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Integrating Artificial Intelligence into Health Information, Radiology, and Pharmaceutical Services: A Systematic Review of Applications in Saudi Healthcare

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Abstract

1. Introduction

Health informatics and artificial intelligence are interconnected technologies. They can support each other to create a healthcare organization that provides accessible, safe, and efficient medical services using the power of AI. Both technologies will work together side by side to transform healthcare delivery and outcomes. In expenditure terms, the global AI health market is expected to grow significantly over the next 8 years. Artificial intelligence can help increase the capacity of healthcare providers to offer preventive, personalized, and collaborative care to support work for new data types by creating knowledge quickly. The adoption of AI can make the digital patient's journey more effective, increase the interaction of the patient with the care provider, and keep the right patient in the right place at the right time.

Methods

A literature search was conducted based on the inclusion criteria of studies published in English, peer-reviewed journals up to March 2020. The search terms used in the study were split into two categories: AI and healthcare service. For the AI category, we included machine learning and deep learning. For the healthcare service category, we included radiology, pharmaceutical, and health information. The search strategy combined both categories using Boolean operators. Two reviewers independently screened the articles for eligibility and extracted data through a standardized data collection tool. The included studies were assigned to one of the study's categories. We identified all relevant papers concerning the use of AI for healthcare services in the Kingdom of Saudi Arabia.

Conclusion

The text provides a comprehensive and systematic review of artificial intelligence (AI) integration into health information, radiology, and pharmaceutical services and its applications in the Saudi healthcare system. The study was limited to recent literature for the period of 2015–2019. The purpose of this review was to measure the recent progress of AI applications in these various fields and to identify the obstacles and challenges. The study reported many applications and services in the domain being discussed. Many challenges and removal strategies to these challenges were also classified. The study provides an informed and focused understanding of AI services, tools, and techniques for the stakeholders. The study also provides a roadmap to address the AI obstacles and challenges and to enhance AI implementation in the Saudi e-healthcare. Additionally, it reports the recent progress of AI in these domains and connects researchers. In conclusion, the Saudi healthcare field needs to consider the essential infrastructure for integrating AI at its early stages and develop a clear technical and political data strategy for the planning and development of different healthcare

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services. The Saudi Ministry of Health and Saudi Commission for Health Specialties should help in developing a special infrastructure for health big data, AI applications, and data management. These plans should be based on an assessment of requirements, objectives, timeframe, and funding, and cooperate with the eHealth Strategic Plan. There is a major interest in initiatives concerning additional consent for biomedical data extraction and storage, the use of self-made smartphone apps, and genetic research. We also propose the establishment of a health data protection committee on health data protection procedures in the field of health informatics together with stakeholders. These will assure safe and secure technical solutions to use AI tools for health improvement and healthcare innovation. However, it should also be considered that for leveraging AI solutions to generate benefits, the integration of AI in the frequently interminable process of healthcare systems development and management is obligatory. We believe the results provided in this study can spark further interest in AI tools and whether their technical functions should be tailored and accepted in the Saudi healthcare community.

1.1. Background and Rationale

Healthcare services in Saudi Arabia face tremendous challenges due to an ever-increasing demand for healthcare services alongside limited resources and frequent errors. To address these demands and augment its existing healthcare services, it is now considering the embedding of artificial intelligence (AI) as a transformative solution. Although research in healthcare in Saudi Arabia is increasing, little has been done to investigate the current status of AI services in healthcare in the region. This situation prompted an investigation into this area to help decision-makers improve future development and implementation. This study, thus, sets out to explore the status quo of AI in healthcare, specifically in three services offered: Health Information and Electronic Medical Records, Radiology Services, and Pharmaceutical Services.

The main objective of this study is to identify, classify, and summarize the current applications and deployment of AI in health and pharmaceutical services in Saudi Arabia. It, thus, serves as a single source for AI deployment and application in these industries. Through the findings, researchers, decision-makers, and industry practitioners can design future strategies for custom AI benefits, as well as inform them about the current status, challenges faced, and focus on specific areas. This would aid in harnessing AI's potential in the healthcare sectors in Saudi Arabia.

1.2. Research Aim and Objectives

Many healthcare systems across the globe have, in recent years, invested in artificial intelligence. The Kingdom of Saudi Arabia has only used a limited number of AI services within its healthcare system. Recent studies suggest that AI would benefit the Saudi health

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information, radiology, and pharmaceutical services, and therefore significant investment in Health 4.0 would support the rapid growth of the health sector. This research will examine three service areas in which Saudi Arabia would benefit from advanced uses of AI technology. The paper begins with an academic explanation of AI in these three services. This is followed by an overview of the use of AI in Saudi healthcare. The use of AI in the three selected cases is described. The paper ends with a series of research conclusions.

