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Artificial Intelligence in Healthcare and Biotechnology: A Review of the Saudi Experience

Fatema Dabdoub[1], Margaretta Colangelo[2], Ola El Kibbi[1], Sahar Shami[1], Abdullah Aljumah[1], Mohamed Boudjelal[3] and Mohammed Aljumah[4,5]*

[1]Itkan Health Consulting, Riyadh, Saudi Arabia

[2]CIO, Alliance for Artificial Intelligence in Healthcare, Saudi Arabia

[3]King Abdullah International Medical Research Centre, King Saud Bin Abdulaziz University for Health Sciences, King Abdulaziz Medical City, Ministry of National Guard Health Affairs, Riyadh, Saudi Arabia

[4]Ministry of Health, Saudi Arabia

[5]King Fahd Medical City, Saudi Arabia

ABSTRACT

Whether in analyzing laboratory and imaging results, devising vaccination plans in a pandemic, or predicting patient prognosis, artificial intelligence [AI] was shown to be an indispensable tool in the field of healthcare. Saudi Arabia is no stranger to the many benefits of AI in medicine. In this paper, we expand on the past, ongoing, and future applications of AI in the Saudi healthcare sector.

***Corresponding author**

Mohammed Aljumah, Itkan Health Consulting Tarim Tower, 6379 Al Olaya, Riyadh, Kingdom of Saudi Arabia. Phone: +966 11 4944666; Mobile +966505418250; E-mail: Jumahm@gmail.com

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Introduction

The term "Fourth Industrial Revolution" [4IR] was coined in 2016 by Klaus Schwab when he described the rapid technological advancement that humankind is witnessing in the 21st century and analyzed the impact this advancement will have on all aspects of human life [1-3]. The concept of 4IR revolves around the change brought on by technological advancements and breakthroughs; a change that is manifested politically, economically, and even socially [2]. It also highlights the inevitable change in marketplace and social values that accompanies the emergence of technologies that interfere and interact with human functioning and behaviors. The industrial revolution is driven by many booming innovations in our time, such as the Internet of things [IoT], biotechnology, blockchain, virtual and augmented reality, smart cities, and artificial intelligence [AI]. Among these innovations that drive the 4IR, AI plays a great role in the dynamics of this industrial age. In fact, many argue that AI will revolutionize everything in the upcoming industrial era, by transforming the functioning of most industries and companies. Artificial intelligence can be defined in many ways but is fundamentally a broad field of science concerned with the understanding and development of systems that exhibit intelligent behavior and the ability to analyze patterns, resembling human intelligence [4,5]. With applications in several areas, AI has been making its way into the field of medicine and healthcare. It has been an essential tool in the development of programs that aim to aid clinicians in diagnosing patients, devising management plans, and predicting patient outcomes in several areas of medicine [6-7]. This paper reviews the impact AI and the 4IR have on the field of health care and biotechnology, the most notable international applications of AI in healthcare, and the Saudi healthcare experience with AI.

Methodology

This paper summarizes research conducted in the field of AI and healthcare and medicine in the past 4 years. The paper focuses on AI tools in the areas of disease diagnosis and prediction, drug discovery, and molecular biology and omics research. It also highlights the progress that has been made in Saudi Arabia in incorporating AI technologies in the health care and public health sectors. The authors restricted their reviews of articles that have been recently published in high-ranking peer-reviewed journals. The selection criteria included keywords relating to artificial intelligence, machine and deep learning, healthcare, and medicine.

This review is qualitative in nature and is not intended to be a systematic review of literature. It is an unstructured review of all available public data about AI in KSA and the scientific publications in the past four years. The authors have restricted their choice of literature to AI applications that will likely impact medical practice and healthcare administration. The time period of around 4 years aims to focus on recent research on medical and biomedical applications of AI that are still relevant.

The review aims to provide high-level data on the application of AI and its technologies in healthcare, and the milestones that Saudi Arabia has reached in this area, to highlight the importance of this new era. The fourth industrial revolution and AI will impact healthcare administration greatly and it is essential for medical practitioners and leaders to learn and adopt these technologies. AI applications in medicine will enhance efficiency in medical care and will allow enhanced healthcare delivery to patients and communities.

