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# EAMS

Experimental and Applied  
Medical Science

**Official Journal of Gaziantep Islam Science and  
Technology University, Faculty of Medicine  
June 2024, Volume 5, Issue 2  
Special Issue: Artificial Intelligence**



**GAZİANTEP İSLAM BİLİM VE TEKNOLOJİ ÜNİVERSİTESİ TIP FAKÜLTESİ**

**GAZİANTEP ISLAM SCIENCE AND TECHNOLOGY UNIVERSITY FACULTY OF MEDICINE**

# **Experimental and Applied Medical Science**

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## Aim

***Experimental and Applied Medical Science*** aims at being a current and easily accessible academic publication in which striking research results that will improve the quality of life and are unique from every field of medical sciences.

## Scope

***Experimental and Applied Medical Science*** is an open-access, internationally double-blind peer reviewed academic medical journal which is published in English four times a year, under the auspices of Medical Faculty of Gaziantep Islam Science and Technology University. The journal receives manuscripts for consideration to be publishing in the form of research articles, reviews, letter to editor, brief notification, summary notification etc. which could have been presented from within the country or abroad and including experimental animal studies related to the pathogenesis of diseases, pharmacological, clinical, epidemiological and deontological studies, also studies in the fields of improving public health, health services or health insurance. During evaluation or publication no charge is demanded from authors. The journal is published every 3 months (March, July, September and December) with 4 issues per year. The literary language of the journal is English. Abstract part of the manuscript only should also be submitted in Turkish.

## Amaç

***Experimental and Applied Medical Science***, yaşam kalitesini arttıracak çarpıcı araştırma sonuçlarının sunulduğu, tıp bilimlerinin her alanında benzersiz, güncel ve kolay erişilebilir bir akademik yayın olmayı hedeflemektedir.

## Kapsam

***Experimental and Applied Medical Science***, Gaziantep İslam Bilim ve Teknoloji Üniversitesi Tıp Fakültesi himayesinde yılda dört kez İngilizce olarak yayınlanan açık erişimli, uluslararası çift kör hakemli bir akademik tıp dergisidir. Dergi, yurt içinden veya yurt dışından, hastalık patogenezi ile ilişkili deneysel hayvan çalışmaları, klinik, farmakolojik, epidemiyolojik, deontolojik çalışmalar ile beraber halk sağlığının geliştirilmesi amacı taşıyan ve sağlık hizmetleri veya sağlık sigortaları konularında araştırma makaleleri, derlemeler, vaka sunumları, kısa bildirimleri, özet bildirimleri vs. yayınlamak için değerlendirmeye kabul etmektedir. Değerlendirme veya yayın sırasında yazarlardan herhangi bir ücret talep edilmez.

Dergi 3 ayda bir (Mart, Temmuz, Eylül ve Aralık) yılda 4 sayı olarak yayımlanır. Derginin yazı dili İngilizcedir. Makalenin sadece özet kısmı Türkçe olarak da gönderilmelidir.

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Manuscripts are only considered for publication provided that they are original, not under consideration simultaneously by another journal, or have not been previously published. Direct quotations, tables, or illustrations that have extracted from any copyrighted material must be accompanied by written authority for their use from the copyright owners. All manuscripts are subject to review by the editors and referees. Deserving to be publishing is based on significance, and originality of the material. If any manuscript is considered to deserve publishing, it may be subject to editorial revisions to aid clarity and understanding without changing the data presented.

***Experimental and Applied Medical Science*** strictly adheres to the principles set forth by "Helsinki Declaration" whose web address is below.

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Editorial Board declares that all reported or submitted studies conducted with "human beings" should be in accordance with those principles.

Manuscripts presenting data obtained from a study design conducted with human participants must contain affirmation statements in the *Material and Methods* section indicating approval of the study by the institutional ethical review committee and "informed consent" was obtained from each participant. Also all manuscripts reporting experiments in which laboratory animals have been used should include an affirmation statement in the *Material and*

## Etik İlkeler ve Yayın Politikası

Makaleler, orijinal/özgün olmaları, eş zamanlı olarak başka bir dergi tarafından incelenmemeleri veya daha önce yayınlanmamış olmaları koşuluyla yayına kabul edilir. Telif hakkıyla korunan herhangi bir materyalden alınan doğrudan alıntılar, tablolar veya resimler, kullanımları için telif hakkı sahiplerinden alınan yazılı izinle birlikte sunulmalıdır. Tüm yazılar editörler ve hakemler tarafından incelemeye tabidir. Yayınlanmaya hak kazanılması, materyalin önemine ve özgünlüğüne bağlıdır. Herhangi bir makalenin yayınlanmayı hak ettiği düşünülürse, sunulan veriler değiştirilmeden netlik ve anlayışa yardımcı olmak için editör revizyonlarına tabi tutulabilir.

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Editör Kurulu, "insan" ile yapılan tüm raporlanan veya sunulan çalışmaların bu ilkelere uygun olması gerektiğini beyan eder. İnsan katılımcılarla yürütülen bir çalışma tasarımından elde edilen verileri sunan makaleler, *Gereç ve Yöntemler* bölümünde çalışmanın kurumsal etik inceleme komitesi tarafından onaylandığını ve her katılımcıdan "bilgilendirilmiş onam" alındığını belirten onay ifadeleri kullanılmalıdır. Ayrıca laboratuvar hayvanlarının kullanıldığı deneyleri bildiren tüm yazılar, *Gereç ve Yöntemler* bölümünde, internet adresi aşağıda

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If there is a commercial relation that contributes to the study process or there is an institution that provides financial support for the study; the authors must declare that they have no commercial relationship with the commercial product, drug, company used, or what kind of relationship (consultant or any other agreement) they have, if any.

Processing and publication are free of charge with the journal. No fees are requested from the authors at any point throughout the evaluation and publication process. All manuscripts must be submitted via the online submission system, which is available at <https://dergipark.org.tr/tr/pub/eams>.

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belirtilmiş olan “Laboratuvar Hayvanlarının Bakımı ve Kullanımı Kılavuzu”na uygun olarak tüm hayvanların insanî bir bakım aldığını doğrulayan bir beyan ile kurumsal etik inceleme kurulunun onayını içermelidir. [https://www.gibtu.edu.tr/Medya/Birim/Dosya/20210818130308\\_dca61056.pdf](https://www.gibtu.edu.tr/Medya/Birim/Dosya/20210818130308_dca61056.pdf)

Çalışma sürecine katkı sağlayan ticari bir ilişki veya çalışmaya maddi destek sağlayan bir kurum varsa; yazarlar ticari ürün, ilaç, aracılık eden şirket ile ticari bir ilişkilerinin olmadığını veya varsa ne tür bir ilişki (danışmanlık veya başka bir anlaşma) olduğunu beyan etmelidir.

Değerlendirme ve yayınlama süreçleri ücretsizdir. Değerlendirme ve yayın sürecinin hiçbir aşamasında yazarlardan ücret talep edilmez. Tüm yazılar <https://dergipark.org.tr/tr/pub/eams>

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Derginin tüm masrafları Gaziantep İslam Bilim ve Teknoloji Üniversitesi Tıp Fakültesi tarafından karşılanmaktadır. Reklam vermeyi düşüne kişi veya kurumlar yayın ofisi ile iletişime geçmelidir. Reklam görselleri sadece Baş Editör’ün onayı ile yayınlanabilir. Tüm araştırmacılar, makaleye doğrudan akademik veya bilimsel olarak katkıda bulunmuş olmalıdır. Yazarlar, makalenin planlanması, uygulanması, yazılması veya gözden geçirilmesi aşamalarından birine veya birkaçına katkıda bulunmuş olmalıdır. Tüm yazarlar nihai versiyonu onaylamalıdır. Bilimsel kriterlere uygun bir makale hazırlamak yazarların sorumluluğundadır.



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All manuscripts involving a research study must be evaluated in terms of biostatistics and it must be presented altogether with appropriate study design, analysis and results. *p* values must be given clearly in the manuscripts. Other than research articles, reviews, case reports, letters to the editor, etc. should also be original and up to date, and the references and, if any, their biostatistical parts should be clear, understandable and satisfactory.

The publication language of the journal is English. In addition, the abstract part of the article must be uploaded in both Turkish and English. Manuscripts should be evaluated by a linguist before being sent to the journal.

All manuscripts and editorial correspondence must be submitted online to the editorial office, <https://dergipark.org.tr/tr/pub/eams>.

According to the Law on Intellectual and Artistic Works, which was first published in the Official Gazette with the law number 5846 on 13/12/1951, whose web address is below, and on which subsequently various changes have been made or novel parts have been added in time, all kinds of publication rights of the articles accepted

Dergide yayınlanan yazılarda ifade edilenler veya görüşler, Gaziantep İslam Bilim ve Teknoloji Üniversitesi Tıp Fakültesi, editörler, yayın kurulu ve/veya yayıncının görüşlerini değil, yazar(lar)ın görüşlerini yansıtır; editörler, yayın kurulu ve yayıncı bu tür materyaller için herhangi bir sorumluluk veya yükümlülük kabul etmez.

Araştırma çalışması içeren tüm yazılar biyoistatistiksel açıdan değerlendirilmeli ve uygun çalışma düzeni, verilerin analizi ve sonuçları ile birlikte sunulmalıdır. *p* değerleri yazılarda açık olarak verilmelidir. Araştırma makaleleri dışında derlemeler, olgu sunumları, editöre mektuplar vb. de orijinal/özgün ve güncel olmalı, kaynaklar ve varsa biyoistatistiksel kısımlar açık, anlaşılır ve tatmin edici olmalıdır.

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Submission of a paper will be taken to imply that it has not previously been published and that it is not being considered for publication elsewhere. Decision as to publication of papers submitted to the Experimental and Applied Medical Science will be based on the opinion of the Editorial Board as to the significance and originality of the work.

Manuscripts should be prepared electronically using an appropriate "office word" compatible text-processing package, formatted for A4 size, double-spaced throughout, and using a "Times New Roman" 12 point font. Articles must be written in English. Abstracts must be written in both Turkish and English. Text should flush left, and not be justified. Words should not be hyphenated. Pages should be numbered sequentially.

There should be a separate title page with:

- a) The title
- b) The authors' names
- c) The laboratory of origin, with complete address of each author
- d) A running title
- e) Corresponding author and e-mail
- f) Conflict of interest
- g) Acknowledgements

The main body of full-length paper should be divided into:

1. Abstract
2. Introduction
3. Material and Methods
4. Results
5. Discussion

## Yazım Kuralları

Bir çalışmanın dergimize gönderilmesi için bu çalışmanın daha önce yayınlanmamış veya başka bir akademik dergide şu anda yayınlanmak üzere değerlendirilmiyor olması koşulu ile mümkündür. Experimental and Applied Medical Science'a gönderilen her türlü çalışmanın yayınlanmasına ilişkin karar, Yayın Kurulu'nun çalışmanın önemi ve özgünlüğü konusundaki görüşüne dayanacaktır.

Çalışmalar, ya "office word" programı ile ya da bu program ile uyumlu uygun bir metin işleme programı kullanılarak, A4 boyutunda hazırlanmalı, baştan sona çift aralıklı ve "Times New Roman" tarzında 12 punto yazı tipi kullanılarak elektronik ortamda yazılmalıdır. Makaleler İngilizce yazılmalıdır. Özetler hem Türkçe hem de İngilizce olarak yazılmalıdır. Metin iki yana yaslandırılmamalı, sadece sola yaslanmamalıdır. Kelimeler kısa çizgi ile hecelenmemelidir. Sayfalar sırayla numaralandırılmalıdır.

Aşağıdakileri içeren ayrı bir başlık sayfası olmalıdır:

- a) Başlık
- b) Yazarların isimleri
- c) Her yazarın tam adresi ile birlikte çalıştıkları laboratuvarlar
- d) Kısa başlık
- e) İletişimdeki yazar ve iletişim bilgileri
- f) Çıkar çatışması beyanı
- g) Teşekkür, bilgilendirme

Tam uzunluktaki kağıdın ana gövdesi şu bölümlere ayrılmalıdır:

1. Özet
2. Giriş

6. Conclusion
7. Conflict of interest
8. Acknowledgement
9. References

In general, there are no specific word lengths for any manuscript. The general principle is that a manuscript can be as long as necessary to communicate clearly and most effectively the scientific message, but should be as short as possible to achieve a complete presentation of the information without undue repetition or redundancy.