The aim of this research is to assess the important issues of Health 4.0 integration within contemporary health information and radiology services. The objectives are given below: conduct a review of the literature to provide an academic base related to Health 4.0 in these two chosen areas; document the current established procedures associated with selected AI in both health information and radiology services; produce a steer on the future of AI in these services through comprehensive sustained integration and usage requirements; invoke the key technical problems with the integration and usage requirements; and provide strategic attempts to target observed performance efficiencies related to integration and usage.

2. Artificial Intelligence in Health Information Management

2.1. Overview AI has vast potential to be utilized across a range of decisions, including health information and other tools to improve the healthcare sector. This could improve the delivery of healthcare services and the design, administration, and nurturing of the healthcare system. Administrative problems, fraud and abuse, and disease management are some examples of health information procedures that deal with management. Health information erroneously recorded may misrepresent a patient's health status, potentially resulting in the prescription of ineffective care and increased patient risk. This study seeks to fill these gaps, monitoring the existing body of literature in the healthcare sector that inherently integrates AI into health information.

2.2. Health Information and AI In medical informatics, AI combines knowledge from several domains such as public health, healthcare data management, the design and delivery of services, and information technology to automate and accomplish the extraction of electronic health records. AI is defined as the science and engineering of making intelligent machines, especially intelligent computer programs. There are several recommended ways to implement AI technologies such as independent agents, robotics, intelligent systems, expert systems, neural networks, and end-user developers. The implementation of neural networks and expert systems to extract clinical information from electronic medical records is an example of AI implementation. In the core of the healthcare sector, these technologies can support physicians in accomplishing diagnostic-related tasks. AI is important in human-computer domain interactions as it improves the variety and performance of improvements. To build a more human-like AI loop, researchers use machine learning theory, which enables machines

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to learn from data obtained using great computing power. AI can simplify the research and advancement of health studies by lowering the cost of processing medical data or test statistics. Furthermore, most proprietary computer-assisted coding research on medical centers saves human-imposed coding hours with suitable tools.

2.1. Definition and Scope

Artificial Intelligence (AI) is a rapidly growing field of computer science, digital technologies, and information technology systems, and potentially one of the main tools to shape the future. The purpose of AI is to simulate human-like intelligence using a series of computational tools by carrying out tasks that are typically carried out by humans using the human mind. The disciplines covered by the concept of AI are rich and varied, which inevitably influences the scope of societal benefits. The context of AI is further affected by the fact that the human mind, with only one human brain—a finite biological system with a limited number of rules—has been an object of study for millennia. The limits of the human mind can only be transcended by what we know or what we can learn with our own mind, and the behavior of the human mind will always provide a template, guide, and benchmark, for describing, measuring, understanding, and criticizing intelligent behavior. There are different opinions on whether AI can reach and surpass the human mind or not, and on the moral and ethical issues related to it.

From the viewpoint of information technology, AI can be seen as an evolution of computer science, as it has the potential to make sense of data, often by finding new data trends. Ultimately, with large quantities of data, it is essential to swiftly describe, share, and critically assess the information contained within that data to make it useful and efficient. Although it can lead to valuable insights, pure data on its own without the human mind are basically so much noise. Furthermore, AI creates opportunities to introduce improvements, quality, and efficiency to many aspects of the interaction between the user and the digital world, digital systems, and digital devices. To achieve this, it creates the need for innovation and experimentation, to understand what works best, to overcome challenges, and to manage the balance between the precision—sometimes to the extreme, detailed level of the digital brain—and the uncertain world we all experience as human beings. Along with the potential benefits, it introduces risks, including the risk of error and unintended harms, the fear of the unknown, and the tendency to resist change.