International Experiences with AI in Healthcare

The technologies of the fourth industrial revolution, namely AI and its associated technologies: machine learning [ML] and deep learning [DL], have paved their way into areas that were previously thought to be only the province of human experts [Figure 1]. Integrating AI into healthcare has already been proven to deliver better healthcare faster and at a lower cost [8]. In an effort to provide better health care to their populations, many countries have joined the AI health care race with the United States, China, England, and Canada leading the way [9].

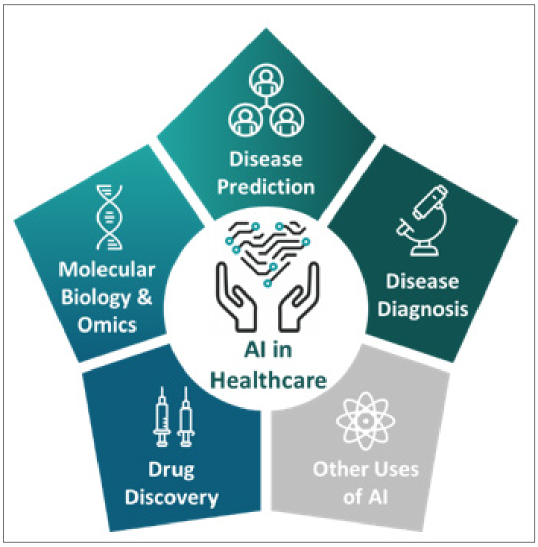

Figure 1: Main Uses of AI in Medicine and Healthcare

Disease Prediction

ML is a subfield of AI that has been gaining momentum in its use in classifying diseases in large datasets using pattern identification mechanisms [10]. This allows AI to quickly analyze big data sets by pulling together patient insights and incorporating algorithms that lead to predictive analysis.

These algorithms include the support vector machine [SVM] algorithms that have been used to predict treatment outcomes and disease prognosis. In one of these studies, a dataset containing data from six countries [that suffer from a high burden of tuberculosis [TB] infections was analyzed using ML methods to extrapolate attributes that predicted treatment failure in patients with TB [11]. ML approaches have also been applied in emergency medicine to examine the predictors of opioid prescription inside the emergency department and post discharge [12]. An Opioid Use Disorder [OUD] classifier was developed using ML to help predict future opioid use in patients receiving opioid prescriptions. Development of the OUD classifier included genomic information, subject demographics, and clinical data elements. It was seen that OUD classifier tool can provide health care providers with additional information regarding a patient's risk in developing OUD [13]. ML can also be employed to overcome challenges in public healthcare. For example, in Singapore, AI predictive models were tested to predict patients with high risk for readmission into public hospitals [8]. This model was used nationwide to enroll high risk patients into individual-centric discharge planning to decrease the likelihood of readmission [8]. The success of ML in public health issues has also been demonstrated in fighting the opioid pandemic in the United States of America.

DL is a more sophisticated technology than traditional ML. This technology can extract patterns and features from data without the need to pre-process it.DL has been studied as a tool to predict the disease prognosis of an individual patient. DL algorithms are heavily being researched and explored in electroencephalography [EEG] with the aim of predicting epileptic seizures and preventing them [14], in electrocardiography [ECG] with the aim of diagnosing and predicting a wide array of cardiac pathologies [15], and in gastroenterology with the aim of extrapolating the efficacy and safety of an expensive drug with little to no cost [16]. Moreover, an Italian study investigated the utility of a DL tool in the prediction of obstructive sleep apnea [OSA] events [17]. This tool was shown to have the potential to allow clinicians to predict the occurrence of OSA events easily and effectively in stroke patients for whom OSA carries great morbidity and mortality [17]. It utilizes convolutional neural networks. The use of DL expanded from more critical health problems to the field of aesthetics where convolutional neural networks are being employed in face-lift surgeries to quantify the age reduction association with the operation [18].

Disease Diagnosis

As a big proportion of what healthcare providers has to do with recognition of patterns in disease manifestations and diagnoses, AI has emerged to provide valuable applications in pattern recognition to advance diagnostics and treatments across medical specialties. The shift to digitalizing healthcare has provided a substrate for development of AI applications.

