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Review paper

Use of Artificial Intelligence in Biomedical Engineering and Medicine: A Mini Review

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Abstract

Background and Aim: Biomedical engineering and artificial intelligence (AI) are closely connected fields with significant potential for innovation and advancement in the field of medicine. This review paper explores the intersection of biomedical engineering and AI in medicine.

Method: The review conducted a comprehensive analysis of articles published between 2003-2023 to explore the use of AI in healthcare. A total of 54 articles were selected based on inclusion criteria, and data were extracted independently by reviewers. The findings were synthesized qualitatively, identifying common themes and patterns in the effectiveness of AI in healthcare. The quality of the studies was assessed using relevant tools, excluding those with a high risk of bias or methodological limitations.

Results: The paper highlights the potential of AI to transform healthcare by analyzing and processing large amounts of medical data, leading to improved diagnosis, treatment, and personalized care. Machine learning algorithms, a subset of AI, can identify patterns and relationships in data that would be difficult for humans to discern. AI is currently being used in medical imaging, analysis of medical images, and the development of predictive models for disease diagnosis and therapeutic response.

Conclusion: The conclusion highlights the need for ethical guidelines and a legal framework for the use of AI in medicine. It emphasizes that AI should complement traditional medicine rather than replace it. The paper suggests that addressing these concerns and providing training and education to healthcare professionals will be crucial for the successful integration of AI in healthcare.

Keywords: *Biomedical engineering, Biomedicine, Artificial intelligence*

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Introduction

Biomedical engineering (BME) is an interdisciplinary field that often focuses on medicine [1]. Due to this field, medical engineers are involved in various medical fields that will lead to better services and products [2]. BME seeks improving the quality of life by using advanced technology [3]. Also, medical engineers by applying the principles of electrical, mechanical, chemical, optical and other principles of engineering help to control, diagnose and treat patients, or by integrating engineering and medicine, they make a tool to be used in the field of health [4], [5].

Artificial intelligence (AI) is a branch of computer science that includes research in robotics, linguistics and image recognition. It can learn and process natural human language, and has the ability to perform activities such as visual perception, speech recognition, and decision making [6], [7]. Machine learning (ML) is a branch of AI that aims to replicate intelligent behavior without extensive human intervention. By analyzing and processing large amounts of data, ML algorithms can identify patterns and relationships that would be difficult or impossible for humans to discern. Unlike traditional programming, which relies on explicit instructions, ML relies on data-driven learning to generate accurate predictions and insights [8], [9]. AI and ML algorithms represent a unique technological advancement that sets them apart from other technologies. Unlike traditional computer programs, these algorithms have the ability to learn and develop problem-solving skills, which are hallmarks of human intelligence [10].

Currently, AI is used in many complex applications and helps to correct difficult problems or improve upon old methods [11]. AI has the potential for data analysis, which can greatly impact the method of diagnosis and treatment, as well as provide personalized care for diseases [12]. In recent years, AI algorithms have been very important in the fields of computer science research, in electronics and biomedicine [13]. Today, AI is used in medical fields and other fields where new technologies help humans [14]. In the field of medicine, the most use of AI is in the analysis of medical images of people suffering from heart and kidney diseases, people with brain tumors or pregnant women to determine the gender of the fetus to assist doctors in analyzing patient data and providing them with precise results [15].

The aim of this mini-review is to provide an overview of recent research on the use of AI in healthcare and BME, with a focus on its potential applications, current limitations, and future directions.

Material and Methods

Comprehensive research was conducted in the PubMed, IEEE Xplore, ScienceDirect, Google Scholar databases to identify books and articles published between 2003–2023 the research terms used include “biomedical engineering”, “Artificial intelligence”, “deep learning”, “machine learning”, “medical diagnosis”, “Artificial intelligence now and future”, “Artificial intelligence benefits and drawback”, “use of artificial intelligence in medicine”

The inclusion criteria were articles written in English, review articles, and focused on the use of artificial intelligence in healthcare. Articles that did not meet these criteria or were duplicates were excluded. A total of 54 articles were selected for the review.

The reviewer independently extracted data from the selected articles, including the study design, sample size, population demographics, type of AI used, and outcomes measured. Data were organized in a table and analyzed using a narrative synthesis approach. The reviewers identified common themes and patterns across the studies, and synthesized the findings to draw conclusions about the effectiveness of artificial intelligence in healthcare.

Two reviewers independently assessed the quality of each study and disagreements were resolved

through discussion and consensus. The studies were evaluated based on several criteria, including the study design, sample size, blinding, and risk of bias. Studies with a high risk of bias or significant methodological limitations were excluded from the review. This mini-review solely relied on the analysis of previously published literature and did not involve any human or animal subjects, thus no ethical considerations were required. Due to the narrative synthesis approach used in this mini-review, statistical analysis was not performed. Instead, the results of the studies were synthesized and analyzed qualitatively to identify common themes and patterns related to the use of artificial intelligence in healthcare.

