, providing data empowerment, and ensuring reliable data management during outbreak tracking. AI offers intelligent computer-aided solutions by analysing a patient's medical images and symptoms caused by coronavirus for efficient treatments, future outbreak prediction, and drug manufacturing. Integrating both blockchain and AI could transform the existing healthcare ecosystem by democratizing and optimizing clinical workflows. Jabarulla and Lee (2021) conceptually proposed a decentralized, patient-centric healthcare framework based on blockchain and AI to alleviate Covid-19 challenges. The authors also explored the significant applications of integrated blockchain and AI technologies to augment existing public healthcare strategies to tackle Covid-19.

3.10 Ethical aspects

In a commentary, Mitchell and Kan (2019) opined that data will become central to healthcare systems. Big data and AI tools will be used widely for surveillance, planning, and management. Personalized data will be stored in the form of universal electronic record systems and customized treatment protocols. Being a disruptive innovation, the growth of digital healthcare has some challenges, including who owns, controls, and manages and who is responsible for errors in the data being collected and processed and how to maintain privacy and confidentiality in this data-rich world. The prospects of these technologies will reflect in universal access to internet-based information, digitally supported healthcare workers, most healthcare at home, improved transportation, and logistics management.

The Pent E approach (Fig 7) was suggested by Prakash, Balaji, Joshi, and Surapaneni (2022) to address ethical and legal issues related to all stakeholders of AI applications in healthcare systems. The approach consists of a five-step process of evaluating, enumerating, engaging, enforcing, and executing for identifying, analysing, and implementing interventions.

The report of the independent High-Level Expert Group on Artificial Intelligence set up by the European Commission, "Ethical guidelines for trustworthy AI" identified trustworthy artificial intelligence as consisting of three components: (i) compliance with all applicable laws and regulations; (ii) adherence to ethical principles and values; and (iii) promotion of technical and societal robustness. These components are important throughout the cycle of development, deployment, and use of AI. The focus of this report is ethics and robustness. The legal aspects have not been considered. Ethical guidance for trustworthy AI is regarded as a fundamental right. The four principles underlying this right are respect for human autonomy, no harm,

fairness, and explicability. Translated into action, these involve human agency and oversight, technical robustness, safety, privacy, data governance, transparency, diversity, no discrimination, fairness, societal and environmental well-being, and accountability. Some of these conflict with each other. Hence ensuring responsible governance and involving all stakeholders is essential. AI and the challenges of using it are highly context-specific. EU's fundamental approach is aligned with the Sustainability Development Goals of the UN. Ethical challenges of AI implementation at the global level include conflicting goals between the interests of the AI industry and UN goals, unequal contexts across countries, risks and uncertainties in lower-income countries due to poor living conditions that could affect precautionary steps to avoid risks, the opportunity cost of replacing human intelligence with artificial intelligence, and weaknesses in the political system (Bærøe, Miyata-Sturm, & Henden, 2020).

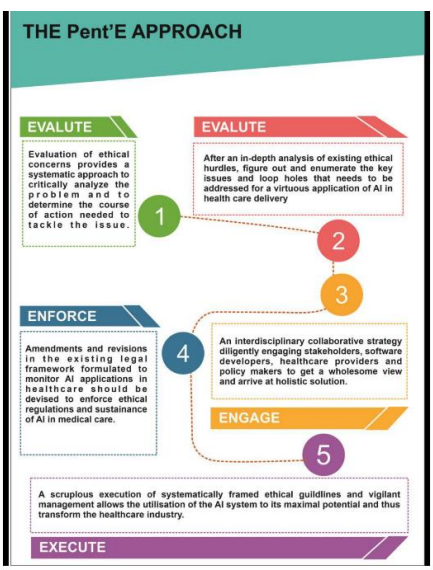

Figure 7. The Pent E approach (Prakash, Balaji, Joshi, & Surapaneni, 2022)

Li, et al. (2020) proposed a secure framework for SDN-based Edge computing in IoT-enabled healthcare systems. In the framework, Edge servers authenticate the IoT devices through a lightweight authentication mechanism. After the authentication, the IoT devices collect data from the patients. The data are sent to Edge servers to store, process, and analyse them. The Edge servers are connected to an SDN controller, which performs load balancing, network optimization, and efficient resource utilization in the healthcare system. The proposed framework was evaluated using computer-based simulations. The system performed better than traditional networks.