In the *Materials and Methods* section, the source of all compounds, equipment or software should be identified by the full name of the supplier, city, state/country. The chemical names of any drug should precede the trade name.

Papers describing animal experiments must define species, strain, sex, age, supplier and number of animals used. An ethical statement concerning the use of animals, or the details of ethical approvals, consent and recruitment of human subjects should be clearly stated. *Results* and *Discussion* can be broken down into subsections for improving the comprehensibility. The Results should not repeat methodological details and should avoid the discussion of the data.

The results of statistical tests should be incorporated in the body of the text, typically in the *Results* section, rather than in figure legends. Adequate description of statistical analysis should be provided. Statistical measures of variation in the text, illustrations and tables, should be identified. All dimensions and measurements must be

3. Gereç ve Yöntemler
4. Sonuçlar
5. Tartışma
6. Bağlam
7. Çıkar çatışması
8. Teşekkür, bilgilendirme
9. Kaynaklar

Genel olarak, herhangi çalışma için şart koşulan belirli bir kelime sayısı/metin uzunluğu yoktur. Genel ilke; bir makalenin bilimsel mesajı açık ve etkili bir şekilde iletmek için gerektiği kadar uzun olabileceği, ancak gereksiz tekrar veya fazlalık olmadan bilgilerin eksiksiz bir sunumunu elde etmek için mümkün olduğunca kısa olması gerektirir.

*Gereçler ve Yöntemler* bölümünde, tüm bileşiklerin, malzemelerin veya yazılımların kaynağı, tedarikçinin tam adı, şehir, eyalet/ülke ile tanımlanmalıdır. Herhangi bir ilacın kimyasal isimleri ticari isminden önce gelmelidir.

Hayvan deneylerini açıklayan makaleler, tür, soy, cinsiyet, yaş, tedarikçi ve kullanılan hayvan sayısını açıkça tanımlamalıdır. Hayvanların kullanımına ilişkin bir etik beyan veya insan deneklerin etik kurul onayları, bilgilendirilmiş onamları ve çalışmaya dâhil edilmelerine ilişkin ayrıntılar açıkça belirtilmelidir. *Sonuçlar ve Tartışma* bölümleri, anlaşılabilirliği artırmak için alt bölümlere ayrılabilir. Sonuçlar, metodolojik ayrıntıları tekrarlamamalı ve verilerin tartışılmasından kaçınılmalıdır.

İstatistiksel testlerin sonuçları, şekillerin altındaki açıklama kısımlarından ziyade metnin gövdesine, tipik olarak Sonuçlar bölümüne dâhil edilmelidir. İstatistiksel analizin yeterli bir şekilde açıklaması sağlanmalıdır. Metinde, resimlerde ve

specified in the metric system.

All subscripts, superscripts, Greek letters and unusual characters must be clearly identified.

In the text, abbreviations should be used consistently. Abbreviations should be defined on first use.

References should be designed in "Vancouver" style. While writing references, "Times New Roman" 10 point font should be used. Multiple authors should be separated by a comma. If there are more than three authors, after the 3rd author, "et al." should be inserted without a comma for both article and book references. If reference is made from a chapter in a book and there are many authors belonging only to this chapter, the title and chapter of the book are indicated, the first three of the chapter authors are written, and "et al." statement is added for subsequent authors.

Example:

1. Perell KL, Nelson A, Goldman RL, et al. Fall risk assessment measures: an analytic review. The journals of gerontology Series A, Biological sciences and medical sciences. 2001;56(12):M761-6.
2. Ha H, Han C, Kim B. Can Obesity Cause Depression? A Pseudo-panel Analysis. Journal of preventive medicine and public health = Yebang Uihakhoe chi. 2017;50(4):262-7.
3. Çekmen MB, Turgut M, Türköz Y, et al. Nitrik Oksit (NO) ve Nitrik Oksit Sentaz (NOS)'ın Fizyolojik ve Patolojik Özellikleri. Türkiye Klinikleri Journal of Pediatrics. 2001;10(4):226-35.
4. Parlakpınar H, Örum MH, Acet A. Kafeik asit fenetil ester (KAFF) ve miyokardiyal

tablolarda istatistiksel varyasyon ölçütleri tanımlanmalıdır.

Tüm boyutlar ve ölçüler metrik sistemde belirtilmelidir.

Tüm alt simgeler, üst simgeler, Yunan harfleri ve olağandışı karakterler açıkça tanımlanmalıdır.

Metinde kısaltmalar tutarlı bir şekilde kullanılmalıdır. Kısaltmalar ilk kullanımda tanımlanmalıdır.

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Örnek:

1. Perell KL, Nelson A, Goldman RL, et al. Fall risk assessment measures: an analytic review. The journals of gerontology Series A, Biological sciences and medical sciences. 2001;56(12):M761-6.
2. Ha H, Han C, Kim B. Can Obesity Cause Depression? A Pseudo-panel Analysis. Journal of preventive medicine and public health = Yebang Uihakhoe chi. 2017;50(4):262-7.
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iskemi reperfüzyon (Mİ/R) hasarı. İnönü Üniversitesi Sağlık Bilimleri Dergisi 2012; 1: 10-5.

5. Yıldırım AB. The effects of maternal hypothyroidism on the immunoreactivity of cytochrome p450 aromatase in the postnatal rat testes. 2015; Doctoral thesis.

6. [https://hsgm.saglik.gov.tr/depo/birimler/kanserdb/istatistik/Trkiye\\_Kanser\\_statis\\_tikleri\\_2016.pdf](https://hsgm.saglik.gov.tr/depo/birimler/kanserdb/istatistik/Trkiye_Kanser_statis_tikleri_2016.pdf) (Last access date: 21.09.2020).

7. Kuran O, İstanbul, Filiz Kitabevi. Sistematik Anatomi. 1983 p. 76-9.

8. Abbas AK, Andrew H Lichtman, Shiv Pillai. Cellular and Molecular Immunology. 6th ed. Philadelphia: Saunders Elsevier; 2007 p. 121-56.

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Tables of numerical data should each be typed with double spacing on separate pages numbered in sequence in numerals, provided with a heading, and referred to in the text, as Table 1, Table 2, etc. Each table should have a brief but descriptive heading. Explanatory matter should be included in footnotes to the table.

We accept electronic supplementary material to support and enhance your scientific research. Supplementary files offer the author additional possibilities to publish supporting applications, movies, animation sequences, high-resolution images, background datasets, sound clips and more.

4. Parlakpınar H, Örum MH, Acet A. Kafeik asit fenetil ester (KAPE) ve miyokardiyal iskemi reperfüzyon (Mİ/R) hasarı. İnönü Üniversitesi Sağlık Bilimleri Dergisi 2012; 1: 10-5.

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# The Application of Artificial Intelligence in the Field of Cardiovascular Diseases Focuses on Both Diagnostic and Therapeutic Aspects

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## Abstract

*In the field of medicine, advanced computer algorithms use artificial intelligence (AI) to retrieve information from large databases. AI has the potential to accelerate the identification and management of cardiovascular diseases (CVDs), including conditions such as heart failure, atrial fibrillation, valvular heart disease, hypertrophic cardiomyopathy, congenital heart disease, and several others. From a clinical perspective, AI improves CVD diagnosis, increases the usefulness of auxiliary tools, aids in stratifying and identifying different types of diseases, and enables accurate outcome prediction. We anticipate that state-of-the-art AI algorithms, designed to extract minute connections from extensive healthcare data, will address more challenging tasks compared to earlier methods. The goal of this review is to emphasize the current uses of AI in CVDs, thereby equipping doctors with little knowledge of computer science to gain a deeper understanding and effectively use AI algorithms in clinical practice.*

**Key words:** *Advanced computer algorithms, Artificial intelligence, Cardiovascular diseases*

## Introduction

Artificial intelligence (AI) simulates human cognitive processes in machines, notably computers. There are three processes: learning, reasoning, and self-correction. AI draws on cardiology, psychology, linguistics, philosophy, neurology, and more. AI enables systems to learn from their experiences without requiring programming. The system incorporates decision trees, neural networks, and clustering methods. These systems advise and solve issues using rules and knowledge systems. This machine learning method involves an agent learning to make choices via environmental interaction. The agent gets incentives or punishments to achieve the desired results (1, 2).

Clinicians can use AI-processed echocardiograms (ECGs) to diagnose heart failure (HF), atrial fibrillation (AF), anemia, hypertrophic cardiomyopathy (HCMP), and pulmonary hypertension (PH). Validated and proven algorithms may minimize doctors' cognitive strain by providing pre-diagnosis, rectifying mistakes, and avoiding misdiagnosis (3-10). AI uses machine learning to uncover minute correlations in data, thereby removing the necessity for human encoding. Subtle findings may transform human illness prediction, diagnosis, prognosis, and recovery (11).

Unsupervised learning classifies samples using data analysis for a large number of samples without category information, such as clustering and association rule-learning algorithms (12). Reinforcement learning combines supervised and unsupervised learning, enabling failures and trials to improve algorithm accuracy (13).

Deep learning (DL), artificial neural networks (ANN), and support vector machines (SVM) are the most often used algorithms in medicine (14). ANNs are better at ECG analysis (15), whereas SVMs improve illness stratification (16). Overfitting, underfitting, and misspecification prevented ANNs and SVMs from disposing of all situations equally (17). Cardiovascular medicine uses CNNs, RNNs, and DNNs for deep learning analysis of visual data (18). Despite their pros and cons, these algorithms diagnose, forecast, and stratify cardiovascular illnesses successfully. This review provides a concise overview of the uses of AI in cardiovascular diseases (CVDs) from the perspective of clinicians, aiming to improve their understanding and utilization of these technologies.

### AI-aided CVD diagnosis

AI-aided CVD diagnosis is used to identify, diagnose, and treat CVDs. AI can improve CVD diagnosis and treatment accuracy, efficiency, and accessibility,

revolutionizing healthcare. AI systems may use data on patient demographics, medical history, and biomarkers to predict CVD risk. The prediction algorithms may identify high-risk individuals who may benefit from early intervention and prevention. AI-powered computerized tomography (CT), magnetic resonance imaging (MRI), and echocardiography may help interpret cardiac pictures. Deep learning algorithms can identify minor irregularities, assess disease severity, and provide diagnostic insights from medical pictures for more accurate and rapid diagnosis. AI systems can analyze symptoms, lab tests, and medical history to help physicians diagnose and treat patients (19-24).

Decision-support technologies may provide evidence-based recommendations, identify mistakes, and propose patient-specific treatment strategies. Wearable gadgets and mobile health apps with AI can track heart rate (HR), blood pressure (BP), and activity outside of clinical settings. Remote monitoring technologies may identify CV irregularities early, enable real-time therapies, and promote patient participation in disease care. AI algorithms can analyze genomes, proteomics, and molecular pathways to find new drug targets, optimize therapeutic candidates, and speed up CV drug development. AI may help researchers create new CVD medicines faster. AI-based predictive modelling may use several

patient data sources to provide personalised risk profiles and therapy recommendations. Precision medicine tactics improve patient outcomes and reduce side effects (25, 26).

### **Valvular heart disease (VHD)**

AI-aided VHD diagnostics uses AI to identify, diagnose, and treat VHD. To discover and quantify heart valve shape and function issues, AI systems may assess echocardiograms, cardiac MRIs, and CT images. These algorithms are capable of quantifying valve characteristics, checking valve shape and motion, and diagnosing valve stenosis or regurgitation. By automating image processing, AI can help physicians analyze complicated cardiac pictures and make accurate diagnoses. AI models may use clinical data, imaging results, and other characteristics to segment VHD patients by risk of disease progression, complications, or bad outcomes. AI-driven risk stratification technologies help refine patient care and clinical decision-making by identifying high-risk patients who may benefit from early intervention or closer monitoring (27, 28).

