LOKMAN HEKIM HEALTH SCIENCES

DOI: 10.14744/lhhs.2024.27920
Lokman Hekim Health Sci 2024;4(3):195–202

REVIEW

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Use of Artificial Intelligence in the Healthcare Sector

Sağlık Sektöründe Yapay Zeka Kullanımı

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Abstract

Artificial intelligence (AI) has profound effects not only on the medical sector but also on many other sectors. AI, whose theoretical foundations were laid in the 1950s, has since developed into different AI subfields. Recently, two prominent subfields within the scope of AI have been machine learning (ML) and deep learning (DL) techniques. ML is focused on analyzing existing data to make predictions, and DL employs neural networks to mimic the functioning of the human brain. Today, observing many projects and even daily applications related to the use of AI in different areas such as medical imaging, diagnosis, drug development, and personalized treatment plans is possible in the health sector. For example, in the field of radiology, making earlier and more precise diagnoses using AI to increase the speed and accuracy of medical image analysis has become possible. Robotic surgery platforms, such as the Da Vinci Surgical System, have begun to integrate AI to automate tasks and improve surgical safety. With smartphones, wearable technologies, and Internet of Things applications, AI-powered healthcare solutions are becoming more accessible and effective. This paper aims to provide a brief overview of AI, examine its contributions and real-world applications in healthcare, assess its impact on medical education, and discuss the ethical challenges of its integration into the medical field. By providing insights into the potential of AI, this study aims to provide healthcare professionals a comprehensive perspective on the role of AI in modern medicine.

Keywords: Artificial intelligence; Artificial intelligence in medicine; Deep learning; Machine learning

Artificial intelligence (AI) is causing a considerable transformation in many aspects of human life, including medicine. Nowadays, a wide range of AI projects and applications, from medical imaging and diagnosis to drug development and personalized treatment plans, are available.

AI dates back to the 1950s when Alan Turing proposed the idea that "computers could imitate human intelligence" and was recognized as an important scientific field after John McCarthy defined the term "artificial intelligence" in 1956.[1,2] Initially, starting with simple "if-then" rules, AI has evolved to include more complex algorithms that can operate similar to the human brain.

Despite encompassing many subtopics, recently, the machine learning (ML) and deep learning (DL) subfields of AI have begun to be widely applied in the health sector as in other sectors.[3] ML involves algorithms that

Cite this article as: *Koyuncu M, Göçer S. Use of Artificial Intelligence in the Healthcare Sector. Lokman Hekim Health Sci 2024;4(3):195–202.*

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analyze specific datasets, learn from these data, and make predictions about future events or behaviors. In other words, ML allows for the development of systems that can make decisions and predictions without requiring human intervention by learning from datasets. On the other hand, DL is a subset of ML that enhances learning and decision-making capabilities, particularly by working with large datasets and using multilayered artificial neural networks. DL uses artificial neural networks that mimic the principles of human brain function, thereby enabling the processing and learning of very complex data.[4,5]

Health technology can be defined as tools that allow healthcare professionals to offer better quality of life to patients and society. Technologies used for early diagnosis, reducing complications, optimizing treatment, and providing less invasive options can become more effective when combined with AI. With the emergence of smartphones, wearable devices, and Internet of Things systems, AI-supported tools can achieve great performance even in small sizes.[6,7]

AI is used in many medical fields for different purposes. Finding many applications of AI such as medical imaging and diagnosis, disease prediction and treatment, robotic surgery, rehabilitation and physical therapy using AI-supported wearable devices, and personal health tracking is possible. When examined in detail, AI is increasingly being used in many medical fields. Radiology is one of the medical fields where AI is most commonly applied. AI is used to analyze medical images, such as X-rays, MRIs, CT scans, and ultrasounds, accelerating and improving the accuracy of early disease diagnosis. For example, Google Health is working with clinicians, patients, and partners to develop an AI system for mammography that can help radiologists detect breast cancer accurately, quickly, and consistently (https://health.google/caregivers/mammography/). The developed AI system has been trained using thousands of mammograms, and the trained system can diagnose diseases at the level of expert radiologists. Another area where AI usage is increasing is robotic surgical platforms. For instance, the Da Vinci Surgical System has been in use since 2000 and is one of the widely used platforms. When examining the latest version of the system, Da Vinci 5 (https://www.intuitive.com/en-us/products-and-services/da-vinci/5), AI and ML are observed to be the new capabilities added to the system. AI models in surgical systems are generally used to automate surgical tasks and enhance intraoperative safety. Therefore, Increasing the number of examples in this paper regarding the use of AI in the healthcare sector is possible.