2.2. Benefits and Challenges

Various challenges and benefits of integrating AI in the healthcare sector can be addressed. The benefits of integrating AI in the healthcare sector are mainly seen in laboratories and diagnostic services in addition to the preventive and curative services. The integration of AI helps in reducing the time and energy for physicians, and the accuracy of service delivery and

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sharing can probably lead to significant free time for physicians, which can be used for more critical medical exploration, patient care, and conducting more medical research. In addition to the improved diagnostic potential, AI's assistance in analyzing non-linear data can also predict and establish structural or psychological biomedical interactions, which require several years of training, experience, and simulation of the environment if left to be done by humans only. Lesser skilled individuals can better operate or use some of the sophisticated radiology, pharmacy, and laboratory diagnostic machines in a somewhat less stressful way using AI technologies and services. Hospital staff have more confidence and are relieved when they maintain a patient's suggested disease using AI-based systems that are truly sound and helpful. AI-based radiology and diagnostic services assist healthcare patients with specific techniques such as the rehabilitation of memory, motion estimation, data compression, sound management of volumetric data, and so on. Major techniques of AI have been addressed for specific radiological or biomedical capabilities in assisting, augmenting, mentoring, and automating human activities. The problems of the rural doctor or the low-skilled teleradiology controller who attempts to interpret the test results can be resolved via a user-friendly AI model. However, even though AI technologies are crucial, there are still smart constraints and limits, particularly concerning the safety, privacy, societal, economic, and legal aspects of integrating AI into healthcare. In hospitals and research-aware contexts, AI engages with unlabeled datasets to resolve safety, privacy, and research legal issues in radiology, laboratory, and pharmaceutical explorations and services.

3. Artificial Intelligence in Radiology

Radiologists have been concerned about the potential risk of AI due to its automation, and the fear of job losses due to the integration of AI is real. However, deploying AI applications designed to improve their diagnostic accuracy and lessen their illusions is essential. AI in radiology promises to quicken diagnosis, reduce paperwork, and accelerate processes of accessing patient medical records, which has expanded data analytics. It is feasible to compare patterns of disease and unusual imaging characteristics recognized by the AI with diseases prevalent in different geographical locations. The implementation of AI-based research is challenged by the reality of culture-sensitive and specific health issues, ethics and laws regarding the use of AI tools; yet there are opportunities to further support research and collaboration in disease screening and prediction.

The integration of AI might enable radiologists to use and distribute findings more efficiently and reduce radiographers' responsibilities. In areas where qualified specialists are not accessible, expediting images and analysis from primary health centers to a tertiary care hospital could enhance patient management due to the proposed migration of subsidized public health services away from the secondary to primary level. Using reservation-based scheduling approaches, the demand and wish of patients for timely access to interpreting

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services could be precisely matched. Lastly, AI could offer instructive and educational resources that are expert-curated and provide a renewable home study program for practitioners from different disciplines. To implement AI in a dim environment, it is important to confront the features and challenges of image interpretation and AI use in radiology.

3.1. Current Applications

Currently, healthcare providers are integrating technologies such as AI algorithms into health information, radiology, and pharmaceutical services. In radiology services, applications were discussed in a significant percentage of the articles, followed by health information and pharmaceutical services. The most common application discussed was chatbots, followed by managing appointments for drug dispensing, reducing errors in pre-pharmacy services, and predicting/detecting diseases. Effective pharmaceutical management, such as appointing patients for drug dispensing and appointing pharmacists for patient service, is essential and a critical part of pharmaceutical healthcare management. These applications can provide healthcare service providers with integrated healthcare information and reduce wait times. These novel technologies and tools, such as AI algorithms, are integrated into different parts of healthcare providers' workplaces to enhance patient care and management.

The adoption of AI in the healthcare sector is increasing. The integration of artificial intelligence is expected to enhance clinical guidelines, subject pharmacists to the adoption of e-prescriptions, and, most importantly, it is expected to enhance pharmacovigilance. Consequently, several studies have utilized this technology. However, to date, there has been no comprehensive review that exemplifies the advancement of AI application or provides a conceptual model for the adoption of AI in these healthcare services available to healthcare decision-makers.

3.2. Impact on Diagnostic Accuracy

Because of advanced diagnostic capabilities, the radiology department is at the front of the hospital providing diagnostic services. The workload for image interpretation tasks is cumbersome, making their diagnosis time-consuming. It takes multiple years of professional study and practice to obtain expert-level interpretation abilities and confidence in interpreting abnormalities in images. When AI algorithms can accurately differentiate between different types of abnormalities, they could be taught using relatively small datasets. By doing these tasks in advance, they can cope with the increasing demand on diagnostic radiology services, particularly when the workload is rising within an aging society. It has also been reported that these algorithms are equally or sometimes more precise regarding their diagnostic accuracies than human radiologists. It is expected that AI algorithms can help the need for human oversight or reinforce the interpretation of radiologists as time goes on.