AI-powered decision support systems, which use patient-specific data such as clinical history, symptoms, imaging findings, and laboratory tests, may provide evidence-based CVD therapy recommendations. Depending on patient features and illness severity, these decision-

support tools may help doctors choose drug therapy, valve repair, or valve replacement. In real time, AI-enabled remote monitoring devices and mobile health apps may measure VHD signs, including heart rate, rhythm, and BP. Remote monitoring technologies may help delay VHD by monitoring patients' CV conditions and alerting doctors to major changes or worsening symptoms. AI algorithms can analyze massive databases of patient outcomes, treatment responses, and clinical characteristics to create customised VHD treatment regimens. AI-driven treatment planning considers age, comorbidities, illness severity, and patient preferences. Modern computer programmes that can look at large amounts of complicated medical data, help with early detection and risk stratification, back up doctors' decisions, and make treatment plans more specific for each patient could make CV care better (29, 30).

### **Atrial fibrillation (AF)**

AI detects, diagnoses, and treats AF, a common heart arrhythmia. Palpitations, shortness of breath, and exhaustion are caused by irregular and fast heartbeats in the atria in AF. AI systems that use ECG records can reliably detect AF. Even with modest or intermittent arrhythmia, deep learning algorithms trained on huge ECG datasets may recognise AF patterns. AI-powered ECG interpretation tools may help

doctors identify and treat AF during regular checkups. AI-enabled smartwatches and fitness trackers may identify AF outside of clinical settings by monitoring HR and rhythm. These devices detect AF episodes using algorithms to analyze HR variability (HRV) and rhythm anomalies. AF management and results may be improved by AI-driven wearable technology's remote monitoring and early diagnosis (31,32).

Demographics, medical history, and comorbidities may be used by AI models to predict AF and its consequences, such as stroke or HF. AI-driven risk prediction techniques may improve AF management and tailored therapy by identifying high-risk patients who may benefit from preventative treatments or closer monitoring. ECG results, symptoms, medication history, and comorbidities may be used by AI algorithms to improve AF therapy. Decision support systems may help doctors choose antiarrhythmics and anticoagulants and weigh the risks and advantages of rhythm vs. rate management. AI-driven therapy optimisation systems that incorporate patient preferences may enhance the results and quality of life of AF patients (33, 34).

AI systems may combine ECG, imaging, laboratory, and electronic health record data to enhance AF clinical decision-making. These systems may analyze and synthesise diverse data sources to deliver actionable

insights, aid healthcare provider care coordination, and aid patient decision-making. Healthcare teams may customize and improve AF treatment using AI-driven clinical decision assistance (35).

### **Coronary artery disease (CAD)**

We use AI to identify, diagnose, risk-evaluate, and treat CAD. Plaque narrows or blocks heart muscle blood channels, reducing blood flow and oxygen delivery. To forecast CAD risk, AI systems may examine vast datasets, including demographics, medical history, lifestyle variables, and biomarkers. By identifying high-risk people who may benefit from preventative treatments or lifestyle changes, AI-driven risk prediction models may prioritize resources and enhance outcomes. CTA and MRI, which use AI, can detect and characterize plaque buildup, coronary artery stenosis (narrowing), and cardiac function. Medical image analysis using deep learning algorithms may uncover minor anomalies, assess illness severity, and give diagnostic insights for a more accurate and fast diagnosis (36, 37).

AI algorithms can identify ischemia and other cardiac irregularities caused by CAD in ECG records. Artificial intelligence-driven ECG interpretation systems may assist doctors in identifying CAD patients and guiding diagnostic and therapeutic strategies by automatically evaluating ECG readings and indicating problematic

outcomes for further assessment. AI systems can combine clinical data, imaging results, laboratory tests, and other factors to provide evidence-based CAD care recommendations. Based on patient features and disease severity, these decision-support systems may assist doctors in choosing drug therapy, percutaneous coronary intervention (PCI), or coronary artery bypass grafting (CABG). Remote monitoring devices and mobile health apps can check blood pressure, HR, and physical activity in real time outside of clinical settings using AI (38, 39).

Remote monitoring technologies may help avoid CAD problems by continually monitoring patients and notifying healthcare practitioners of major changes or worsening symptoms. AI algorithms may assess clinical history, genetic data, and therapy responses to create customized treatment recommendations. AI-driven treatment planning technologies improve therapeutic options and patient outcomes by incorporating age, comorbidities, illness severity, and patient preferences (35).

### **HF**

We use AI to identify, forecast, risk-evaluate, and treat heart failure (HF). To forecast HF or bad outcomes like hospitalisation or death, AI systems may examine massive datasets of demographic data, medical history, laboratory results, imaging findings, and other factors.

Artificial intelligence-driven risk prediction models have the potential to improve patient care and outcomes by identifying high-risk people who may benefit from preventative measures or closer monitoring. AI-enabled wearable devices and mobile health apps can monitor HR, rhythm, breathing rate, and activity levels to identify HF decompensation and aggravation. Remote monitoring technologies may help avoid hospital readmissions by assessing symptom intensity and notifying patients and healthcare professionals when HF symptoms are deteriorating (3, 5).

HF patients may benefit from AI-powered echocardiography, cardiac MRI, and nuclear imaging to examine cardiac anatomy and function. To improve HF diagnosis and risk stratification, deep learning algorithms can analyze medical pictures to detect cardiac anomalies, measure ventricular size and function, evaluate valve function, and forecast outcomes. AI algorithms may analyze N-terminal pro-B-type natriuretic peptide (NT-proBNP), cardiac troponins, and inflammatory markers to diagnose disease severity, track therapy response, and predict clinical outcomes in HF patients. AI-driven prediction models may monitor disease development and guide treatment by merging biomarker readings with clinical and imaging data (20).

AI algorithms can enhance HF therapy by analyzing patient-specific data such as symptoms, test findings, medication history, and comorbidities. Depending on the patient's condition and how bad the illness is, clinical decision support technologies may help doctors choose which drugs, device-based interventions (like cardiac resynchronization therapy (CRT) or implanted cardioverter-defibrillators (ICD)), and lifestyle changes to make. AI algorithms can customize HF therapy strategies based on patient data. AI-driven care planning systems may improve patient outcomes and quality of life by addressing each HF patient's individual requirements and problems, taking into account age, comorbidities, disease severity, treatment choices, and socioeconomic position (40).

### **CM**

We use AI to identify, classify, risk-evaluate, and treat CM, a diverse set of cardiac muscle illnesses. AI-powered imaging modalities, including echocardiography, cardiac MRI, and nuclear imaging, may help evaluate heart anatomy and function in CM patients. Deep learning algorithms can look at medical images and find patterns of myocardial dysfunction, measure ventricular size and function, check myocardial perfusion and viability, and guess how CM will turn out. This makes diagnosis and risk stratification

better. Based on the results of DNA sequencing, AI systems can look for genetic variations that are connected to inherited CMs like hypertrophic, dilated, and arrhythmogenic CM. AI-driven prediction models may help genetic CM patients make tailored treatment choices, interpret genetic testing and counseling, and understand disease pathophysiology by combining genetic, clinical, and imaging data (23, 41). By looking at biomarker data like NT-proBNP, cardiac troponins, and inflammatory markers, AI algorithms may be able to figure out how bad a patient's CM is, how well their treatment is working, and what their clinical outcomes will be. Biomarker measures combined with clinical and imaging data may help AI-driven prediction models forecast disease progression and guide treatment. In ECG records, AI algorithms may identify CM symptoms such as ventricular enlargement, conduction problems, and arrhythmias. AI-driven ECG interpretation technologies may help doctors discover CM patients and improve diagnosis and therapy by automatically evaluating ECG readings and reporting bad outcomes. AI algorithms can enhance CM therapy choices by analyzing patient-specific data such as symptoms, test findings, medication history, and comorbidities. Based on patient characteristics and disease severity, these decision support systems may assist doctors

in choosing pharmaceutical medications, device-based interventions, and lifestyle changes (42, 43).

### **Congenital heart disease (CHD)**

CHD is the most common congenital disability, causing considerable postnatal mortality (44). Pregnancy restricts the detection of CHD due to a shortage of skilled sonographers or missing imaging frames (45). Clinicians cannot detect abnormal image frames, whereas trained AI-ECG models can (43). To distinguish normal hearts from CHD, Arnaout et al. (43) trained a neural network on over 100,000 echocardiographic and screening ultrasound images from 18 to 24 weeks. It distinguished normal from diseased hearts in the internal test set, with an AUC of 0.99 and a 100% negative predictive value. Even on lower-quality fetal images taken outside of hospitals, the DL-based screening ultrasonography model efficiently identifies CHD. AI models may help clinicians make decisions (5, 23, 42). AI technology is becoming more widespread, so AI-based models may screen for and improve early disease identification and treatment in settings with limited equipment (6, 23, 25).

### **AI-aided CVD stratification and typing**

AI-aided CVD classification and typing accurately labels and rates cardiovascular conditions in individuals. Modern computer algorithms analyse medical history, clinical testing, imaging examinations, genetic data,



and lifestyle variables. AI systems may use varied data sources to classify people by CVD risk. AI-driven risk stratification models may find high-risk patients who could benefit from preventative measures or closer monitoring by looking at their demographics, medical history, biomarkers, and other factors. This can help make the best use of resources and improve outcomes. AI can categorize CVD subgroups by aetiology, pathophysiology, and clinical symptoms (46, 47).

Using clinical data and imaging investigations, AI systems can distinguish HCMP and DCMP cardiomyopathy or CAD phenotypes. AI-driven typing algorithms enhance illness categorization and therapy techniques. Using longitudinal patient data, AI models may predict CVD development and outcomes. Using patient characteristics, treatment responses, and disease trajectories, these predictive models may predict disease progression, adverse events (e.g., myocardial infarction (MI), stroke), and death. By identifying high-risk patients, AI-driven predictive modeling may support tailored therapies and clinical decision-making. AI can predict cardiovascular disease therapy responses using patient-specific data (48-50).

AI-driven prediction models can estimate therapeutic efficacy, adverse effects, and treatment failure by looking at genetic variability, biomarker profiles,

comorbidities, and treatment history. This lets clinicians make treatment plans that do the most good and the least harm. By incorporating patient-specific data, AI may create personalised CVD treatment programmes and risk reduction measures. Artificial intelligence-driven personalised medicine may maximize therapeutic choices, treatment adherence, and patient outcomes by incorporating genetic, clinical, and lifestyle aspects (51-53).

#### **AI-aided CVD outcome prediction**

AI helps predict the evolution and prognosis of CVDs in people. Modern computer algorithms analyze medical history, clinical testing, imaging examinations, genetic data, and lifestyle variables. AI can classify people at risk for CV events, including MI, strokes, and cardiac death. By assessing demographics, medical history, biomarkers, and other data, AI-driven risk stratification models may identify high-risk patients and lead customized therapies to minimize risk factors and enhance outcomes. AI models can anticipate CVD development. Data from large patient cohorts may help AI-driven disease progression models predict illness exacerbations, comorbidities, and functional decline (54-59).

Clinicians may use these predictive models to forecast disease trajectories, adapt therapy, and improve patient care to avoid poor consequences. AI algorithms may anticipate varied CVD therapy responses.

Prediction models that are run by AI look at genetic differences, biomarker profiles, comorbidities, and treatment history to figure out how well drugs work, what side effects they have, and whether a treatment failed. To enhance therapeutic benefit and avoid damage, these prediction models provide individualised therapy selection, dosage adjustment, and monitoring. In individual individuals, AI models may be able to predict MI, stroke, and HF aggravation. By combining clinical, imaging, and biomarker data, AI-driven event prediction models may be able to find people who are more likely to have bad outcomes and help them receive more targeted treatments. Early identification of high-risk patients allows for appropriate pharmaceutical, lifestyle, and procedural treatments to reduce adverse events and improve patient outcomes (60-63).

### **Limitations**

Several challenges must be resolved before AI may be employed in supplementary diagnosis:

(1) Humans cannot comprehend AI network intermediate layers, requiring further research to improve user trust in AI tools (6, 23, 26).

(2) To confirm the reliability of these models on a larger scale and with more patients, more research is required (23, 26, 29).

(3) Further research is required to assess AI technology's cost-effectiveness in auxiliary diagnostics and clinical impact (5). The main topic points of recent studies are shown in Table 1.