The aim of this study is to briefly introduce AI, review its contributions to the field of medicine, present concrete examples of its usage, identify the potential contributions of AI to medical education, discuss possible ethical issues related to AI, and offer a perspective on AI for healthcare professionals. This study is prepared as a narrative review article. PubMed and Google Academic searches are performed using various keywords, including "artificial intelligence in medicine/healthcare," "artificial intelligence in radiology/pathology/ cardiology/oncology/ orthopedics," "artificial intelligence in medical education," and "artificial intelligence and medical ethics." Related articles were selected based on their relevance to the aim of this study. The selected articles are first reviewed and evaluated, and then, this paper is structured and developed based on the authors' knowledge of related domains.

What is Artificial Intelligence?

AI refers to computer systems that attempt to mimic the intelligence and learning abilities of humans when performing specific tasks. Together with its subfields, such as ML and DL, AI sometimes surpasses human capabilities by analyzing large amounts of data, recognizing patterns in the data, and making predictions. Alternatively, it is the effort to equip machines with human-like thinking and learning abilities.[8]

AI is commonly used for the following purposes:

- **Data Analysis:** Analyzing large datasets to identify patterns, trends, relationships, and anomalies in the data. Such inferences facilitate trend determination, prediction, and decision-making processes.
- **Learning:** Adapting to new situations in the environment and improving performance by learning from data. For example, AI can improve its performance by learning in games. Another example is robotic systems, which can explore their environment and adapt, thereby enhancing their performance.
- **Problem Solving:** Using various algorithms and techniques to solve complex problems. Nowadays, AI models that can reason through mathematical problems and provide solutions with concrete evidence have been developed. A good example is DeepMind's AlphaProof model.[9]
- **Natural Language Processing:** Understanding human language and generating results based on it. Sentiment analysis, text classification, automatic language translation, and voice assistants, such as Siri and Alexa, are examples of AI applications in this field.

- **Image Processing:** Analyzing images, recognizing, and classifying objects. Facial recognition and medical image processing are examples of work done in this context.

Subfields of Artificial Intelligence

As shown in the list below, different types of AI are available that can be used together or separately as AI techniques in various applications. In terms of technological developments in recent years, ML and DL technologies have particularly come to the forefront. Therefore, ML and DL are explained in greater detail in the following subsections.

Machine Learning: A subfield of AI that enables machines to make predictions or decisions by learning from data. The goal of this technique is to develop algorithms that can improve themselves using the provided data and evaluations.

Deep Learning: A subfield of ML that learns complex patterns from large datasets using multilayered artificial neural networks. Recently, it has become the underlying AI technology for several successful image processing applications.

Natural Language Processing: This subfield of AI allows computers to understand and produce human language. Sentiment analysis, chatbots, and language translation services are examples of natural language processing (NLP) applications.

Large Language Models: DL models are used to understand and generate text similar to human text. Large Language Models (LLMs) can be considered an evolution of NLP models, which are typically fed large amounts of text data from the Internet and can learn the language, grammar, and real patterns used in the given language. They are designed to predict the probability of the next word or sentence based on the previous words. Recently, this type of AI has become quite popular.

Computer Vision: A subfield of AI that allows computers to interpret visual information. It is a widely used AI technology in applications such as medical image analysis and video surveillance systems.

Robotics: This involves the design and production of intelligent robots that can interact with the physical environment. In robotics, which requires the collaboration of many disciplines, AI provides techniques that allow robots to learn from their experiences, adapt to new situations, and perform complex tasks.

Expert Systems: These AI systems answer questions and solve problems in specific areas of expertise using rule-based systems.