A review of the literature by Murphy, et al. (2021) revealed that most papers focused on the ethics of AI in healthcare rather than the ethics of AI in public and population health. Common ethical concerns identified by the selected papers were related to privacy, trust, accountability and responsibility, and bias. Ethics of AI in global healthcare, especially related to low and middle-income countries.

In WHO guidelines (WHO, 2021), the key ethical principles of AI in healthcare were described as "the protection of human autonomy, protection of human well-being, safety and public interest, ensuring transparency, explainability and intelligibility, fostering responsibility and accountability, ensuring inclusiveness and equity, and promoting responsive and sustainable AI." (p xii to xiv).

4. Discussion

4.1 Comparison of Saudi Arabia and other countries

The papers reviewed on the use of AI were from resource-poor developing low to middle-income countries. Covid-19 was a major area of AI application both in Saudi Arabia and other countries. The serious issue of ethical aspects when using AI in healthcare was covered only in the case of other countries.

4.2 Some quantitative trends

Frequency according to year of publication
Table 1 provides the distribution of the 40 selected papers according to their years of publication.

Table 1. Frequencies of papers according to their years of publication

Year	No
1990	1
2016	1
2018	4
2019	2
2020	10
2021	12
2022	4
2023	6

Most papers (22) were published during 2020-2021. Covid-related papers accounted for most of these papers, as they were published in 2020. The topic-wise distribution of reviewed papers. The topic-wise distribution of reviewed papers is presented in Table 2.

Table 2. The topic-wise distribution of reviewed papers

Saudi Arabia-	
Topic	**No**
Low levels of acceptance and adoption	8
AI models	2
Covid-19	5
ChatGPT	1
Clinical decision support systems	3
General	1
Other countries-	
Topic	**No**
AI applications	4
Resource-poor low-to-middle-income countries	6
Covid-19	4
Ethical aspects	6

In the case of Saudi Arabia, eight papers were on low levels of acceptance and adoption of AI in the country's healthcare systems. There were five papers on Covid-19. In the case of other countries, there were six papers each on resource-poor low-to-middle income countries and ethical issues and four each on AI applications and Covid-19.

4.3 Comparison of Saudi Arabia with other countries

Item-wise comparison of various aspects related to AI applications in healthcare systems of Saudi Arabia and other countries is presented in Table 3. Other countries are resource-poor, low-to-middle income and developing countries. Their economic development status is almost similar or inferior to Saudi Arabia, depending on the specific country.

Notably, Saudi Arabia was slightly late in adopting AI because it started AI applications during the Covid period out of necessity. Many other developing countries had at least initiated and were testing some AI applications before the pandemic. Saudi Arabia started by interconnecting hospitals using AI. Its AI applications made a quantum jump during the Hajj seasons of 2020 and 2021, as many innovative AI applications were implemented for the protection of pilgrims from the pandemic. However, there is no evidence that these innovative applications were continued thereafter for own citizens' healthcare. Other countries, meanwhile, developed mobile fitness applications for general use. Problems in rural areas are yet to be fully solved although empowering local health workers with AI applications has been suggested.