### **Conclusion**

Medical professionals use AI to extract data from large databases using sophisticated computer algorithms. AI may speed up the detection and treatment of CVDs, including HF, AF, VHD, HCMP, CHD, and others. Clinically, AI improves CVD diagnosis, auxiliary tool effectiveness, disease stratification and type, and outcome prediction. We predict that recent AI algorithms, designed to capture tiny correlations from large healthcare data, will tackle more challenging tasks than previous approaches. This study aims to highlight current AI applications in CVDs, enabling physicians with modest computer science backgrounds to better comprehend and use AI algorithms in clinical practice.

**Table 1.** The main topic points of recent studies.

Reference no.	Authors	Subjects	Main theme
Ref [1]	Xu et al.	gastric cancer	The agent gets incentives or punishments to achieve the desired results.
Ref [2]	Montull et al.	sports monitoring	The machine learning method involves an agent learning to make choices via environmental interaction.
Ref [4]	Attia et al.	left ventricular dysfunction in COVID-19	AI ECG has been demonstrated to identify ventricular dysfunction in a broad general population, which may be beneficial for COVID-19 screening.
Ref [5]	Yao et al.	patients with low ejection fraction	In primary care, an AI system based on ECGs may detect poor EF early.
Ref [7]	Kwon et al.	anaemia patients	Anaemia was discovered by a DLA utilising raw ECG data. ECGs with AI might check for anaemia.
Ref [8]	Ko et al.	hypertrophic cardiomyopathy	AI-based ECG-based HCM detection is effective, especially in younger patients.
Ref [9]	Kwon et al.	pulmonary hypertension	Using 12-lead and single-lead ECGs, the AI programme predicted PH accurately.
Ref [10]	Cho et al.	human-computer interaction	This simple and systematic heuristic assessment technique may be utilised at different phases of system development to decrease the time and expense of proving a system's usefulness before wider adoption.
Ref [11]	Emile et al.	COVID-19	Machine learning is used in AI to identify tiny correlations in data, eliminating the need for human encoding.
Ref [12]	Zhu et al.	biomedical computation	Unsupervised learning classifies samples using data analysis for a large number of samples without category information, such as clustering and association rule-learning algorithms.
Ref [13]	Yadav et al.	a case study of India	Reinforcement learning combines supervised and unsupervised learning, enabling failures and trials to improve algorithm accuracy.
Ref [14]	Kahr et al.	machine learning with synthetically generated data	Deep learning (DL), artificial neural networks (ANN), and support vector machines (SVM) are the most often used algorithms in medicine.
Ref [15]	Muller et al.	neuromorphic hardware	ANNs are better at ECG analysis.
Ref [16]	Yadav et al.	complex disease biology	SVMs improve illness stratification.
Ref [17]	De Mattos et al.	extreme learning machine	Over-fitting, under-fitting, and misspecification prevented ANNs and SVMs from disposing of all situations equally.
Ref [20]	Vaid et al.	right and left ventricular dysfunction	ECG-DL can build cheap screening, diagnostic, and prognostic tools for LV and RV dysfunction.

Ref [23]	Shrivastava et al.	patients with dilated cardiomyopathy	High sensitivity and negative predictive value for DC identification made AI-ECG a simple and cost-effective screening technique for first-degree relatives of DC patients.
Ref [24]	Elias et al.	left-sided valvular heart disease	Deep learning ECG analysis can correctly identify AS, AR, and MR in this multicenter population, which might fuel a valvular heart disease screening programme.
Ref [25]	Siontis et al.	cardiovascular disease management	Decision-support technologies may provide evidence-based recommendations, identify mistakes, and propose patient-specific treatment strategies.
Ref [26]	Attia et al.	Electrocardiograms	AI algorithms can analyse genomes, proteomics, and molecular pathways to find new drug targets, optimise therapeutic candidates, and speed up CV drug development.
Ref [29]	Kwon et al.	aortic stenosis	AI-powered decision support systems may provide evidence-based CVD therapy recommendations.
Ref [30]	Cohen-Shelly et al.	aortic stenosis	AI algorithms can analyze massive databases of patient outcomes, treatment responses, and clinical characteristics to create customized VHD treatment regimens.
Ref [32]	Davidson et al.	atrial fibrillation	AI is used to detect, diagnose, and treat AF, a common heart arrhythmia.
Ref [33]	Khurshid et al.	atrial fibrillation	AI models may predict AF and its consequences, such as stroke or HF, using demographics, medical history, and comorbidities.
Ref [34]	Noseworthy et al.	atrial fibrillation	AI-driven risk prediction techniques may improve AF management and tailored therapy by identifying high-risk patients who may benefit from preventative treatments or closer monitoring.
Ref [35]	Sun et al.	cardiovascular diseases	AI systems may combine ECG, imaging, laboratory, and electronic health record data to enhance AF clinical decision-making.
Ref [38]	Lin et al.	coronary artery disease	AI algorithms can identify ischemia and other cardiac irregularities in ECG records caused by CAD.
Ref [39]	Yan et al.	atrial fibrillation	AI systems may combine clinical data, imaging results, laboratory tests, and other factors to provide evidence-based CAD care recommendations.
Ref [41]	Khursid et al.	left ventricular mass and hypertrophy from 12-lead ECGs	AI-driven prediction models may help genetic CM patients make tailored treatment choices, interpret genetic testing and counselling, and understand disease pathophysiology by combining genetic, clinical, and imaging data.
Ref [43]	Arnaout et al.	complex congenital heart disease	AI algorithms can enhance CM therapy choices by analysing patient-specific data such as symptoms, test findings, medication history, and comorbidities.
Ref [52]	Reel et al.	hypertension subtypes	By considering genetic variability, biomarker profiles, comorbidities, and treatment history, AI-driven prediction models can estimate therapeutic efficacy, adverse effects, and treatment failure,

allowing clinicians to tailor treatment regimens to maximise benefit and minimise harm.

Ref [57]	De Souza et al.	coronary artery disease	AI-driven risk stratification models may identify high-risk patients and lead customised therapies to minimise risk factors and enhance outcomes by assessing demographics, medical history, biomarkers, and other data.
Ref [58]	Backhaus et al.	acute myocardial infarction	Data from large patient cohorts may help AI-driven disease progression models predict illness exacerbations, comorbidities, and functional decline.
Ref [60]	Min et al.	coronary stent underexpansion	Clinicians may use these predictive models to forecast disease trajectories, adapt therapy, and improve patient care to avoid poor consequences.
Ref [62]	Kilic et al.	aortic valve replacement	AI algorithms may anticipate varied CVD therapy responses.
Ref [63]	Sherman et al.	cardiac surgery	In individual individuals, AI models may be able to predict MI, stroke, and HF aggravation in individuals.

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# The Current Status and Future Vision of Artificial Intelligence Applications in Healthcare

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## Abstract

*This study examines the impacts of artificial intelligence (AI) technologies in the healthcare sector, particularly in the areas of medical imaging, diagnosis, treatment planning, and patient monitoring. AI's ability to analyze medical images more accurately and quickly, diagnose diseases at an early stage, create personalized treatment plans, and continuously monitor patient conditions has significantly enhanced the quality and accessibility of healthcare services. However, the ethical, privacy, and security issues associated with AI underscore the need for these technologies to be responsibly integrated into the healthcare sector. Moving forward, the role of AI in healthcare services is expected to expand, and realizing this potential in an ethical and secure manner will require ongoing effort.*

**Key words:** *Artificial intelligence, Medical imaging, Diagnosis and treatment planning, Patient monitoring, Ethics and security*

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## Introduction

In recent years, artificial intelligence (AI) technologies have increasingly been used in the healthcare sector. Particularly in the field of medical imaging, AI-supported solutions have shown significant progress in the diagnosis and treatment of diseases. Medical imaging enables doctors to visualize internal organs, tissues, and bones, aiding in more accurate and rapid diagnoses. Traditionally, interpreting these images requires expertise and is time-consuming. However, artificial intelligence significantly accelerates this process, enabling faster and more accurate diagnoses (1, 2).

Artificial intelligence can analyze medical images and detect details that might be overlooked by the human eye. This is crucial for diagnosing early-stage diseases, personalizing treatment plans, and monitoring patients (3). AI also continuously improves its ability to recognize disease patterns and predict treatment outcomes by learning from large datasets. These capabilities not only enhance the quality of healthcare services but also contribute to reducing the costs of patient care (4).

However, the use of AI technologies in healthcare brings significant issues such as ethics, privacy, and security. Protecting patient data, risks of misdiagnosis, and transparency of AI decisions are

fundamental areas that need responsible integration of this technology in the healthcare sector (5).

This study examines how artificial intelligence is used in healthcare, especially in medical imaging, diagnosis, treatment planning, and patient monitoring, and how these technologies have enhanced the quality of healthcare services. Additionally, the challenges faced by AI technologies and the future expectations in this field are also evaluated.

### 1. The Use of Artificial Intelligence in Medical Imaging

Medical imaging is one of the most important tools in modern medicine. Various imaging techniques such as MRI, CT, X-rays, and ultrasound help doctors diagnose diseases, plan treatments, and monitor patients' health conditions. However, analyzing these images can be complex and require a high level of expertise (6). Artificial intelligence (AI) has the potential to transform these processes by automating and accelerating image recognition and analysis.

AI algorithms, utilizing deep learning techniques, learn from large datasets and acquire the ability to recognize complex patterns and anomalies in medical images. These algorithms assist doctors, especially in diagnosing difficult cases and planning treatment processes. For example, AI can detect microscopic tumors in mammograms

or analyze fine details in lung tomographies to identify early-stage cancer cases (7).

AI-supported medical imaging not only accelerates the diagnosis processes but also improves doctors' decision-making processes. Artificial intelligence reveals subtle details in medical images and offers a second opinion for diagnoses, enabling more accurate and personalized treatment planning (8).

Visually, the use of AI-supported medical imaging systems demonstrates the difference this technology makes in healthcare services (9). These systems contribute to advancements in the field of medical imaging, significantly improving patient care and shaping the future of healthcare services. Figure 1 shows the AI-supported 3D scan data of a human brain.



**Figure 1.** 3D scan image of the human brain.

## **2. Artificial Intelligence in Diagnosis and Treatment Planning**

The impact of artificial intelligence (AI) technologies in the healthcare field is not limited to medical imaging; it also offers innovations in diagnosis and treatment planning. AI is transforming healthcare services across a wide range, from early disease diagnosis to personalized treatment plans (10, 11).

### **2.1. Early disease diagnosis with artificial intelligence**

Early diagnosis is a critical factor in the successful treatment of many diseases. AI systems can analyze complex medical data to detect early signs of diseases (12). For example, deep learning algorithms can analyze photos of moles and lesions in skin cancer screenings to warn about potential malignancies. Such AI systems enable the early diagnosis of skin cancer, increasing the chance of successful treatment (13).

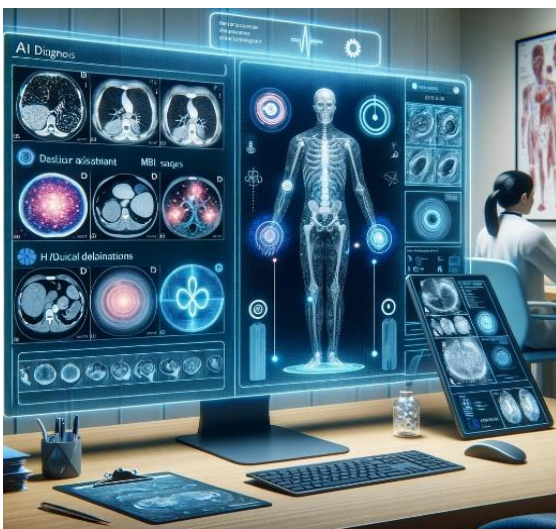
### **2.2. The role of artificial intelligence in treatment processes**

AI technologies play a significant role in the treatment planning process. By suggesting the most effective treatment methods based on the type of disease and the patient's specific condition, AI personalizes treatment processes. AI learns from extensive clinical databases and analyzes treatment outcomes from patients with similar disease profiles. This information helps doctors select the most suitable

treatment methods for the patient's condition (14).