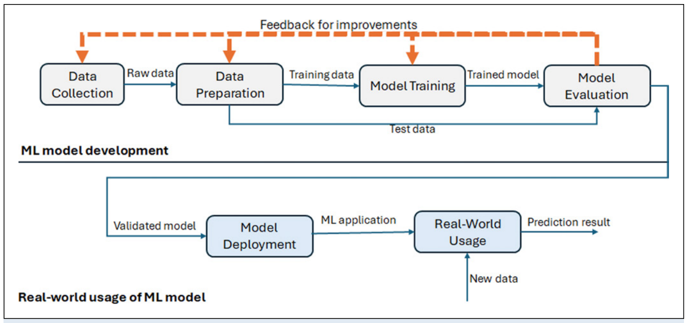

Figure 1. Machine learning process flow.

What is Machine Learning and How Does it Work?

ML is a subfield of AI in which computers gain the ability to make predictions or decisions to perform specific tasks by learning from datasets.[10,11] Alternatively, like a child learning from experiences, ML algorithms can make accurate predictions or decisions when faced with similar situations by finding patterns and relationships in the large amounts of data they are fed. The process of obtaining the ML algorithm up and running generally follows the steps outlined below and illustrated in Figure 1:

1. **Data Collection:** Initially, a large amount of data is collected to train the ML model. The larger the dataset and the more diverse the examples that the algorithm will encounter in the future, the higher the success rate of the ML algorithm. For example, thousands of different facial images are required to train a facial recognition system.
2. **Data Preparation:** The collected data are converted into a format that the ML algorithm can understand. This process includes cleaning, normalizing, and extracting features from the data. In cases where supervised learning is used, labeling the data is also necessary to ensure that the input–output relationship can be learned.
3. **Model Training:** The prepared data are fed into the chosen ML algorithm. The algorithm identifies patterns in the data and builds a model. During this process, a loss function is used to measure the accuracy of the model's predictions. The goal is to minimize or reduce the calculated error to very small values. Model training is typically completed at the stage where the error is minimized.
4. **Model Evaluation:** The trained model is tested on new data that it has not used during the training process. The model's performance is assessed based on the test results. If the obtained results are not satisfactory, it can be returned to one of the previous steps for improvement. It is a common practice to select more than one ML

model for training and testing. In this case, the evaluated models are compared in the model evaluation step and the best model is selected for final use.

5. **Model Usage:** The trained and evaluated model can produce predictions or decisions by applying it to real-time problems. Therefore, the selected model in the evaluation step is embedded in a domain application and deployed to solve real-time problems.

ML algorithms generally use one of the following learning techniques:

- **Supervised Learning:** Each example in the dataset is paired with a correct label. The model learns the relationship between the input and output using these labels. For example, algorithms used to determine anomalies in a patient's blood values that are associated with a disease are examples of supervised learning.
- **Unsupervised Learning:** The dataset contains no labels. The model attempts to meaningfully represent the dataset by discovering natural groups or patterns in the dataset. For example, patient segmentation and data clustering can be performed using unsupervised learning.
- **Reinforcement Learning:** An agent gains experience by performing actions in an environment. After each action, it receives a reward or penalty. The agent learns its actions to maximize rewards and minimize penalties. For example, a computer program that plays chess can learn more about the game through reinforcement learning.

ML technologies are used in many fields. Some applications and examples of ML are listed below:

- **Health:** Diagnosis, drug discovery, and personalized medicine
- **Finance:** Fraud detection, risk analysis, and portfolio management
- **Marketing:** Customer segmentation, targeting, and product recommendations
- **Autonomous Vehicles:** Image processing, object recognition, and decision-making
- **Natural Language Processing:** Text analysis, translation, and voice assistants

What is Deep Learning and How Does it Work?

DL discovers complex patterns in large datasets using the backpropagation algorithm to determine how a machine should adjust its internal parameters to compute values at each layer based on the values of the previous layer.[12] As a result, groundbreaking results have been achieved in many areas such as image recognition, NLP, and speech recognition. The fundamental components and working principles of DL are as follows:

Artificial Neural Networks: These are the building blocks of DL and are based on the operating principles of the neurons in the human brain. Many interconnected artificial neurons process information and produce outputs.

Layers: DL networks comprise multiple layers. Each layer processes the data from the previous layer and transforms it into more abstract features.