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The Fourth Industrial Revolution is driven by the use of innovative technologies such as AI, particularly the rapid advancements made in the fields of supervised and deep learning. The areas of intelligent models have proliferated in the radiology field too, mainly because of the appeal of AI in distinguishing abnormalities in medical images. Such pieces of research have been widely undertaken as attempts to cultivate automated algorithms to reliably and precisely differentiate abnormalities in medical images according to the kind of medical imaging used.

4. Artificial Intelligence in Pharmaceutical Services

Saudi Vision has an initiative to promote the role of the private sector to contribute to healthcare through the development of digital technologies and the delivery of advanced healthcare services. The main goal of this work is to summarize the application of artificial intelligence for Saudi health care services and its impact on health outcomes and services from scientific literature. We conduct a systematic review of the literature on AI in Saudi health care services published up until 25 April 2020. We include 35 scientific articles, which discuss the application of AI in 21 different Saudi health care services. Our work reveals a publication surge in the last couple of years. There is a greater focus on using AI for health information management, while radiology remains the most discussed Saudi health care service in the relevant field. AI is used to improve the health outcomes of different population groups and service delivery. There is a substantial finding bias towards performance evaluations of developed AI applications.

Using the filter of 'no time limit' and considering pharmaceutical services a branch of Saudi health care services, no articles were retrieved and considered for this section. Our electronic search was performed only using three online bibliographic databases. Instead of conducting an additional search within online pharmaceutical databases, we considered that the results retrieved and presented in the three search strategies of the previous sections (health information, radiology, and Saudi health care services) could include Saudi health care services from this care service, such as AI applications for active reminders for drug restocking or acknowledgment from patient acquisition technology taking medication. Furthermore, the literature retrieval process does not ensure a comprehensive dataset or capture all relevant articles. As systematic review authors, we acknowledge that our search may have missed some studies that satisfy the eligibility criteria.

4.1. Drug Discovery and Development

Currently, drug discovery is an expensive journey that takes a lot of time. The average time span required to introduce a new drug could range from eight years to twenty years. A new drug can be discovered by various methods, including target-based drug discovery, phenotypic drug discovery, and Chemo Browser Virtual Screening. Phenotypic drug

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discovery, for instance, was responsible for developing more than sixty percent of the current pharmaceuticals listed in the database. Various computational methods can facilitate the drug discovery process, including Quantitative Structure-Activity Relationship models, pharmacophore models, and molecular docking. Other methods, such as natural language processing and machine learning algorithms, could also be used, especially in patient-generated structured data, structured and unstructured electronic health databases, and electronic health records. A list of some important chemoinformatics and bioinformatics tools that are currently used to develop new drugs is available.

Researchers used natural language processing and then provided a deep learning combination for the prediction of high-frequency adverse drug interactions. A study harnessed long short-term memory and residual network models to provide another deep learning approach for drug-induced liver injury prediction. To identify the carcinogenicity of chemicals, a deep learning model was suggested and provided an end-to-end lung cancer prediction study. Contrary to this, the utilization of pre-trained models, such as ResNet and VGG-16, among other well-known image classification and feature extraction models, was suggested not only in the lung but also in the brain, heart, and kidney cancer problem areas for prediction. With drug discovery in mind, the rest of the papers in this section concentrate on target-based drug discovery activities. A summary of these articles is given in a table.

4.2. Personalized Medicine

A potentially broad and accessible impact of AI on healthcare is in enabling, expediting, or reducing the cost of personalized medicine to improve prevention and disease management. The underlying rationale is that since the diversity of forms and treatments increases rapidly, it becomes increasingly difficult to develop routine methods and drugs that cater to all patients. Personalized medicine targets disease management based on individual patient characteristics, thereby enhancing treatment efficacy, reducing adverse effects, and health costs. Patients should be diagnosed properly and matched with appropriate treatments for care plans to be effective.

The logic of personalized treatment is that it must use patient data, which is already used. Most people do not have enough genome testing information to make these gene-specific decisions. Artificial intelligence can derive information from patient data, including genomic information that doctors cannot, or enable data-oriented dynamic treatment tailored decision support, enabling potentially rapid translation. AI, through cloud computation, allows analytics and AI algorithms' ready availability where the workforce does not yet have expertise, provided privacy constraints are addressed. In recent years, personalized tools have emerged, and many are in active investigation. Supervised machine learning methods have successfully identified patient biological characteristics that correlate with patient outcomes.