### **2.3. The importance of artificial intelligence in personalized treatment planning**

Personalized approaches in disease diagnosis and treatment are a significant trend that enhances the quality and effectiveness of patient care. Artificial intelligence can develop individual treatment plans by analyzing various factors, such as patients' genetic information, lifestyle, and previous health records. For example, in cancer treatment, AI-supported systems analyze the genetic structure of the tumor to recommend the most effective drug combinations (2, 15, 16). These personalized treatment plans can significantly increase the success of the treatment. Figure 2 provides a visual representation of diagnosis and treatment planning with AI.



**Figure 2.** An example of diagnosis and treatment planning with artificial intelligence.

These technologies are shaping the future of the health sector by making healthcare services more accessible, effective, and personalized.

### **3. The Use of Artificial Intelligence in Patient Monitoring**

Artificial intelligence (AI) extends its impact in the healthcare sector beyond diagnosis and treatment planning to play a significant role in patient monitoring and management processes. AI technologies are employed across a broad spectrum from chronic disease management to remote patient monitoring, offering patients more proactive and personalized care (17, 18).

#### **3.1. Artificial intelligence in the management of chronic diseases**

The management of chronic diseases is a challenging process that requires continuous monitoring and evaluation. Artificial intelligence can analyze patients' health data in real-time, identifying potential health risks and the sudden worsening of diseases. This is particularly valuable for patients with chronic diseases such as diabetes or heart disease. AI-supported systems monitor critical health indicators like blood sugar levels or blood pressure, and send alerts to both patients and healthcare providers when abnormal values are detected. This proactive approach prevents emergencies and allows for more effective management of chronic diseases (2, 19, 20).

### 3.2. Remote patient monitoring and artificial intelligence

Remote patient monitoring has become a significant trend in the delivery of healthcare services, especially during and after the pandemic. Artificial intelligence plays a crucial role in this process, as it analyzes data collected from remote monitoring devices to continuously assess patients' health conditions. This technology allows for close monitoring of patients' health even while they are at home, reducing the need for hospital visits and alleviating the burden on healthcare systems (14, 20, 21).

### 3.3. AI-Supported mobile health applications

Mobile health (mHealth) applications enable users to track their health data and access healthcare services. Artificial intelligence makes these applications smarter and more personalized. For example, an AI-supported mHealth app can analyze data such as the user's activity level, heart rate, and sleep quality to provide personal health recommendations. Furthermore, these applications allow users to enter their symptoms and perform an AI-supported preliminary assessment, guiding them on when to consult a doctor (21, 22). Figure 3 shows an example of a mHealth application visual.



**Figure 3.** An Example of Patient Monitoring System with Artificial Intelligence.

Visually, the use of a patient monitoring system powered by artificial intelligence showcases the technology's impact on patient care and the delivery of healthcare services. These systems significantly improve patient care by making healthcare services more accessible and effective.

## 4. Ethical, Privacy, and Security Issues

The use of artificial intelligence (AI) technologies in the healthcare sector presents significant potential benefits, but it also raises important issues related to ethics, privacy, and security. Responsible use of these technologies is critical both to protect patients' rights and to maximize the benefits AI can provide to healthcare services (5, 23).

#### **4.1. Ethical considerations in the use of artificial intelligence**

Ethics play a crucial role in the design and implementation of AI systems. AI algorithms can make incorrect decisions based on biases and deficiencies in the data sets they are trained on. This can lead to adverse outcomes, especially for ethnic minorities or specific demographic groups (24). Therefore, AI systems need to be fair, transparent, and accountable. Additionally, the role of AI in medical decision-making processes requires the establishment of boundaries on the impact of AI on doctors' clinical decisions (5, 23).

#### **4.2. Privacy and security of patient data**

For AI systems to be effectively used in healthcare services, they require access to large amounts of patient data. Protecting the privacy and security of this data is vital for patients' rights. Measures must be taken to guard against unauthorized access to patient data and to ensure that these data are used in accordance with ethical standards. Data protection laws and regulations provide guidance on how this data can be collected, stored, and processed (5).

#### **4.3. Risks of incorrect diagnosis and treatment with artificial intelligence**

The use of AI systems carries the risk of incorrect diagnosis and treatment. The decisions made by AI algorithms depend on the quality and scope of the training data. If an AI system is trained with insufficient or

biased data, it can produce misleading results. This can lead to incorrect diagnoses or unnecessary treatments. Therefore, AI-supported diagnosis and treatment recommendations should always be evaluated and approved by expert medical personnel (25).

As technological and visual advancements expand the use of AI in healthcare, a meticulous approach to ethical, privacy, and security issues must be adopted. Healthcare providers, technology developers, and regulatory bodies need to work together to address these issues and ensure the safe and ethical use of AI in the healthcare sector.

#### **Conclusion**

Artificial intelligence (AI) holds significant importance in the healthcare sector, especially in the areas of medical imaging, diagnosis, treatment planning, and patient monitoring. This technology has greatly enhanced the quality and accessibility of healthcare services by enabling faster and more accurate analysis of medical images, early disease diagnosis, the creation of personalized treatment plans, and continuous patient monitoring. Thanks to its ability to learn from large datasets, AI is continuously evolving and has the potential to further improve healthcare services.

However, the implementation of AI in healthcare also brings serious issues related to ethics, privacy, and security. It is essential that these technologies are



ethically designed, patient data security is ensured, and the risks of incorrect diagnoses or treatments are minimized. Overcoming these challenges requires close collaboration among technology developers, healthcare providers, and regulatory bodies.

Looking to the future, the role of AI in healthcare services is expected to expand, contributing to the development of new treatment methods, improving patient care, and reducing the costs of healthcare services. Realizing this potential fully requires continuous effort to overcome encountered challenges and to integrate AI into healthcare services ethically and securely.

Artificial intelligence is an increasingly important technology in healthcare services. Research and developments in this field have the potential to significantly improve both patient care and the overall efficiency of healthcare services. The applications of AI in the healthcare sector are expected to reshape how healthcare services are provided in the future, bringing innovations in the protection and improvement of human health.

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# Artificial Intelligence in Geriatric Medicine

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## Dear Editor,

The use of artificial intelligence (AI) is increasingly being employed in various fields of geriatric medicine like dementia, delirium, fall, and other geriatric syndromes. AI can improve the health and well-being of the elderly and has the potential to assist and improve geriatric care.

By using AI as the latest entry into our ecosystem, we can enhance the capabilities of clinicians, patients, and their broader communities. AI is usually defined as a computing platform or a machine that is capable of making intelligent decisions. AI research aims to create systems that approach human intelligence through computer software (1). Most AI applications in healthcare apply some form of 'machine learning', where computers learn from datasets to perform tasks (2). Also, AI systems like ChatGPT can provide rapid and accurate information on a wide range of topics and can be used to aid in decision-making and patient care (3).

There are many potential applications of AI in healthcare for older adults, and the impact of AI technologies on older adults' healthcare is promising. AI could enhance diagnostic, prognostic, morbidity or mortality risk assessment and treatment approaches for the growing aging population. Specialties such as cardiology, radiology, and pathology are already using AI in the process of image analysis. However, due to the advancement of AI technologies, there is currently a lack of clarity regarding the types and roles of AI technologies in the healthcare of older adults.

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The AI devices utilized in older people's healthcare can be summarised as robots, intelligent homes, exoskeleton devices, wearables, AI-enabled health smart applications, virtual reality, and voice-activated devices (4).

For instance, early recognition of frailty syndromes, prediction of dementia, and identification of delirium may also be facilitated by AI-enabled clinical decision support systems. Using machine learning to identify targets for drug repurposing in Alzheimer's disease, and falls can be detected through AI analysis of kinetic data from a smartwatch. In addition, social assistance robots provide emotional support to the elderly, and physical rehabilitation robots assist with physiotherapy exercises (2, 5).

These functions can meet the increasing unmet healthcare needs of the elderly and compensate for the current situation of inadequate healthcare resources. It is crucial to note the significant benefits of AI in improving patient care outcomes, both clinically and financially. However, AI systems should be used in conjunction with clinical knowledge and experience. More well-designed randomized controlled trials are needed to validate the roles of AI technologies in older adults' healthcare.

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# The Use of Artificial Intelligence in Physiotherapy

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## Dear Editor,

The active role that technology has taken in the field of health with the progress it has made in recent years has not only provided many temporal, spatial and financial benefits in health services, but also increased quality and efficiency.

The ability to interpret the data collected from individuals with technological systems through models created by simulating human neural networks, to produce information on the targeted subject, to make analysis and to organize all these is called the concept of 'Artificial Intelligence' (1). As artificial intelligence is used in many areas of healthcare, it is also used in physiotherapy and rehabilitation in many stages such as diagnosis, evaluation, shaping rehabilitation practices with the results obtained and monitoring the clinical development of the patient. At the same time, it offers significant advantages by contributing greatly to the collection of data that can be used to determine the level of disease and treatment efficacy in the clinical decision process (2, 3).

Among physiotherapy and rehabilitation treatment approaches; robot-assisted therapy, brain-computer interface (BCI), orthosis-prosthesis technologies, wearable technologies, tele-rehabilitation applications, mobile application-based technologies, virtual reality applications, video-based rehabilitation systems are artificial intelligence-based treatments.

Robot-assisted therapy is an innovative treatment approach in physiotherapy that allows high repetition numbers, customization, modulation and measurable results. With this system, electrical stimulations can be generated in paretic muscles as well as assisted movement in accordance with the amount of dysfunction (4). Brain-computer interface (BCI) is a computer-based system that receives brain signals, analyzes and translates them into commands that can be transmitted to an engineered output device in order to elicit movement in weakened muscle in neurological patients such as cerebrovascular events and Amyotrophic Lateral Sclerosis.

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It is an important technology that facilitates daily life adaptation in these individuals with functional loss (5). Orthoses are artificial devices used to support the functionality of the existing limb, while prostheses are artificial devices used to replace the function of the missing limb. When orthosis, prosthesis technology and wearable technologies are combined with artificial intelligence, devices that adapt to the tissue and physiological structure of the individual, can be customized, are much more functional and aesthetically preferable (6).

Although its widespread use is still limited in terms of cost, the acceleration of the development of artificial intelligence integrated orthoses, prostheses and wearable devices will be very valuable for patients who need orthoses and prostheses within the scope of physiotherapy to lead a better quality of life, to adapt to daily life activities and to be emotionally self-confident. Tele-rehabilitation is the integration of artificial intelligence technology and telecommunication systems to provide consultancy, preventive approaches, diagnosis and treatment services to patients in physiotherapy and rehabilitation through the interaction of two or more people. The most important advantage of tele-rehabilitation is that it provides a solution to transportation problems for individuals to receive physiotherapy services (7). Mobile application-based technologies, which are referred to as the M-Health concept in the literature, enable physiotherapy services to be provided through various applications on smartphones in the field of physiotherapy and rehabilitation in many subjects such as joint range of motion assessment, postural assessments, exercise training and follow-up. It also enables health-related data transfer and health-related interaction over long distances (8). Unlike classical physiotherapy approaches, virtual reality applications and video-based applications are current rehabilitation methods that take place in a virtual environment with the help of artificial intelligence. Virtual reality and video-based applications are methods that offer motor, sensory and cognitive gains through fun and task-based applications that provide many repetitions, feedback, active participation, guidance and motivation, which are the basic requirements of motor learning (9).

In conclusion, the disadvantages of artificial intelligence-based smart technologies include being expensive, not replacing manual physiotherapy approaches, difficulty in adapting to some advanced musculoskeletal limitations such as spasticity, which causes an increase in muscle tone, especially in robotic applications, and the individual's cognitive inadequacy. Despite all these, it offers many opportunities such as facilitating access to rehabilitation, intensifying the amount of rehabilitation by saving time for the patient and physiotherapist, ensuring the continuity of treatments in the home environment in cases with the risk of transmission such as covid, which we have recently experienced, and reducing health expenditures by increasing the

number of patients treated from a single center. Also, providing a preventive treatment approach by providing feedback with easily accessible devices such as smart watches and phones developed with artificial intelligence, providing simultaneous feedback from the monitor with video-based applications, and allowing the measurements made for evaluation to be objective and re-accessible are among the important advantages. Considering the advantages such as customizing parameters such as time, intensity, difficulty, speed suitable for the patient level, enriching treatment programs, reducing the possible burnout of the patient and therapist during the rehabilitation process, and increasing motivation, artificial intelligence within the scope of physiotherapy rehabilitation services will increase the quality of rehabilitation services and provide cost-effective results in the long term.