Learning Process

Forward Propagation: The input data progress through the layers of the network and are processed in each layer.

Backward Propagation: The output produced by the network is compared with the expected output, and the error is calculated. This error is used to update the weights of the network. This process is repeated until the performance of the network reaches an acceptable level or the error is minimized.

Depth: DL networks have more layers than traditional artificial neural networks. This allows them to learn more complex features and obtain results with higher accuracy.

The advantages of DL over other machine learning algorithms are as follows:

- **Automatic Feature Extraction:** DL networks can automatically extract features from data. This allows for better results without the need for human intervention.
- **Working with Large Datasets:** DL is ideal for large datasets. It can analyze large amounts of data to produce more accurate and reliable results.
- **Solving Complex Problems:** It is highly effective in solving complex problems such as image recognition and NLP.

Contributions of Artificial Intelligence to the Health Sector

Today, AI is being used in many fields, and its usage continues to increase day by day. Health is one of the fields where AI is intensively used, and some of its contributions are summarized below.[13–15]

- **Data Analysis:** As mentioned previously, one of the common purposes of AI is data analysis. Medicine is a field that generates large amounts of data. AI can contribute to the early diagnosis of diseases and the determination of treatment options by analyzing these data quickly and accurately.

- **Image Analysis:** AI algorithms may assist doctors in making more accurate and faster diagnoses by detecting abnormalities in medical images (MRI, CT, X-ray, etc.). AI is particularly important for the early diagnosis of certain diseases, such as cancer.
- **Treatment Planning:** AI can create personalized treatment plans by analyzing a patient's genetic profile, medical history, and other data. This leads to the development of more effective treatments with fewer side effects.
- **Drug Development:** AI can play a substantial role in processes such as discovering new drug candidates, designing clinical trials, and predicting drug interactions.[16] This allows for developing new drugs in a shorter time frame and at a lower cost.
- **Patient Care:** AI-supported chatbots and virtual assistants can improve the patient experience by answering questions, facilitating appointment scheduling, and monitoring treatment processes.

Historical Development of Artificial Intelligence in Healthcare

1950s and 1960s (First Steps): During this period, studies were conducted on fundamental AI concepts, such as simple expert systems and artificial neural networks. However, because of limitations in computing power and data, the impact of these studies was limited.

1970s, 1980s, and 1990s (The Rise of Expert Systems): In this period, expert systems that mimic the knowledge and experience of specialists in specific fields, as mentioned above, were developed as a subfield of AI. These systems began to be used in medical diagnosis and treatment processes. An important example of an expert system is MYCIN, which was developed at Stanford University for about 6 years in the early 1970s.[17] MYCIN was designed as an expert system using AI to identify bacteria causing serious infections, such as bacteremia and meningitis, and to recommend antibiotics adjusted according to the patient's body weight.

2000s (Data Mining and Machine Learning): With the emergence of the concept of big data, data mining and ML techniques began to be used more widely in the healthcare sector. This has led to substantial advancements in areas such as early disease diagnosis and treatment planning.

From the 2010s to Present (Deep Learning): The development of DL algorithms has resulted in innovative outcomes in areas such as image recognition and NLP. In the healthcare sector, DL-based models have gained considerable interest in fields such as medical imaging, genomic data analysis, and drug discovery. In particular, in the 2020s, technological advancements, such as the use of powerful computer hardware, the collection of large datasets, the development of LLM, and effective DL models, have led to an explosion of interest and investment in AI in the healthcare sector as in all other fields. Notably, now many ideas have been transformed into commercial products beyond academic research. For instance, SaaS-type commercial cloud applications can segment lesions in CT and MRI images with a single click, assist in report generation based on AI analysis, and integrate AI-supported tools into existing healthcare systems for workflow optimization, providing services through the cloud (e.g., www.tempus.com).

Application of Artificial Intelligence in Medicine

By examining the use of AI in various medical branches, a more detailed picture of AI's application can be observed in health technologies. In this context, examples of AI use across numerous medical branches can be found. This study focuses on branches in which AI is used more intensively.