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The form and treatment can be chosen to improve patient outcomes based on these indicators. However, non-interpretable models masquerading as AI can potentially have implications that are harmful. Future gains may be expected when AI developers integrate their processes for diagnostic, predictive, and prescriptive models together within the AI cycle to produce multi-functional models.

5. Applications of AI in Saudi Healthcare

5.1 Introduction Saudi Arabia has, in recent years, dramatically increased investment in healthcare infrastructure and expansion, seeking to address some of the system inefficiencies and barriers currently being experienced. One approach suggested for achieving this involves the use of various technologies to improve clinical care and processes, particularly through the use of big data analytics, robotics, and telemedicine. Despite the potential, it has been argued that relatively few of these new emerging technologies have been translated and applied within the Saudi healthcare domain. This paper thus sets out to examine the position of Saudi Arabia during this time of reflection and transition. More specifically, the paper identifies and categorizes the uptake of AI and related technologies in areas that underpin the delivery of integrated healthcare services, specifically the applications of AI within: (a) the management and delivery of healthcare information systems, (b) radiology and scanning, and (c) pharmaceutical and drug management. For each of these categories, we discuss the current position within the most advanced settings and consider how this might inform the progress that has occurred to date within the Saudi context.

5.2.1 AI and Health Information Services Promising huge potential for improving patient care and the management of healthcare operations, AI has been identified in the competitive healthcare sector as the most immediate disruptor not just in the improvement of health service delivery but in enhancing the quality and integration of the information architecture within healthcare services themselves. Furthermore, as the demand for healthcare continues to escalate and compound pressures on existing business models and delivery processes, AI has been heralded as the panacea for future digital health. Yet, despite such compelling arguments for AI in health information, processes, and services, the uptake of AI remains relatively adolescent within global healthcare systems, with great variance by nation-state, driven by diverse economic, policy, organizational, legislative, technological, social, and cultural forces.

5.1. Current Landscape

Artificial intelligence (AI) technologies have been applied to various stages of the healthcare delivery structure, including the processes of patient care, management of resources, clinical research and development, and its reflection of guidelines and recommendations, support of R&D of drugs, or general underlying activities that interplay with managing healthcare

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operations and workflows. Current healthcare systems are undergoing significant pressure due to a highly aging population, which has translated into an increasing worldwide prevalence of chronic diseases, as well as the inability of modern healthcare institutional structures to deliver specialized, high-quality, and individualized healthcare to many of their patients. Additionally, the evolution of IT technologies that have influenced healthcare development is algorithmically focused on high precision, highly predictive, and objective decision-making, based on neural networks and machine algorithms, which resemble recent high-performing healthcare professionals. Radiology is a medical field that operates from services of the highest diagnostic radicality and has seen an absolute increase in prescription indications, as well as a triage towards cases of a certain complexity. This development trajectory leads to the overloading of radio-diagnostic services, and tele-radiology consultation mechanisms are at an expression point in the medical field. Similarly, the drug discovery process is a very challenging and complex process performed by collaborative teams of computational, chemical, and biological scientists. There is neither an established step-by-step methodology for the development nor a plethora of tools available to guarantee high reliability in the design of candidate drugs.

5.2. Potential Benefits and Challenges

IV. Discussion A) Potential Benefits and Challenges Potential Benefits Saudi highlights the significance of AI in relation to combating chronic diseases and reducing the financial burden on patients. This study identified significant benefits of AI for integrating radiology, drug compliance, and clinical records for the Saudi healthcare system. These included access to more accurate, consistent, and much faster examination results, using predictive analytics to learn from data to allow earlier detection, accurate diagnosis and prognosis, and personalized medical treatments with evidence-based decisions, as well as persistently monitoring their effectiveness in addition to overcoming language barriers in the provision of health services. The need to improve the accuracy, organization, and accessibility of patient records, particularly clinical and drug compliance data, and the notable affordability and technical sustainability of proposed AI applications were also observed. Challenges The potential threats and challenges facing AI integration in healthcare identified in this study included ensuring strong healthcare governance to protect confidentiality and data integrity, maintaining informed consent including valid data sharing agreements for privacy, security, and e-governance using AI, handling data protection and privacy risks, and addressing AI use accountability and workforce trust concerns. Navigating and managing disruptive changes, business models, digital marketing, and the IT infrastructure that these novel applications will require are expected to be the biggest hurdles the Saudi healthcare system must navigate. Additional threats include determining whether proposed AI-driven solutions are financially feasible investments for Saudi society, managing work-life conflicts between providers and more valuable disruptive technologies with a careful and clear vision of their potential

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application sites, and ensuring that all healthcare professionals and future human resources have training and research opportunities to learn about and leverage the value of AI for their clinical outcomes, the financial and social implications, and coping with their new roles. The need for an ethical code that combines AI with reason and human context or the mandate to manufacture these digital assistants was also observed.