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# Is Artificial Intelligence against/for Better Ethical Scientific Research?

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## Abstract

*Artificial intelligence has become a highly debated topic globally. Its impact and the changes it brings in every field prompt a reassessment of the human factor's contribution. This study aims to examine the use of artificial intelligence for academic purposes for researchers. In the study, ethical concerns about the use of artificial intelligence in scientific research are explained descriptively. Various studies and opinions regarding this matter in the literature have been examined. While artificial intelligence has become a part of everyday life and a reality, it cannot be separated from scientific research processes and environments. It should be remembered that regardless of how successful artificial intelligence is in all these processes, the role and impact of researchers remain constant. Researchers have to be capable of responding to the changing needs and demands of the evolving world, producing works that are free from any bias and incorrect information, and being ethically sensitive.*

**Key words:** *Artificial intelligence, Ethics, Scientific research*

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## Introduction

In today's global arena, artificial intelligence (AI) has become a widely popular issue for its ever-changing face. The applications based on AI are developing themselves as they are being fed by people. Before trying to understand AI, the 'Can machines think?' question by Alan Turing should be implied. When this question is asked, one of the first things that flash through the mind is to mind. Can a machine think, solve, be sensitive, be careful, or be practical? A program is typically made to carry out tasks in a predefined, accurate manner; whereas the mind is made to make the most of whatever resources it has (1). A programmed machine can't think but a machine designed like a human mind can.

The study of intelligent behavior in humans, animals, and computers, as well as the effort to figure out how to design that behavior into any kind of product, is known as AI (2). The main purpose of AI is to expand upon existing human understanding (3). When it is carefully thought about what AI is, serving the human is the basic principle. This serving varies every day thanks to the fast and big steps of AI. One of the areas that AI is serving is the academy.

The researchers can use a variety of AI tools in research processes such as outlining,

reviewing the literature, referencing, analyzing the data, etc. Additionally, some tools can translate and proofread the texts written. It is also an outstanding aspect that some of those tools can write text according to the needs of the prompter in a unique way which means that an AI tool can write even a thesis for the prompter. The nature of AI should be understood properly, and if a precaution is needed, it should be taken.

A researcher should understand and know the past and present (4). Artificial neural networks used in AI applications have a wide range of uses, thanks to the ability to benefit from previous learning, and are not only a numerical and computational concept, but can also transition to social issues, contrary to popular belief (5). Considering that scientific research is open to all fields, today's academics need to learn general information about AI and its possible pros and cons. The use, progress, and benefits of new technologies need to first be known to society at large and decision-makers; and education and financial policies need to be updated and widened in this direction (5). Although many ChatGPT users state that it produces very satisfying answers, some also encounter wrong answers (6). To understand why those have arisen and how they can be avoided are fundamentals of the AI trend. As it changes perpetually, future

problems may occur (6). Because of that reason, being alert all the time and critically evaluating information produced by AI is a necessity for actors. Especially considering the educational connection of academics with young people, it is vital to examine this field so that both they and their students are informed and up to date on the latest developments. For example, ChatGPT has a greater capability when compared to humans in assessment; when the questions of an exam are asked it, it can get higher scores showing better performance (7). Misuse of AI may occur in those situations. While AI technologies can accomplish some duties, human stakeholders must make sure the technologies are used appropriately and that they are capable of performing the duties assigned to them (8). Academicians should nurture themselves and their students to be critical thinkers who can evaluate the knowledge and prove its validity, correctness, and reality. Today's world urges every person to be digitally literate. Trying to escape from the current hot topics in science may be useless or even dangerous as adapting to the needs and requirements of the age is very important for a researcher. The purpose of this study is to explain the use of AI for writing scientific research and evaluating it in terms of ethics and different perspectives. Maintaining high scholarly standards while using the capabilities of AI tools remains

essential for scientific growth as the area develops. AI's impact and changes in every field cause the human factor to review its efforts. Consequently, AI can help scientists at every stage of the process by acting as a directing and problem-solving aid as well as a means of sparking new research. On the other hand, constant training and evaluation are needed to ensure the quality of information produced by AI (9).

### **Evaluation of Ethics of AI in Scientific Research**

AI is observed in medicine, engineering, agriculture to education. It contains lots of fields according to needs and developments. The multidisciplinary nature of AI is the cause of its definitional difficulties as AI benefits from the contributions of all areas, each of which contributes its vocabulary and point of view (14). In general, AI systems, regardless of their degree of autonomy, social awareness, or learning capacity, are human-made objects meditated to perform specific tasks (15). Those specific tasks may include scientific research and its steps.

Although AI can't produce new ideas, it can organize the ideas produced by humans creating an outline and improving those ideas (16). The use of AI tools in scientific writing is growing, as they provide researchers with a wide range of tools to improve their work. Deciding which AI tool(s) to use depends on the human's



purpose(s). To illustrate; Elicit, Inciteful, Research Rabbit, and Litmaps are some of the AI tools for literature review, while ChatPDF and Papertalk are for summarizing a paper. AISEO, Notion AI, and Quillbot can paraphrase the texts. Furthermore, Quillbot can be used for both translation and referencing. Numerous tools can write different texts on the same topic. Some of them are ChatGPT, Scholarly, and Simplified. They are easy and time-saving to use and can produce well-structured texts. All AI tools only wait for a prompt texted by a human.

It can easily conduct effective literature searches, which help researchers quickly access a wide range of relevant articles and data points based on the research question or keywords. Moreover, writing aids driven by AI can contribute to developing manuscripts that are clear and cohesive, increasing readability and ensuring adherence to scientific standards. Furthermore, advanced algorithms for natural language processing can help generate coherent and well-organized arguments, improving the general standard of scientific publications. They are capable of producing nearly error-free language writing when given prompts. Those that include comprehensive details like text type, word count, recommended usage of language, and writer role could lead to richer and more suitable material for

researchers. Though there are many advantages to using AI tools, researchers still need to be aware of the possibility of bias in AI algorithms and the necessity of human oversight to guarantee the integrity and correctness of their study results. It is now a matter of debate in the literature whether texts generated by AI can be used in scientific studies.

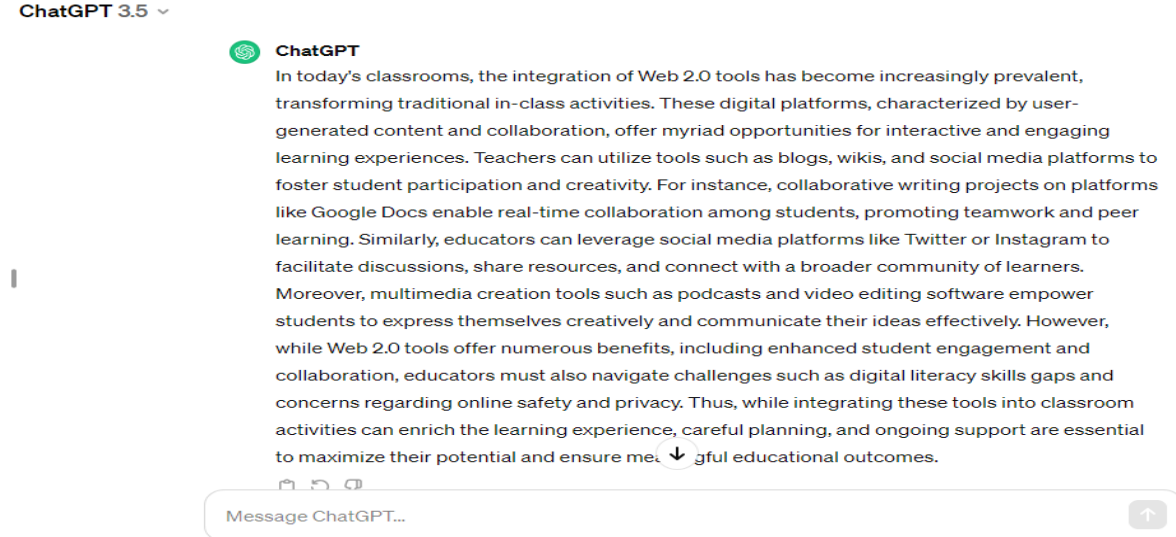
There are several issues to be cleared up when speaking of AI. One of them is the ethics of AI. Ethics is a science that examines behaviors that are deemed to be good or bad and seeks to provide a methodical justification for the assessments of these behaviors from the perspectives of good and bad as well as right and wrong (17). Every human should take into account the ethics of a specific job, task, environment, and culture. Here is the question: Is AI usage good/bad or right/wrong when scientific ethics is considered?

While doing research, AI can produce many different texts in a short time, helping researchers get over being blocked (14). To explain more transparently, the use of AI for scientific writing has been exemplified via ChatGPT. The prompt is “Act as a researcher in the field of education. Can you write a paragraph about the use of Web 2.0 tools in-class activities? While writing that paragraph, don't use other researchers' sentences. Be precise and approach the

issue analytically and critically. The paragraph should include 300 words. The level of the language should be at B1 level

of English.”. The answer provided by ChatGPT is shown in Figure 1.

**Figure 1.** The Answer Provided by ChatGPT.



This answer has been suitable in terms of educational technology and language features such as grammar correctness, accuracy, and cohesion. The only problem has been the word count. Although the prompt has asked for 300 words, ChatGPT

has been able to produce 180 words. Then, this text was checked via Turnitin to understand originality and plagiarism. The writer hasn't added any words. The result of Turnitin is shown in Figure 2.

**Figure 2.** Turnitin Report of the Text Produced by ChatGPT.



The result is so outstanding that Turnitin couldn't diagnose any plagiarism. Especially 0% is very difficult for a writer in scientific research. The text was short for scientific writing but without adding any words or paraphrasing a body paragraph has been produced. This is the reason why ethics becomes a challenging problem for scientists and publishers.

UNESCO admits that AI gives a lot of chances to improve existing scientific theory and practice and suggests its all members use AI to understand its advantages, limitations, and risks (15). Based on the current usage and the results born from the usage can highlight the future paces, applications, and legislations. Science is cumulative research which means that relies on previous studies, so citation is a substantial part of proper research (14). But for citation, academic integrity and honesty become nebulous. Text-generator AI such as ChatGPT is not able to cite a source properly (14). The writer should take responsibility for the wrong citation, so academic dishonesty. Although ChatGPT may produce non-existing references or made-up citations, some other tools can do that task. While a review article is being written, the plagiarism risk continues but when AI is used in responsible and suitable ways for appropriately citing and referencing, this risk may be degraded (17). Although AI is

also doing well in proofreading and editing tasks, the last determiner should be the superior, highly-educated mind (16). It is seen that even though AI is useful for various purposes in the academic context, it still needs investigation and critical thinking of the human mind when production by AI is encountered. If a writer is determined to be perfect in writing, no machine or tool can achieve better writing than him/her, so AI can be used as a supporter or guide but human creativity and knowledge are requisite and they are still the main skills in a scientific writing process (16). If humans don't develop their critical thinking in evaluating the material produced by AI, the result is the same with or without AI. Plagiarism occurs in any case (17). Essentially, the writer should have the wisdom of plagiarism and the possible results and responsibilities of it.