The tremendous potential of DL to transform care at a community level has been highlighted over the course of the pandemic where smart cameras have been developed to monitor mask use in cities and their temperature [19]. Perhaps there is no better field that demonstrates the success of AI than the field of radiology particularly over the course of the pandemic. A study utilized computer-assisted analysis of lung ultrasound imagery and showed great potential for diagnosing pulmonary conditions, being a viable alternative for screening and diagnosing COVID-19 [20]. The use of DL has also served the silent ongoing Human Immunodeficiency Virus [HIV] pandemic where DL has been incorporated in diagnosis of HIV by classifying over 11,000 images of rapid HIV tests [21].

Despite the success in AI in increasing diagnostic certainty, faster turnaround, and better outcomes for patients, and better quality of work life for clinicians, the success is still hindered by the deficit in technical expertise of medical experts [22]. Moreover, diagnostic AI in medicine is currently limited to predicting diagnostic labels. The future of diagnostic medicine lies in a "WayFinding" process that engages in real time processing of the clinical cues and information to help the physician reach his diagnosis faster and more efficiently [23].

Molecular Biology and Omics

The role of AI in improving healthcare is not limited to diagnosis. ML allows the integration of data from various omics sources such as genetics, proteomics, and metabolomics to discover new biomarkers that allow the prediction, patient stratification and delivery of individualized medicine [24]. For better cancer management, the Linked Omics system used existing cancer data portals to help physicians discover and compare cancer multi-omics data within and across 32 tumor types [25].

Employing ML in the analysis of molecular biomarkers allowed AI to play a role in the proper management of patients in critical and time sensitive situations. ML has been employed to predict of sepsis among ICU through analyzing biomarkers of sepsis in large databases [26]. An algorithm developed by Johns Hopkins University aims to allow clinicians enough time to intervene before the patients suffer damaging effects of sepsis and mortality [27]. Another version of the score has been shown to predict mortality in the emergency department [28].

Another application of AI in the field of omics was in the prediction of the outcome of in vitro fertilization [29]. A recent study aimed to investigate the possibility of replacing invasive procedures like colonoscopies by detecting metabolomics and metatranscriptomics data from simple noninvasive fecal sampling [30]. The study showed favorable results while using a previously developed Inflammatory Bowel Disease Multi'omics Database [31].

Integration of multi-omics data using AI is not without challenges. The large data and heterogeneous datasets available require the development of universally standardized data filtering tools. Moreover, it is necessary to develop a robust method to integrate omics data with the non-omics data such as clinical metadata which will allow for a holistic understanding of illnesses of patients underlying these large datasets [32].

Drug Discovery

The pharmaceutical industry is facing a challenging era, and for the past two decades, has been in a drug discovery slide. Drug discovery has become more expensive and less profitable, and the largest pharmaceutical companies now pay nearly $80 billion a year to come up with fewer successful drugs [33]. AI technologies, namely ML and DL, are expected to revolutionize the area of drug discovery and the pharmaceutical industry. Major companies in the industry are announcing partnerships with AI firms [33]. Only very few AI-discovered drugs have reached the phase of human testing, and none have yet reached phase 3 trials, but the future is promising [34].

The main DL architectures used in small molecular drug discovery are: convolutional neural networks [CNN], recurrent neural networks [RNN], and generative deep neural networks [GDNN] [35]. These DL models have been reported and utilized in three major areas of small molecule drug design: [1] predicting interactions between the drug and the target, [2] generating novel molecules and drugs, [3] predicting various properties of a molecule under translational research [absorption, distribution, metabolism, excretion, and toxicity] [35, 36].

Since the SARS-CoV-2 pandemic emerged, different AI based approaches have been used to predict potential epitopes to design vaccines and to identify old or new drugs to combat this virus. Drug hunters for the COVID-19 virus have benefited from AI in the virtual screening of both repurposed drug candidates and new chemical entities. Gordon et al worked on repurposing old drugs for the treatment of COVID-19 by identifying 66 human proteins linked with 26 SAS-Cov-2 proteins [37]. Another research group from Taiwan used AI platforms to identify drugs with the aim of repurposing them for use against COVID-19, then they tested these drugs against a feline coronavirus and fed the results into the AI platform to generate a modified model that will search for other old drugs [38].