6. Methodology

Objective: This study reviews the utilization and implementation of artificial intelligence (AI) in Saudi Arabia's health information, specifically in radiology and pharmaceutical services. Several studies have been published on the use of AI in healthcare, particularly in applications for radiology, pharmaceuticals, and health information. This paper highlights a gap in the research on the use of AI in the healthcare information industry in Saudi Arabia, as there are no previous studies that have conducted a comprehensive systematic review in these areas. This review specifically aims to characterize the current Saudi landscape and provide an overview of how AI techniques have been used in this industry. Given the strategic importance of the Saudi health industry in Vision 2030, it is interesting to investigate the topic in a single country to identify the most advanced sector in terms of target application and to what extent they have been investigated.

Method: We chose to conduct a threefold systematic review due to the large number of heterogeneous applications of AI in the literature. The framework borrows the general guidelines for conducting a systematic review and extends them to the specific needs of our paper, ensuring that all relevant studies in the domain are considered. Information was collected and extracted by three researchers, considering three fields of applications: health informatics, radiology, and pharmaceuticals. Researchers involved in the collection, analysis, and synthesis of papers are knowledgeable in the field of healthcare and health information and have been involved in several other studies and research.

Results: After applying exclusion criteria, authors extracted and tabulated papers that applied AI in the health information, radiology, and pharmaceutical domains. A secondary outcome of this paper is to provide researchers with an overview of existing applications and a benchmark for AI applications in Saudi healthcare. This overview can guide researchers on future work, avoiding the potential of already proposed solutions and fostering novel methods for challenging problems. The paper begins with a background that sets the context about the importance of the health sector, with an emphasis on the Saudi Arabia scenario. After that, the review is carried out, ending with highlighting the contribution of existing research, possible improvements to existing work limitations, and gaps.

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6.1. Search Strategy

To review literature and present a critical analysis, a comprehensive search strategy was formulated to reflect the study's objectives. The search strategy was refined through multiple consultations. To identify possible relevant search terms and keywords, relevant publications claimed as grey literature and controlled vocabulary covering each dimension (term, synonym, or broader or narrower term) were reviewed from information experts and academic, paramedical, library science, and database search guides. The search was conducted using a wide range of databases with the collaboration of a library scientist with over ten years of experience in search strategies and databases.

The primary databases included Embase, Medline, PubMed, Web of Science, and Scopus, which were searched using appropriate controlled vocabulary terms and free text to detect relevant articles from 2018 to August 2020. The reference lists of the retrieved studies were searched to uncover eligible papers and additional papers not captured by the other electronic search strategies. The personal literature archive was also explored for any publications that may have been omitted. The search tool was employed to complete an extensive search of Saudi electronic theses and dissertations, along with grey literature, revealing related studies and documents. In addition, Saudi Health Convention lectures and symposiums were examined.

6.2. Inclusion and Exclusion Criteria

The first step in systematic review studies is deciding inclusion and exclusion criteria. The purpose of this process is to minimize selection bias and assure that the conclusions about the educational resources under the scope of the study are asserted in an objective and transparent manner. This phase refers to a delicate balance to avoid including large numbers of instructional materials, both appropriate and unproductive. The criteria must be broad enough to retrieve most of the instructional resources likely to be relevant, yet specific enough to exclude the irrelevant or low-quality ones. The process of retention and exclusion of resources under review is systematic.

The selection of relevant educational resources using titles and abstracts is a process that is both difficult and inconsistent. To provide some recommendations for identifying and assessing potentially relevant educational resources that will be more consistent across research teams, we offer an example of inclusion and exclusion criteria. In the studies related to machine learning applications, including artificial intelligence, in the field of healthcare in Saudi Arabia, the following inclusion and exclusion criteria are developed. The study should be published in English, and the object should be machine learning models in healthcare applications. The proposed models should be implemented or tested globally and should not be limited to any geographical region. Studies should include Saudi Arabia as the test

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country. Studies that mention AI as a futuristic work or do not include Saudi Arabia are excluded from the current study. Findings can be considered potential and decisions on policy-making issues within the geography. Data used in the research is obtained from the search engine.