Chen (14) highlights that scientific writing with the help of AI is not ethical and there are skeptical approaches to this issue. These skeptics are based on different problems. First of all, as long as the idea is produced by the writer, it doesn't matter for AI to write a text whoever is the prompter, whatever the product. Galiana et al. (18) question whether "consciousness" is something that AI shares with humans, or is something else entirely, and if consciousness is thought to be possible, the ethical implications of treating AI with

respect, its rights, and its subjective "experiment" will become clear. AI doesn't care about the conflicts or plagiarism but the writer does. Then, a more careful writer is needed for accurate and honest use of AI in research conducted. Seeing scientific studies consisting at least partly of AI tools being presented in the journal is inevitable soon, but they shouldn't be used in any part of a scientific study till it's internally and externally verified for the purpose and is correct (19). According to Kacena et al. (20), the time of writing process has become shorter but there have been important mistakes so AI shouldn't be used purely; it should be seen as an assistant to help writing integrated with careful surveillance. Copying a constructed text without a genuine touch of the writer violates academic integrity (12). If the text is written by AI, another question arises: Should AI be seen as a co-author or not? If AI gains legal status, then its responsibility comes to the mind: How can AI be responsible for its acts and decisions (18)? Indeed, Turnitin (21), which is used to assess plagiarism, announced that they developed themselves for AI detection in writing to direct educators about the next step of action. By doing this, AI developments can be observed, and precautions by the institutes can be taken. If AI achieves consciousness or substantial autonomy, whether the rights need to be granted and how these rights may

be defined and conserved becomes a significant challenge (18). Should they have a copyright? The answer is clear for now. As AI isn't aware of what it produces and can't separate right and wrong, it can't be responsible and can take no responsibility, because those reasons can't be seen as an author (22). The more developed and autonomous AI becomes, the more challenging the question reveals whether AI should be accepted as a personage with suitable rights or not (18). The answer to this challenging question may change according to the next applications. For now, the responsibility of ethics and liability for choices and acts that rely on AI of any kind should always fall on the shoulders of AI actors according to their position within the AI's life cycle (15). If the writer enters the prompt to be informed about anything, the responsibility may be on the writer who doesn't evaluate the information gathered by AI. The human mind can criticize, evaluate, and falsify knowledge based on its natural capacity and power to implement those acts. After AI becomes correct, the tools may be limited to specific tasks that do not compromise the integrity and authenticity of the work and will be subject to strict human supervision (19). Most crucially, before a scientific paper is utilized or submitted for publication, it must be written under the direction and oversight of knowledgeable human researchers in the

field to guarantee the content's accuracy, consistency, and reliability (12).

As AI continuously develops, new regulations may be required. The advent of conscious or autonomous AI has the potential to reshape human-machine interactions, prompting a re-evaluation of the established dynamic between individuals and technology (18). Re-evaluation should include some evolutions on existing rules because it is not worth trying to prevent using them. No matter how trials to prevent it will probably result in new secret use of AI with newer versions of it. They might be useful, however, they require the researcher's involvement, and poor input will produce poor results (12). In the light of the present situation and usage, AI needs human qualifications and it is not adequately equipped to be an individual. Although AI is a good way of starting research, it is highly difficult for it to switch roles with humans in terms of creative and critical thinking and expert views in a scientific writing process (12).

How can public safety and prosperity be balanced with AI autonomy (18)? If they gain more autonomy and become more independent from humans, when will they stop doing human work as assistants? As they learn from the information and experiences, what is the probability of misusing AI governing the human mind? Despite being more skillful and

autonomous, the misuse and trouble probability of AI is increasing and that may result in damage to societal and global safety (18).

Theories, techniques, and algorithms are needed to integrate AI technical advancements into all phases of development, including analysis, design, building, distribution, and evaluation, in order to uphold social, legal, and moral standards (11). While AI tools are presently free, there's no telling if they won't eventually need payment and if they are paid for, inequalities in scientific paper between high- and low-income nations, as well as between less qualified and older specialists may increase by creating unfair facilitations with uncertain effects on scientific research (12). Economically low countries and researchers can't be equal in opportunity. While some researchers can benefit from fast and advantageous AI tools for their studies, others can have limited access to those tools. In the long run, some group of researchers and countries may develop their scientific areas widely, but low ones, who lack limitless and expensive AI tools, can't carry out their research as practical as the others. Moreover, the number of papers of a researcher in any field may increase although those papers don't increase the experience of him/her, so ethical considerations should be questioned whether to focus on the quality or quantity

(12). In other saying the increase in the quantity can't be guaranteed by quality. To stop fraud and make sure that it is utilized in safe and ethical ways, it is crucial to set up frameworks for AI governance and regulation (18). When the quality is described, newer regulations are needed. The machine's autonomous reasoning on matters that it is believed have ethical implications should also be covered by these frameworks, but above all, there is a requirement for a framework that will direct design decisions, control the reach of AI systems, facilitate appropriate data handling, and assist humans in determining their level of engagement (11). High honesty, accuracy, critical thinking, and responsibility are the needed qualities that are vital for the effective and developmental use of AI especially in the scientific research area. A multidisciplinary perspective on AI ethics is needed gathering not only technology but also ethics and legacy approaches and cooperating a variety of methods (23). Approaches, models, and proceedings that are driven by data should be ensured as powerful and believable to attempt to understand AI (15). Another problem is that if the user doesn't prompt properly, it may supply false/wrong answers (7). Then, prompt writing becomes a necessary skill for writers to reach the most consistent and comprehensible results from AI. AI tools are also fed by human

interactions to gather data. It can be developed and specialized by humans as the interaction increases or necessary information is provided. As AI can be trainable, the trainer is highly important to supply high-quality and diverse data, but this may cause problems as any trainer -no matter what level of information quality s/he supplies- can nurture AI (9). Every human can add any type of information, so here is the point of danger of biased information. Because biased models can occur and develop as interaction increases with those biased trainers there will be some irreversible results in different parts of life including health and law (9). If a researcher publishes biased information based on biased AI, it will have terrible effects on the scientific growth of the area written on.

### **Conclusion**

In addition to its ever-changing nature, AI has opened a new debate in science. Several topics are speaking of it and there is much confusion to be enlightened by policymakers, institutions, or directors. In this review, general concerns of AI ethics have been tried to be explained with the current debates. Whether an AI tool can be stated as the author of writing or not (12), can be seen as a personhood, and can have a legal degree (18) are discussed. Whatever the situation is, there hasn't been a clear size that fits all. Writers who search in the scientific arena from all departments should

be aware of AI at first. They should learn how to make use of AI tools instead of embarrassing about not being familiar with their algorithms (14). Scientific research requires a set of different skills. When it is considered that research is a total of ideas and results constituting a process, writing is one of the small steps (14). Although recent studies have been focusing on ethics and AI or AI ethics, a detailed examination is still needed to see the big picture of the AI field (13). The big picture should contain where it started, how it is moving on, and where and how it will be. If the first trials of computers are thought, humans are at an unstoppable point. So, how about AI? It started as a dream years ago and now it has become an inevitable part of our lives in every aspect. Some departments in higher education are planned to open to raise brain and work power for that area. All members should back up scientific areas to support policy and take the role of enhancing AI awareness with its pros and cons (15). Thus, in general, AI shouldn't take the position of human researchers' knowledge, discretion, character, and responsibility (12). Otherwise, overtrust in AI will reduce the critical thinking and problem-solving skills of scientific stakeholders (9).

Only 180 words have been taken from ChatGPT in this study. When it is overused, a scientific paper can be written only ChatGPT which creates an ethical

responsibility for a writer. Longer texts written by ChatGPT should be investigated in terms of plagiarism. Additionally, different plagiarism tools like iThenticate should be examined whether they can diagnose texts written by AI. Furthermore, ethical decisions should be made urgently on whether those tools can be accepted as co-authors or references. There is no clear rule for definite circumstances. To be clear, if AI helps writing, should the writer cite, or declare it as co-author? Although Turnitin declared that they developed an AI-detection tool, why didn't it work in this experiment? If AI can be used in scientific writing, to what extent is it acceptable? Further research is needed to reveal the drawbacks of AI in terms of scientific writing paying attention to ethical violations.

Students should be aware of what and why they learn in a specific way to prevent their misuse of AI. To overcome the limitations and misuse of AI, supporting academic staff to be trained to write proficient prompts, develop critical perspectives, and train their students can enhance AI literacy and get more proper results from AI. AI doesn't have enough scientific validity itself, so while applying any tasks, human is required to take control of the actions (8). While researching scientifically, every step of it should be revised and checked by the researcher. Additionally, culture-specific

and/or multidisciplinary studies should be conducted to understand psychological reasons, effects, or results as well as the success of AI in taking necessary actions and making amendments on scientific publishing.

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# The Rise of the Machines: Artificial Intelligence in Ophthalmology - A Boon or Bane?

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## Abstract

*Ophthalmology, the medical field dedicated to eye care, is undergoing a transformation due to the advent of artificial intelligence (AI). This review article explores the growing use of AI in ophthalmic practices, focusing on disease diagnosis, screening, and surgical guidance. We examine the potential benefits of AI-powered tools, including their ability to improve the accuracy, efficiency, and accessibility of eye care. However, we also acknowledge the ethical and practical challenges associated with this technology, such as algorithmic bias, the lack of explainability, and potential job displacement. We envision a future where ophthalmologists and AI collaborate to improve patient care and usher in a new era of ophthalmic practice.*

**Key words:** *Artificial Intelligence, Ophthalmology, Disease diagnosis, Public health, Health literacy*

## Introduction

The ocular system, a remarkable display of biological complexity, is still susceptible to a variety of advancing conditions. While swift identification and timely intervention are crucial for preserving eye health, certain limitations burden traditional approaches in the field of eye care.

The increasing number of eye conditions, coupled with a shortage of specialised doctors, drives the exploration of innovative treatment methods. In this context, the emergence of artificial intelligence (AI) has become a powerful tool that is set to revolutionise the field of ophthalmology (1-3).

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The emergence of AI, particularly with the application of deep learning techniques, has revealed tremendous potential for revolutionising diagnostics and treatment methods in the field of ophthalmology. This paper explores the emerging use of AI in the field of ophthalmology, highlighting its benefits and the challenges that need to be overcome for its widespread integration into clinical practice.

### **AI in Ophthalmic Diagnosis: A Powerful Tool for Early Detection**

One of the most promising applications of AI in ophthalmology lies in its ability to interpret ocular images for disease detection and staging. AI systems can analyse various types of images, including colour fundus photographs, optical coherence tomography (OCT), and visual field tests, with remarkable accuracy (1, 4, 5) This has significant implications for the early detection of prevalent eye diseases like diabetic retinopathy (DR), glaucoma, and age-related macular degeneration (AMD). Early detection is crucial for timely intervention and improved patient outcomes, particularly in chronic and progressive eye diseases.

AI-powered diagnostic tools boast several advantages over traditional methods. Firstly, they can analyse images with superior speed and sensitivity, detecting subtle changes in blood vessels and retinal

features that might escape the human eye (6). This can lead to more accurate diagnoses and earlier intervention, potentially preventing vision loss. Secondly, AI systems offer the possibility of standardized and objective analysis, reducing inter-observer variability often seen in human grading methods (7-9).

Furthermore, AI shows immense promise for application in public health screening programs for eye diseases, especially in regions with limited access to ophthalmic expertise. AI-based tools can be used to triage patients, flagging those who require specialist evaluation, thereby optimizing healthcare resource allocation (6).

### **AI in Ophthalmology: A Spectrum of Applications**

AI encompasses a diverse set of technologies, with deep learning algorithms forming the backbone of many ophthalmic applications. These algorithms are trained on massive datasets of medical images, such as retinal fundus photographs and optical coherence tomography (OCT) scans. Through this process, they learn to identify patterns and features associated with various eye diseases, including:

**Diabetic retinopathy (DR):** A leading cause of blindness, DR is a complication of diabetes that damages blood vessels in the retina. AI algorithms have been explored for analysing retinal fundus photographs to

detect DR at various stages, enabling timely intervention with laser treatment to prevent vision loss (10).

**Glaucoma:** This chronic condition damages the optic nerve, causing progressive vision loss. AI can analyse OCT scans, retinal images and visual field tests to identify structural changes associated with glaucoma, aiding in early detection and treatment (4, 11).

**Age-related macular degeneration (AMD):** A leading cause of vision loss in the elderly, AMD affects the central vision. AI can detect subtle changes in retinal images suggestive of AMD, allowing for monitoring and management strategies to slow disease progression (12).

**Pathological Myopia:** This is a severe form of near-sightedness associated with an increased risk of retinal detachment. AI models have shown promising results in detecting pathological myopia from fundus photographs, enabling early intervention to prevent vision-threatening complications (6, 13).