ML-aided molecular docking has been one of the most prevalent approaches for virtual screening, and it serves to ascertain the binding interactions of the experimental drug with the target proteins. A research group from Pakistan identified 5 phytochemicals that can inhibit the HR1 domain on the SARS-CoV-2 spike protein. They did that through virtually screening a set of 2750 phytochemicals by employing a set of AI techniques including ML-aided molecular docking, molecular dynamics simulations, and quantum computation-based density functional theory analysis [39]. Vaccine research efforts have been focused on the identification of B and T cell epitopes using AI to guide the development of vaccines. Fast and Chen used two supervised neural network driven tools [MARIA and NetMHCPan4] to identify T-cell epitopes close to the virus spike-receptor binding domain [40].

AI drug discovery approaches have been employed in other disease areas as well. One of the most notable efforts is the BPM31510 drug developed by Berg. This drug was developed using a DL program software and is currently being tested in clinical trials for a number of solid tumors, including pancreatic cancer and glioblastoma multiforme [41].

Other Uses of AI

AI has also allowed the development of tools that assist in patient-physician communication. With the emergence of telehealth and the use of chatbots for patient follow up and recommendations, an AI experiment compiled electronic data belonging to patients with Inflammatory bowel disease and used natural language processing to categorize the data for the development of a chatbot. As a control, three physicians also categorized the data. The smart categorizations had minimal differences—results that are promising for the development of a smart chatbot [42]. Interestingly, the fields of artificial intelligence and robotics have allowed scientists to develop a sense of social cognition in robots in attempt to serve elderly patients with dementia. Studies done a small sample of elderly dementia patients in Australia has shown favorable responses in communication with social robots [43].

Most AI innovations in medicine are still in the research and validation phases, however, in recent years, there has been a movement to implement and deploy these technologies in clinical practice [6]. There is growing interest in deploying AI strategies to develop improved public health interventions, including improving existing disease surveillance systems, screening programs, facilitating preventive interventions, and public health education. However, many barriers remain, and further research and collaboration are needed to better regulate AI in public health [44-46].

The Saudi Experience

Timeline of Digital Transformation in the Kingdom of Saudi Arabia [KSA]:

Ever since the Saudi Vision 2030 was launched in 2017, the race towards digitalizing healthcare has been in full speed. Most of the impact of this digitization was in health services management and delivery, in addition to large ongoing projects for the use of AI in health services delivery and research. Shortly after the framework was established, the Saudi Red Crescent Authority launched a mobile application [Asefni] with the aim of facilitating emergency service requests using GPS services [Figure 2]. In 2019, the Saudi Data and Artificial intelligence Authority [SDAIA]'s transformation strategy was approved giving this entity and its sub-entities access to national data and the national AI agenda. This digital transition was tested as COVID-19 spread to the kingdom by the end of March 2020.Quickly, Saudi Arabia became a hub for AI in healthcare as Saudi King Salman Bin AbdulAziz hosted the G20 summit on COVID-19 and the Global AI summit. During the latter, Saudi Arabia's National Center for Artificial Intelligence [NCAI] and China's Huawei signed a Memorandum of Understanding [MoU] to train Saudi AI engineers and students, and to address Arabic language AI-related capabilities [47]. Another MoU between the SDAIA and China's Alibaba Cloud was signed during the summit with the goal of developing digital and AI solutions in areas including safety and security, mobility, urban planning, energy, education, and health [47]. During the same year, the SDAIA developed the "Tawakkalna" App to support government efforts aimed at countering Covid-19. Tawakkalna App is now active in 74 countries with many different medical and non- medical applications. The medical applications include booking COVID-19 testing and vaccination appointments, creating a health passport that shows the number of doses of COVID-19 vaccines, sharing health condition cards with other uses, and the Umrah permit feature which allows monitoring the health conditions of pilgrimages. The SDAIA also developed "Tabaud" application to notify those who are in contact with people infected with coronavirus.