Radiology: AI algorithms help in the early diagnosis of many diseases by detecting fractures, tumors, and other abnormalities in medical images (MR, CT, X-ray, etc.).[18,19] Medical images contain large amounts of data. AI algorithms can analyze this data faster and in more detail than the human eye even for detecting small abnormalities. They reduce the likelihood of human error by providing objective results that are independent of subjective interpretations. By automating routine tasks, AI allows radiologists to focus on more complex cases, increasing the chances of early disease detection and treatment.

Pathology: AI is also leading to a substantial transformation in the field of pathology.[20,21] Pathologists conducting detailed analyses of tissue samples under the microscope can make more accurate and faster diagnoses, reduce their workload, and even make to new discoveries thanks to AI. For example, AI can recognize cancer cells in biopsy samples, which reduces the workload of pathologists and improves diagnostic accuracy.

Cardiology: AI predicts the risk of heart diseases by analyzing data from tests such as electrocardiography (ECG) and echocardiography and assists in the early diagnosis of emergencies such as heart attacks.[22–24] By analyzing ECG signals, it detects conditions such as arrhythmias and the risk of heart attacks. By evaluating heart muscle movements, blood flow, and the condition of heart valves, AI aids in the diagnosis of heart diseases. Furthermore, it is used to analyze detailed images of heart structures and identify patients at high risk of heart diseases. In addition, it can track the effectiveness of treatments and adjusted treatment plans accordingly.

Oncology: AI can automatically detect tumors in medical images (PET, CT, MR, etc.), determining their size, shape, and texture.[25] It is used to identify the type (benign or malignant) and subtypes of tumors in medical images. By analyzing the genetic structure of tumors, AI can be used to develop personalized cancer treatments.[26] It helps make more accurate predictions regarding disease progression and treatment response. AI is also used in planning treatments such as radiotherapy and chemotherapy.

Orthopedics: AI has great potential in enhancing the efficiency and accuracy of orthopedic diagnosis, treatment, and surgical processes.[27] AI can assist in the detection of fractures or degenerative diseases by automatically evaluating images, such as X-rays, MRIs, and CT scans, particularly through DL algorithms. The classification of fractures, creation of treatment plans, and monitoring of recovery processes can be improved through AI algorithms. AI-based systems can continuously monitor patients' physical conditions, personalize exercise programs, and accelerate recovery processes.

Artificial Intelligence and Medical Education

Initially, computers and computer-based systems were used in education, followed by the emergence of web-based and online training platforms. Advancing technologies have enabled the development of chatbots that perform functions similar to those of teachers and instructors. Today, AI offers better learning experiences for students by customizing learning materials according to their needs and abilities. In general, AI has made a substantial impact on the education sector, particularly in terms of management, teaching, and learning.[28]

From the medical education perspective, the effects of AI are evident at every stage of education, from medical students to expert doctors. AI is generally used in medical education for the following purposes:

- **Simulations:** AI-supported simulations allow students to practice in realistic scenarios. They are used in many areas, from surgical procedures to diagnosis. Medical students have the opportunity to practice in a simulation environment before applying their skills to real patients. The use of simulation tools in medicine will also considerably reduce the need for cadavers.
- **Access to Knowledge:** AI enables easy access to vast medical knowledge and accelerates the learning process. For example, an LLM trained with medical documentation can help students quickly access accurate information.
- **Data Analysis:** By analyzing large datasets, AI can provide students with a deeper understanding of disease progression and treatment effectiveness. For example, it can clearly and quickly identify and show student changes in consecutive medical images.
- **Personalized Education:** AI offers customized educational materials based on students' learning speed and style. It can analyze the performance and progress of a student, and accordingly, it can propose personalized content and methods for students.
- **Virtual Patients:** AI-supported virtual patients can help students develop their skills for recognizing and treating various disease conditions. This method allows students to practice with different types of patients with different complaints.

With regard to the future of medical education, AI can play an increasingly important role. In the future, interactive and personalized educational materials will likely be developed using AI, thereby making medical education easier and more effective. AI holds great potential in medical education; however, AI cannot replace human instructors. Care must be taken to ensure that this technology is used correctly and ethically. Ideally, AI should be used to complement the skills of human instructors. When combined with the experience and empathy of human educators, AI can yield better medical education outcomes.