Biomedical Engineering

Biomedical engineering (BME) is an interdisciplinary field that combination of principles from engineering and biomedical sciences. In this field, biomedical engineers work in various areas, including medicine, regenerative medicine, and related fields, to develop better products and services. Biomedical engineers use their knowledge of engineering principles to design and develop medical equipment, devices, and procedures to improve patient care and outcomes. In addition, the collaboration between biomedical engineers and medical professionals has led to progress in the development of new diagnostic tools and treatments [2]. AI has the potential to transform healthcare by offering innovative and efficient solutions to the most pressing challenges in the medical field [16].

The history of BME from the mid-twentieth century to the present experienced significant growth and diversification during the 1950s-60s with the establishment of academic programs. The 1970s-80s saw the emergence of new subfields, and the 1990s-2000s saw the development of AI and ML in BME. Today, BME is an interdisciplinary field with various areas of focus [17]. The first BME program was held in 1959 at the Master's level at Drexel University (Philadelphia, PA, USA), and it was followed by Ph.D. programs at Johns Hopkins University (Baltimore, MD, USA) and the University of Pennsylvania (Philadelphia, PA, USA) added the doctoral level of this field to their university courses. Currently, this academic field is globally popular and rapidly developing [18]. Different branches of BME include: biomechanics, medical and biological analysis of biosensors, clinical engineering, medicine and bioinformatics, rehabilitation engineering, physiological modeling, biological nanotechnology, biomedical precision instruments, neuroengineering, tissue engineering, medical biotechnology, bioinformatics, Biomaterials, Medical imaging, Prosthetic devices & artificial organs [4].

Artificial Intelligence

Artificial intelligence (AI) has transformed medical technologies and is considered a branch of computer science that can effectively handle highly complex problems in areas with massive amounts of data but limited theory [19]. AI has had a profound impact on society, bringing with it a multitude of economic benefits and improving various aspects of daily life [20]. The concept of AI was first introduced in 1950, but early models were limited in their capabilities and were not widely used in the field of medicine. However, in the early 2000s, significant advancements were made in the field of deep learning (DL), which helped to overcome many of these limitations. Today, AI has the ability to analyze complex algorithms and learn autonomously, making it a valuable tool in clinical practice [21].

AI subfields are:

1. Machine Learning (ML): Machine learning is a subset of AI in which computer algorithms learn patterns by studying data without explicit programming [8].

2. Deep Learning (DL): Deep learning, a subset of machine learning, involves the development of multi-layer neural networks that work like the human brain and make decisions like humans [8].
3. Natural Language Processing (NLP): process that enables computers to extract data from human language and make decisions based on that information.
4. Computer Vision (CV): process by which a computer gains information and understanding from a series of images or videos [21].

Artificial Intelligence in Biomedicine and Biomedical Engineering

Artificial intelligence-based medical systems are quickly becoming practical solutions for clinical use. DL algorithms are able to process large amounts of medical data efficiently [19].
The field of AI in Medicine (AIM) has evolved significantly over the past five decades. With the advancements in ML and DL, AIM has expanded its applications, creating opportunities for personalized medicine. The use of predictive models in AIM can be used for diagnosis of diseases, prediction of therapeutic response, and potentially preventative medicine in the future. AI has the potential to improve diagnostic accuracy, provider workflow, clinical operations, disease and therapeutic monitoring, procedure accuracy, and patient outcomes. The growth and development of AI in medicine is chronicled below, organized by specific time periods of seminal transformation [21]. AI is functionally useful and plays a fundamental role in analyzing complex data in BME. It can collect information from sensors like ExG signals, ECG, EEG, sEMG, PPG, speech signals, and inertial data, which have complexities that make manual checking difficult and time-consuming. AI is also used in neuroimaging techniques such as sMRI, fMRI, diffusion tensor imaging, PET, and SPECT for rapid disease diagnosis and data classification through computer-aided diagnosis (CAD). This aid of AI is crucial for doctors and nurses, making its application very important [13]. AI is a powerful tool that is capable of transforming the medical field and can elevate the quality of care for patients and rehabilitation and helps doctors to analyze large amounts of data [16]. AI has emerged as a powerful tool in the field of BME, enabling the diagnosis, treatment, and prevention of many diseases [22]. The use of AI in medicine has rapidly increased in recent years, with applications ranging from medical imaging and diagnosis to drug discovery [23], [24]. In the future, it will be important to direct AI towards its tasks properly and carefully. If AI is to be integrated with medicine, it needs to have a beneficial relationship with doctors in which they use it to diagnose complex clinical cases. This way, the human element of medicine is not lost, as doubt remains the biggest obstacle to using AI. People need to be willing to accept this new technology [25]. There is a lot of hope that in the future, AI can not only help humans in diagnosing diseases and discovering drugs, but also be upgraded to be used as a doctor's assistant and provide more personalized services [26].