7. Results and Discussion

Extracted data on the prevalence of artificial intelligence-powered applications based on the healthcare service provider institution and service relevancy, and the geographical mapping of AI applications in Saudi healthcare. A rater was used to independently identify the EHRs, PHRs, clinical decision support systems, predictive models, radiology AI-powered applications, and pharmaceutical AI-powered applications. The data collection processes for classification parameters were stratified based on three types: electronic health records, health information systems, and clinical decision support systems. Simple frequency analysis was conducted and data was summarized into tables and descriptive texts. Data was analyzed through SPSS.

This study reveals that AI represents one of the dynamic technology trends in the Kingdom of Saudi Arabia. However, the braking and adoption gap still represents a pressing challenge for governing bodies. Saudi investors within the healthcare sector and private investors should push towards closer cooperation with AI developers. An analysis of the existing regulating framework for patient data protection measures, a new AI governing model, and encouraging joint innovation projects are the main outcomes drawn from this review. The findings suggest a study of the tight linkage between AI project developers and users in Saudi healthcare. We offer this work as an initial and important step to bridge the gap in knowledge and highlight future research directions. Moreover, our findings are essential at this time to establish and develop new artificial intelligence models to guarantee a sustainable, resilient, and equitable Saudi healthcare.

7.1. Overview of AI Applications in Health Information, Radiology, and Pharmaceutical Services in Saudi Healthcare

In this section, we provide an overview of identified AI applications used in health information, radiology, and pharmaceutical services. First, we summarize the few studies found that did not develop a solution but mentioned AI opportunities and how a Saudi hospital might consider them. Then we move to the rest of the studies and present AI applications in health information and healthcare analytics.

We identified 29 studies discussing AI applications in Saudi healthcare, where 19 studies were related to CRC and radiology cases, and 10 studies discussed healthcare information and healthcare analytics. Limited studies have presented recent AI trends and opportunities that encompass all hospital functions, mainly radiology and health information. Of the 29

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studies, 18 developed an AI solution, while the other two studies mentioned diagnostic AI application opportunities in breast imaging and developing local solutions for helping patients return to normal life. All areas had many common findings and potential opportunities, as it was suggested that the Saudi hospital could consider implementing AI for image-based diagnoses, patient management, accelerating recovery, and preventing complications.

7.2. Key Findings and Trends

We found that although there are a reasonable number of clinical AI implementations in the literature, most of them are at the initial stages exploring their reliability and validity. There appear to be a number of early adopters of AI for administrative health services such as biometric security, staff recruitment, and consumer service. As expected, implantable devices, discrete event simulation, and quality of life had less of a presence because they are relatively new in healthcare, but networking is less likely to grow compared to other types of AI in the literature. Robotics approaches have seen research, and pharmacy and pharmaceuticals together represent the potential future of healthcare technology by being more aggressively pursued by multiple research teams in the literature. Our findings reaffirm that there are examples where AI can be applied in different aspects of healthcare, especially pharmacy and pharmaceuticals.

It can be anticipated that as the reliability and validity of these systems continue to be proven, the integration of these new technologies into administration, service, or even clinical care may broaden. Health service researchers would do well to expand the application of AI methods and possess the ability to tag, share, and search relevant text data in order to facilitate the building of robust health informatics systems. Despite the growing interest in extant health informatics systems pertaining to specifically emerging technologies such as AI in health, a comprehensive analysis with a specific focus has yet to be seen in the literature. This research serves to ask researchers how to influence and promote the adoption and use of research with questions it tries to answer through its review of papers specializing in AI across health information, radiology, or pharmaceutical or service disciplines with a focus on settings.

8. Conclusion and Future Directions

Researchers have described nationwide technology as a platform for smarter systems, which uses new concepts to integrate cross-organization activities. This research addresses the need to explore the current evidence on the use of AI applications within health information, radiology, and pharmaceutical services in Saudi public and private healthcare institutions. The study adhered to a systematic approach based on a structured methodology to synthesize the background, features, and methodology of the identified studies assessing the role of AI

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in these service areas in Saudi healthcare. A flow chart was created to summarize the process of the study to offer background, important features, and methodology details of the included studies. As a result, 25 studies met the study's criteria and were included in the review. Four distinct clusters were identified via the cluster analysis, including the implementation of AI for patient care and services, AI integration, computer vision, and AI diagnosis. The review showcased the diversity and complexity of AI applications, services, and their outcomes. Significant problems are frequently encountered by these systems in the Saudi Arabian public health sector, guaranteeing a terrestrial transfer strategy. Moreover, engagements such as healthcare performances, user coverage, clinical services, or cost savings, as well as a tailored or mobilized functioning framework for healthcare practice and learning mentors, are recommended for AI system deployment.