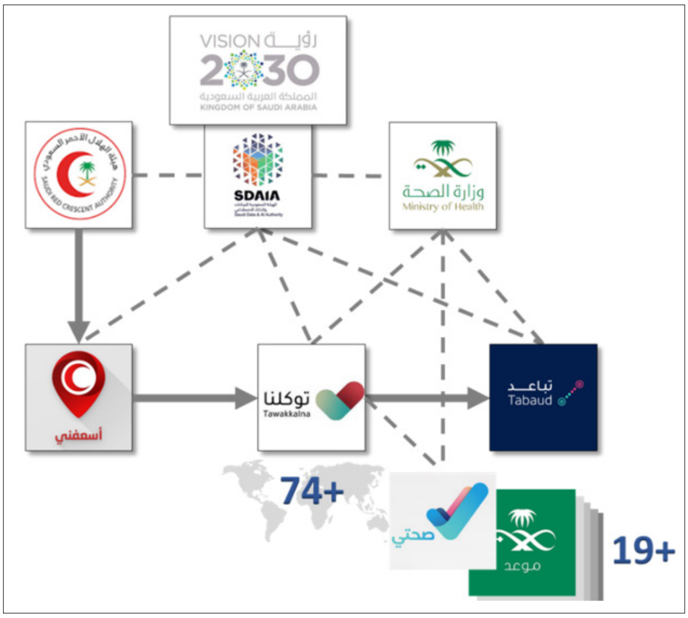

Figure 2: Different digital applications developed in Saudi Arabia in recent years and the agencies sponsoring them

Besides Tabaud and Tawkalna, the Saudi Ministry of Health has implemented multiple informatics tools to provide public health information for individuals as well as the community. Saudi Arabia's government and private sectors combined, developed, and launched approximately 19 apps and platforms that serve public health functions and provide health care services. These applications were versatile and included digital screening applications [Mawid application, Sehatty application], surveillance of confirmed cases [health electronic surveillance network, taqasi and the Saudi COVID-19 map], contact tracing [tawakalna, tabaoud], and mental health services [Labayh]. The use of telehealth and telepharmacy services also increased as lockdowns extended in the kingdom [48] . The pandemic has also shed light on the shortage of infectious disease specialists in the kingdom and encouraged innovation in the fields of AI and healthcare. For example, a study from King Abdel Aziz in 2020 presented a diagnosis and management prototype using advanced intelligent technology and medical knowledge approved by the Saudi MOH and the WHO. The 5-system prototype does not only allow physicians to better manage their patients during hospitalization, but also helps manage the disease remotely but controlling the spread of the disease [49].

The successful use of AI in healthcare in KSA depend on the awareness of medical experts of its applications. A recent study showed a deficit in the knowledge of the uses of AI and its implications on the job market among doctors, nurses, and technicians at four of the largest hospitals in Riyadh, Saudi Arabia [50]. On the other hand, recent questionnaire assessing attitudes of radiologists, radiology technologists, technicians, and radiological sciences students from different regions around Saudi Arabia on the use of AI in diagnostic radiology showed an acceptable level of knowledge on AI and a consensus to include AI education in medical curriculums four.

The Fourth Industrial Revolution Conference in Saudi Arabia: Key Message

Saudi Arabia recently launched the Center for the fourth industrial revolution along with the World Economic Forum [WEF] [51]. The center will develop frameworks to advance multistakeholder collaboration on agile governance frameworks and AI, IoT and blockchain. This boost for AI in Saudi Arabia will prioritize the healthcare field.

Conclusion

Innovative research in the field of AI and medical applications has been booming in the past decade with evidence showing improved clinical diagnosis and decision-making performance in several medical task domains. The 2030 vision of Kingdom of Saudi Arabia [KSA] is an organized effort to join the global race towards integrating artificial AI in all life domains including healthcare. The success of this step towards advancement will depend on how well financially prepared our healthcare ecosystem is. Most importantly, this shift will depend on how nimbly clinicians will adapt to the new tools AI provides and how the medical education system will prepare to co-evolve with the rapid advancements in artificial intelligence.

Conflict of Interest Statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contribution Statement

Fatema Dabdoub worked on the Conceptualization, Methodology, Writing – Original Draft Preparation. Margaretta Colangelo worked on Data Curation, Writing – Review & Editing. Ola El Kebbi worked on Writing – Original Draft. Sahar Shami worked on Writing – Review & Editing. Abdullah Aljumah worked on image creation and editing. Mohamed Boudjelal worked on Writing – Review & Editing. Mohammed Aljumah worked on Writing – Review & Editing.

Contribution to the Field

It is the first article to highlight the timeline of digital transformation in the Kingdom of Saudi Arabia [KSA] using AI. Here we summarize the latest uses of AI in disease prediction and diagnosis, molecular biology and omics, and drug discovery. For the latter, we highlight the role of digital learning, machine learning, recurrent neural networks, convolutional neural network, and generative neural networks.

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