Future Expectations

Probably, the first discussion about the future of AI is whether it can become a dangerous tool for humans in the future. Whether AI will be inherently dangerous or benign is impossible to determine. This will depend on how we manage and regulate its development. If we can build ethical, transparent, and human-value-compatible AI systems, they can potentially improve lives and solve some most serious problems of humanity. However, if AI is misused, ignored, or developed without appropriate security measures, it can pose substantial risks, ranging from economic disruption to existential threats. Ensuring that AI is developed in a way that maximizes its benefits while minimizing its potential harm is our responsibility as humans.

When examining the healthcare sector specifically, AI is certain to have substantial impacts in the future. AI can be expected to be increasingly used in the following areas; however, this is not limited to

- **Virtual Reality and Augmented Reality:** AI will be used alongside VR and AR technologies in surgical simulations, patient education, and medical imaging.
- **Robotic Surgery:** AI-supported robots can perform more precise and safer surgical procedures.
- **Personalized Medicine:** AI will create personalized treatment plans based on each patient's genetic profile and medical history, resulting in more effective treatment outcomes.
- **AI-supported Prosthetics:** Smart prosthetics that integrate better with patients' bodies can be developed.
- **Big Data Analysis:** Analyzing large amounts of data collected from different medical departments will make it possible to identify new scientific findings.

Artificial Intelligence and Medical Ethics

With the widespread use of AI in the healthcare sector, certain challenges and concerns are emerging for the future. The incredible potential of AI in the medical field is also raising ethical concerns. Medical ethics is based on four fundamental principles: beneficence, nonmaleficence, autonomy, and justice.[29,30] How AI will align with these principles is one of today's most important discussions.

The risks and uncertainties associated with AI use in medicine include the following:

- **Data Privacy:** Due to the sensitive nature of medical data, data privacy and security are major concerns. However, AI requires the extensive use of patient data, which raises privacy and security concerns.
- **Algorithmic Bias:** AI algorithms can reflect biases in training data, potentially leading to discrimination against specific patient groups or producing erroneous results.
- **Responsibility:** Who will be responsible for the negative consequences that will arise because of the wrong decisions made by AI is an unanswered question.
- **Job Losses:** AI may lead to unemployment of healthcare professionals as certain medical tasks will be automated.
- **Human-Machine Relationship:** Another uncertainty is how widespread AI adoption will affect fundamental human interactions, such as the patient–physician relationship.

The aforementioned risks can be mitigated, and concerns regarding AI can be addressed through the following measures:

- **Transparency:** The decision-making processes of AI algorithms must be understandable and explainable.
- **Accountability:** AI systems must be able to identify errors and issues, and a mechanism should be developed for holding these systems accountable for errors.
- **Prevention of Bias:** Training data should be diverse and free from biases.
- **Data Privacy:** Strong security measures must be implemented to protect patient data.
- **Human Oversight:** AI systems should always be monitored by humans.

The potential of AI in the medical field is undeniable; however, ethical concerns must not be overlooked. When developed and used in accordance with medical ethics principles, AI can greatly enhance the quality of healthcare and provide substantial benefits to humanity. Therefore, prioritizing ethical issues in the development and application processes of AI and adopt a multidisciplinary approach is essential.

Conclusion

AI is the source of many innovations in the healthcare sector. AI-powered technologies can contribute in making the healthcare sector more effective, faster, and accessible. These developments are paving the way for a new era in the sector, and we are likely to see more enhancements in the future.

Despite its great potential in the healthcare sector, AI faces some challenges and criticisms. Solutions are required to be identified to address issues such as data privacy, algorithmic bias, and high costs. Despite these challenges and criticisms, the impact of AI in the medical field is expected to increase day by day and AI is expected to be widely used in the future. AI will play an important role in improving patients' quality of life, ensuring healthcare accessibility, and accelerating medical research.

Ethics Committe Approval: A review article. Ethics Committee Approval is not required.

Authorship Contributions: Concept: MK; Design: MK, SG; Supervision: MK; Literature Search: MK, SG; Writing: MK; Critical Review: MK, SG.

Conflict of Interest: None declared.

Use of AI for Writing Assistance: Not declared.

Financial Disclosure: The authors declared that this study received no financial support.

Peer-review: Externally peer-reviewed.

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