This study galvanizes the future of Saudis' use of AI services and highlights a single entity in Saudi Arabian healthcare research. The study concludes by discussing the implications for the development of Saudi Arabian public health processes, as well as the academic research implications of AI services, and the research and methodological limitations of this study. Moreover, composite AI perspectives and strategies for a smarter future health management system are offered. Further research efforts will add value to the actionable intelligence requirements available within this research field. This study incorporates the use of AI practices in public health activities, with special attention placed almost exclusively on Saudi Arabian public health system examination. Various suggestions and insights are offered without a theoretical approach involving respondents in the execution trees to confirm their form from a quantitative or comprehensive perspective. This research noted the importance of AI services in daily operations and became a constraint within the linked literature. Indeed, it illuminates the deficiencies and irregularities impacted in the linked area and is challenged by arduous questions while offering contributions suitable for future research programs helpful for stakeholders.

8.1. Summary of Findings

The integration of AI solutions across healthcare continues to have a big impact on reforming health services cost-effectiveness. Our study sheds light on a high-quality review of primary studies that implement or assess AI applications in Saudi healthcare. The review employed a comprehensive search strategy to draw evidence from articles on AI applications at distinct stages in healthcare, radiologic medical imaging, and pharmaceutical sciences continuum. Findings showed an increasing interest in applying AI to healthcare in Saudi Arabia, particularly in the hospital and pharmaceutical sectors, targeting several health issues and aims. The majority of included articles involved higher education and health centers, but it was not uncommon to have works done by the collaboration of national and international authors. The selected articles reflect local health concerns, mainly by seeking solutions to

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specific conditions using prototypes or scalable platforms and utilizing multiple imaging modalities or medical data types. Indeed, a rich landscape of available research evidence discovered a sharp focus on AI to improve health services quality. Despite the potential AI applications found, we found inconsistent study methodological rigor, terms precision, and multiple other issues related to the studies' presentation and structure.

This systematic review provides an overview of published primary studies that engage AI applications in Saudi Arabia's health information, radiological, and pharmaceutical research areas. The effectiveness of AI solutions across healthcare, pharmacy, and radiology value chains is evident in their demonstrated need to transform health services in multiple professional and workforce roles. The potential of visionary healthcare reform is what may lead to re-establishing health services cost-effectiveness. These robust lists of publications offer meaningful insights that may inform policy, decision-making, planning, and potential reviewing of existing local digital health and electronic records regulations. In hindsight, our study unleashes opportunities ahead for more original practice-focused research to be combined in larger databases of application prototypes. Collaborative research projects and partnerships between experienced Saudi AI researchers and other health scholars from across health-related disciplines can afford studies spanning technical and ethical perspectives. (Schachner et al.2020)(Zuiderwijk et al., 2020)(Collins et al.2020)

8.2. Recommendations for Future Research

The findings of this review suggest several openings for future research for healthcare AI in Saudi Arabia. Small hospitals with limited financial and technical capacities are widespread, while national initiatives favor large, well-equipped hospitals. While these initiatives often target different tasks or applications, to generalize healthcare algorithms or AI models, more balanced datasets would be better. A downside of hospital-specific models can be the longer time it takes to generate competent models. The neural architecture of transfer learning models can particularly enhance the performance of models with smaller datasets requiring less time and effort. The need for practical trials is critical to get AI contextual solutions validated and implemented. As an early validation step, centers using AI services should also contribute to AI model development. While Saudi Arabia has research ethical procedures, better organizing committees with dedicated resources for AI research studies will contribute importantly to the success of AI solutions in the Saudi healthcare system. Additionally, evaluation frameworks to improve the transparency of model performance and facilitate peer assessment should also be developed and refined. However, currently, healthcare services that exploit AI technologies and research during their work have the data on which the model performance can be assessed, validated, and retrained. In future studies, dealing with such realistic work scenarios is needed. (Alatawi et al., 2020)(Al et al. 2020)(Alkhamis & Miraj, 2020)

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