Table 3. Comparison of Saudi Arabia with other countries

Item	Saudi Arabia	Other countries
Starting AI use	From Covid period.	Even earlier, gradually from simple to more complex applications.
Areas of AI use	Interconnecting hospitals	Mobile fitness applications
	Mobile care, Hajj season	Problems in rural areas-empower local health workers with AI applications.
Data-driven health services	Mussawah	Some possible selective applications to reduce errors, build quality data, and ethics, improve patient outcomes.
Diabetic care	AI-integrated e-health	
Acceptance and adoption of AI	Low level	Varying, but generally low level due to resource constraints, technical problems, poor quality and absence of required data, and many other problems.
Availability of good quality required data	Low	Low
Development of models	AI-integrated mobile applications.	MCDM, SWITCHes, Guidelines, Building blocks.
Fear of loss of job due to AI	High	High
Need for education and training in AI	High	High
Ethical issues	Serious	Serious
Status of adoption	Factors favourable, but adoption low.	Factors are not that favourable, adoption is low.
AI use during Covid-19	G2G knowledge exchange for decision-making, diagnosis, reducing steps to reach patient outcomes, prevention, reducing the workload of healthcare workers, reducing costs, and medical robots in hajj season.	Data integration for decision support, risk prediction, diagnosis, drug development, and surveillance. Blockchain and AI integrated systems.
Use of ChatGPT	Tested and found useful for various purposes.	
Clinical decision support systems.	Developed	
Ethical aspects	Very important	Very important, the Pent E approach, EU and WHO guidelines, other models.

Some data-driven approaches were developed both in Saudi Arabia and other countries. The use of AI-powered e-health through mobile phones was developed in Saudi Arabia for diabetic patients due to the high and rapidly increasing prevalence of this disease in the country. However poor compliance with the recommendations by diabetic patients is a problem. The acceptance and adoption level of AI in healthcare are low in both Saudi Arabia and the resource-poor low-income countries. In other countries, these levels are better. Availability of good quality required data is a serious problem in both contexts. Many AI-integrated models are available in both contexts. There is a high level of fear of losing their jobs among health workers. Hence, there is a dire need for education of

the health workers. In tackling problems related to Covid-19, Saudi Arabia and other countries differ. Saudi Arabia used AI for G2G knowledge exchange for decision-making, diagnosis, reducing steps to reach patient outcomes, prevention, reducing the workload of healthcare workers, reducing costs, and medical robots in hajj season. Other countries used AI for data integration for decision support, risk prediction, diagnosis, drug development, surveillance and integration of blockchain and AI in healthcare systems. One paper reported the usefulness of ChatGPT for various purposes related to public healthcare. Saudi Arabia is now working on developing clinical decision support systems with AI. Although ethical aspects are important in any context, more papers discussed it in the case of other countries.

Overall, it can be said that there are both similarities and differences in the approaches of Saudi Arabia and other developing countries in the adoption and use of AI in their healthcare systems.

4.4 Methods to raise the level of AI applications and patient outcomes in Saudi healthcare systems

Based on this review and comparing with other countries, some possible methods to raise the level of AI applications in Saudi healthcare systems for enhanced patient outcomes are listed below.

1. Saudi Arabia developed several innovative AI applications for specific contexts like the hajj season, comparable with developed countries. However, most of these applications were not carried forward for application in protecting the health of its citizens. Saudi Arabia needs to consider how best these innovative applications can be integrated into its public healthcare systems.
2. Unlike the resource-poor low-income countries, Saudi Arabia is a resource-rich and high-income country. It should use its resources efficiently to develop AI-integrated models for the holistic healthcare of the public.
3. Healthcare workers need to be educated on AI, its benefits, and drawbacks and how to use AI ethically for better patient outcomes. Training will remove the fear of losing jobs when AI is adopted.
4. Timely and regular collection of high-quality public health status data is important for effective AI applications.
5. Equity and social justice need to be ensured by providing access to AI-integrated healthcare to people in remote locations.
6. More research is required to develop AI-integrated decision support systems. Further research and development is required on the AI-integrated mobile e-health application for diabetic patients and other chronic diseases.

5. Conclusion

The review of 20 papers each for Saudi Arabia and other countries revealed both similarities and differences in their approaches to use AI in healthcare systems. Saudi Arabia is a late-comer. However, it developed many innovative AI applications for hajj season. These applications can be used for public health problems also. Being a resource-rich and high-income country, Saudi Arabia must only be willing to adopt AI in its healthcare system. There is a lot of scope for researching and developing more innovative AI applications to facilitate the building up of a healthy and productive population, as stipulated in its Vision 2030 goals.

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