Discussion

AI has made significant progress in recent years and is now being used across various fields. In the health care field, AI has shown great potential to analyze medical data, including electronic health records, imaging, -omics, sensor data and text, which are complex and it also improves patient outcomes and advance medical research [27], [23]. AI can extract important information from a patient's electronic medical records. Its use can increase efficiency and save time, and in the future, it could even help manage hospitals with detailed planning. To demonstrate the effectiveness of AI, the process of diagnosing diabetes can be used as an example. Currently, physicians must spend a lot of time reviewing patient records, including tests, discharge letters, and clinical guidelines. However, with the help of AI, the best course of action can be prepared in

a shorter period of time based on the patient's clinical records. It may even be possible for AI to generate a letter summarizing the conversation between the patient and doctor, which the doctor can then approve after reviewing it [25]. AI holds immense potential to enable more precise, accurate, and scientifically-informed personalized medical care. As AI technology continues to advance, it will increasingly become an indispensable tool in healthcare [28]. AI enables systems to analyze large amounts of data and provide more accurate diagnoses and treatments by identifying abnormalities [29]. The integration of AI into the field of medicine is expected to advance significantly, potentially leading to revolutionary changes. AI technology has the ability to enhance learning capacity and provide decision support systems on a scale that has the potential to transform the future of healthcare [30]. Currently, AI is being used in multiple areas of medicine, including medical imaging, drug development, and patient monitoring. For example, AI can assist radiologists in interpreting medical images, potentially reducing diagnostic errors [31]. AI can also accelerate the drug development process by predicting drug effectiveness [32]. Additionally, it can improve diagnosis accuracy, prevent accidents, and facilitate more effective patient recovery [33]. Despite the benefits of AI in medicine, there are also concerns about its use. Lack of transparency in AI algorithms can lead to errors in diagnosis and treatment [19]. Side-by-side however, there are also unrealistic expectations of what AI can do and what the landscape of the healthcare industry will look like in the future [26]. The use of AI-based systems raises concerns about data security and privacy. Given the sensitivity and significance of medical records, the use of AI is vulnerable to cyber-attacks, and the lack of standard ethical guidelines for its use in healthcare exacerbates this issue. The need for ethical guidelines for AI in medical care is a topic of debate due to the absence of a universal definition for this matter. Therefore, it is imperative to ensure and maintain the confidentiality of medical records [34]. Although AI has brought great progress to the field of medicine, it may face resistance from healthcare professionals, particularly doctors. There are four reasons for this: First, specialists may lack the necessary training to use digital medicine due to a lack of previous experience with this technology [35]. Second, the promise of improving patient care through digital technology was not fully realized, and instead, physicians were burdened with additional administrative tasks that negatively impacted their work and caused burnout [36], [37]. Third, there is a fear that AI will replace doctors [38], although the theory is that it will complement medicine rather than replace it [22], [39]. Fourth, there is a lack of a legal framework and ethical standards for the use of AI in medicine, and doctors may be unsure of the legal implications of using it [40]. Two of the more common false beliefs regarding the application of AI systems in healthcare are:

1. It is a misconception that doctors will be replaced by AI. While the future is uncertain, those in the field of medicine and healthcare recognize that artificial intelligence will be a beneficial tool in the future. For example, the American College of Radiology posted a job advertisement seeking a radiologist who is certified by the American Board of Radiology and excited about a future where radiologists are supported by AI.
2. Another misconception is that doctors need programming knowledge to successfully use AI. In reality, AI in any field is composed of various components, and programming is only one part of it. Therefore, doctors do not necessarily need programming skills to use it effectively. Data scientists can help doctors build an AI system by providing expertise in programming and other areas, while doctors can contribute by providing information on how AI can improve their role in healthcare [26].

Conclusion

In conclusion, AI has the potential to revolutionize the field of medicine by processing and analyzing large amounts of data to enable accurate diagnosis and treatment. It can be used in various areas, including medical imaging, drug development, and patient monitoring, to improve patient outcomes. However, there are concerns about the lack of transparency in AI algorithms, the risk of cyber-attacks and system disruption, and the absence of an ethical and legal framework for its use. Despite the benefits of AI, medical professionals, especially doctors, may resist its adoption due to a lack of knowledge and experience, fear of replacement, and uncertainty about the ethical and therapeutic implications of its use. However, it should be noted that AI is meant to complement traditional medicine, not replace it. Addressing these concerns is crucial for the advancement of AI in the medical industry. Ethical guidelines should be established to ensure the safe and transparent use of AI in medicine. Additionally, doctors do not necessarily need programming knowledge to use AI effectively, but they can provide valuable information to data engineers to develop useful and trustworthy AI systems. The future of digital medicine depends on our ability to embrace and utilize the potential of AI while also addressing the challenges that arise. By collaborating and working towards a common goal, we can ensure that AI is used safely and effectively to improve patient outcomes and advance medical research.

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Conflict of interests

The authors declare that there are no competing interests.

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