AI in ophthalmology offers numerous benefits, including enhanced diagnostic accuracy, improved efficiency, increased accessibility of care, surgical guidance, personalized medicine, and drug discovery and development. AI algorithms can detect eye diseases with accuracy comparable to or even surpassing human ophthalmologists, leading to fewer missed diagnoses and more

timely treatment. They can automate tasks like analysing medical images and generating reports, freeing up ophthalmologists to focus on more complex cases. Telemedicine platforms can enable remote screening and diagnosis in underserved areas (14-16).

Imagine a future where AI acts as a surgeon's digital co-pilot. Researchers are developing AI-powered surgical navigation systems that can provide real-time guidance during delicate procedures like cataract surgery and retinal detachment repair. These systems have the potential to analyse intraoperative data, overlay crucial information onto the surgical field, and even predict potential complications, leading to improved precision and potentially reducing surgical errors (17, 18).

The rise of AI-powered wearables presents a groundbreaking frontier in ophthalmology. Wearable technology offers a convenient platform for continuous, real-time health parameter monitoring. This continuous data collection holds immense promise for the integration of AI functionalities specifically tailored for eye health applications (19-23).

Consider smart contact lenses embedded with AI that can constantly track important ocular metrics. These AI-powered wearables could potentially revolutionize preventative eye care by facilitating the

early detection of glaucoma and other sight-threatening conditions.

For instance, a study by Zhang et al. (23) explored the development of smart contact lenses with integrated sensors for intraocular pressure monitoring. Their research suggests that such lenses have the potential for continuous IOP measurement, enabling early detection of glaucoma progression. Similarly, research by Amini&Okeme (24) investigated the feasibility of AI-powered smart wearables for tear film analysis. Their findings demonstrate the potential of these wearables for monitoring tear composition and identifying eye disease and potentially other systemic conditions.

These advancements pave the way for a future where AI-powered wearables seamlessly integrate into daily life, empowering individuals to proactively monitor their eye health. Early detection of eye diseases facilitated by such technologies can significantly improve patient outcomes and potentially reduce the burden on healthcare systems.

### **The Socioeconomic Impact of AI in Ophthalmology: A Brighter Future for Eye Care**

The widespread adoption of artificial intelligence (AI) in ophthalmology has the potential to revolutionize healthcare delivery systems, fostering significant

socioeconomic benefits. Here is a closer look at some key areas of impact:

**Cost Reduction:** Early detection and intervention are paramount for managing eye diseases effectively and minimizing long-term complications. Studies have shown that AI-powered screening programs can be instrumental in achieving this goal. For instance, a study published in *Ophthalmology* by Gulshan et al. (25) demonstrated the efficacy of a deep learning algorithm in detecting diabetic retinopathy (DR) from retinal fundus photographs with high accuracy. Early detection of DR through such AI-powered programs allows for timely intervention with laser treatment, potentially preventing vision loss and the associated economic burden for both patients and healthcare systems.

Furthermore, a cost-analysis modelling study by Xie et al. (26) investigated the economic feasibility of implementing AI-based diabetic retinopathy (DR) screening programs on a national scale. The study, conducted in Singapore, revealed that switching from traditional human-graded screening to a semi-automated AI-assisted model could lead to significant cost savings of approximately 20% per patient per year. The potential cost reductions were even greater with fully automated AI models. These findings suggest that AI-powered screening programs have the potential to not only improve patient outcomes but also

generate significant cost savings for healthcare systems.

**Improved Resource Allocation:**

Ophthalmologists are often stretched thin, managing a high volume of patients while also being responsible for administrative tasks such as scheduling appointments, generating reports, and managing patient records. These administrative burdens can significantly impact efficiency and limit the time available for direct patient care. The study by Yang et. al. (27) explores the potential of AI for automating various tasks within health clinic workflows, highlighting its potential to streamline workflows and improve efficiency. The study identifies several administrative and clinical tasks that could be beneficially automated using AI, including appointment scheduling, referral management, clinical documentation, and insurance claim processing. By alleviating these burdens, AI can free up valuable time for ophthalmologists to dedicate to patient care, consultations, and complex procedures, ultimately improving the quality of care delivered. Furthermore, research by Chen et al. (28) in their book "Artificial intelligence in healthcare: An essential guide for health leaders" emphasizes the importance of AI-powered automation for reducing administrative workload and improving physician productivity in healthcare settings. By alleviating these burdens, AI can free up

valuable time for ophthalmologists to dedicate to patient care, consultations, and complex procedures, ultimately improving the quality of care delivered.

**Democratization of Healthcare:** Limited access to qualified ophthalmologists remains a persistent challenge in many regions, particularly in underserved areas and low- and middle-income countries (LMICs). AI-powered telemedicine platforms hold immense promise for bridging this gap and expanding access to eye care. Telemedicine platforms that utilize AI algorithms for remote screening and diagnosis can offer preliminary assessments, triage patients, and connect them with appropriate ophthalmic care when necessary. This can be particularly beneficial for geographically isolated communities or areas with limited access to specialists.

A scoping review by Bailey et al. (29) explored the potential of telemedicine for addressing healthcare disparities. The study identified several positive outcomes associated with telemedicine use, including improved access to care, increased patient satisfaction, and enhanced chronic disease management, particularly in underserved communities.

Furthermore, a study by Purcell&Burrell (30) investigated "Dynamic Evaluation Approaches to Telehealth Technologies and Artificial Intelligence (AI) Telemedicine

Applications in Healthcare and Biotechnology Organizations". Their research highlights the importance of ongoing evaluation and adaptation of AI-powered telemedicine technologies to ensure they meet the specific needs of diverse patient populations and healthcare systems.

AI integration in ophthalmology presents a compelling opportunity to transform healthcare delivery. By enabling cost reduction, improving resource allocation, and democratizing access to eye care, AI has the potential to create a more efficient, equitable, and sustainable healthcare landscape for the future.

### **AI in Ophthalmology: Beyond Diagnosis and Towards Collaborative Care**

The transformative potential of artificial intelligence (AI) in ophthalmology extends far beyond its initial focus on diagnosis. Researchers are actively exploring diverse applications of AI that promise to revolutionize various aspects of eye care:

**Referral Management:** Streamlining referral pathways is crucial for ensuring timely access to appropriate care. AI systems can analyze a patient's medical history, including symptoms, imaging data, and other relevant clinical information. This analysis can be used to suggest optimal referral pathways, potentially reducing delays and ensuring patients receive the necessary level of care at the most

appropriate time frame. The integration of AI with electronic medical records (EMRs) can further enhance this process. An AI system, guided by the embedded EMR system, can comprehensively analyze a patient's medical data, including past diagnoses, treatment history, and current medications. This holistic analysis can provide valuable insights to inform referral decisions and ensure patients are directed to the most suitable specialist for their specific needs (31, 32).

**Risk Stratification:** The traditional "one-size-fits-all" approach to eye care is poised for a paradigm shift as artificial intelligence (AI) ushers in an era of personalized medicine in ophthalmology. Ongoing research explores the potential of AI algorithms to analyze a patient's medical history, genetic data, and eye scans to predict their individualized risk of developing specific eye diseases.

This early identification of high-risk individuals empowers preventative strategies and interventions, offering a significant advancement in patient care. AI models have demonstrated immense promise in this domain. A study by Bhuiyan et al. (33) investigated the use of AI for risk stratification in age-related macular degeneration (AMD) – a leading cause of vision loss. Their research suggests that AI models can effectively identify patients at high risk for developing AMD by analyzing

a combination of factors, including genetic data, lifestyle habits, and retinal imaging. This personalized risk assessment paves the way for preventive interventions and tailored treatment plans. By enabling early intervention and potentially slowing disease progression, AI has the potential to significantly improve patient outcomes.

**Prognostication:** Accurately predicting the course of a disease and potential treatment response is paramount for personalized medicine. AI algorithms can be trained on vast datasets of patient information and medical records. For example, AI models could analyze a combination of factors, including retinal images, visual acuity measurements, and blood sugar control data, to predict the likelihood of DR progression. This information can be used by ophthalmologists to tailor treatment plans based on individual patient needs and risk profiles (34).

These AI-powered applications hold immense promise for improving overall patient care and outcomes in ophthalmology. However, for successful integration, a collaborative approach that leverages both AI and human expertise is essential.

### **The Road Ahead: Challenges and Considerations for Responsible Implementation**

While ongoing research offers a glimpse into the exciting future of AI-powered ophthalmology, several questions continue to exist.:

**Data Privacy and Security:** The use of AI in healthcare necessitates the collection and analysis of vast amounts of sensitive patient data. Seamless integration of AI algorithms with Electronic Health Records (EHR) is crucial for a holistic view of patient data. Research efforts are needed to develop standardized data formats and ensure smooth integration between disparate systems, allowing AI to leverage the wealth of information stored within EHRs for more accurate diagnoses and personalized care plans. Ensuring the privacy and security of this data is paramount. Healthcare providers must adhere to stringent regulations such as the Health Insurance Portability and Accountability Act (HIPAA) in the United States, and the General Data Protection Regulation (GDPR) in the European Union. Robust data encryption and anonymization techniques are essential to protect patient data during storage and transmission (35).

**Algorithmic Bias:** AI algorithms are trained on large datasets, and their performance is heavily influenced by the quality and diversity of these datasets. If the training data is not representative of the population the algorithm will be used on, it can lead to biased results. For instance, if an AI system is trained primarily on data from



Caucasian patients, it may not perform as well when used on patients of other ethnicities. Efforts must be made to ensure that training datasets are diverse that represent various ethnicities and demographics to mitigate bias and ensure the generalizability of AI models across different populations (36,37).

**Clinical Validation and Regulation:**

Before AI systems can be integrated into clinical practice, they must undergo rigorous testing and validation to ensure their safety and efficacy. This includes clinical trials to compare the performance of the AI system against standard diagnostic methods. Additionally, AI systems used in healthcare are subject to regulation by bodies such as the U.S. Food and Drug Administration (FDA) and the European Medicines Agency (EMA). Developing clear ethical frameworks and robust regulatory oversight for AI in healthcare is crucial. This ensures that AI tools are developed and used in a way that prioritizes patient safety, fairness, and transparency (38).

**Interpretability and The Psychological**

**Impact of AI:** The expanding integration of artificial intelligence (AI), particularly deep learning models, into healthcare brings both exciting opportunities and significant ethical considerations. While these algorithms offer immense potential to enhance efficiency and diagnostic accuracy,

their inherent lack of interpretability – often likened to a "black box" – can create a barrier to trust among clinicians and patients alike (39). This lack of transparency necessitates a critical examination of the psychological impact of AI on patients and healthcare professionals (40).

Beyond the technical considerations of algorithms and data security lies a complex human element. The potential for increased efficiency and accuracy must be balanced against the potential for AI to foster feelings of alienation, erode trust and autonomy, or heighten anxiety and fear in patients. To mitigate these concerns, healthcare professionals must strive to maintain a human-centered approach to patient interaction. This includes ensuring transparency, fostering patient education, and promoting shared decision-making (41).

Building trust and alleviating concerns requires a commitment to transparency and patient education. AI should be viewed as a tool to augment - not replace - human expertise. Patients should be active participants in discussions about their care plans, alongside healthcare professionals who possess a deep understanding of both the limitations and capabilities of AI-powered interventions.

Informed consent becomes paramount in this context. Clear and concise explanations

outlining the benefits and risks associated with AI-powered healthcare interventions are essential. Patients must have the right to opt-out of AI involvement if they have concerns or discomfort. This ensures respect for patient autonomy and preferences and guarantees that alternative options remain readily available (42).

### Conclusion

The growing use of AI in ophthalmic practices has shown great potential for earlier disease detection, improved diagnostic accuracy, referral management, risk stratification, personalized treatment plans, and increased accessibility to care. AI systems based on deep learning have been applied to interpret ocular images, including colour fundus photographs and OCT, for the detection and staging of ocular diseases. However, responsible development and implementation are crucial. Addressing concerns about bias, ensuring transparency in AI decision-making, and fostering effective human-AI collaboration are paramount. The ongoing research in AI-powered ophthalmology makes a strong

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case for continued investment and collaboration. As we negotiate this fascinating yet complicated frontier, let us guarantee that AI is a powerful tool for empowering healthcare professionals, improving patient outcomes, and, ultimately, preserving everyone's valuable gift of sight.

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Declaration of generative AI and AI-assisted technologies in the writing process During the preparation of this work the author(s) used QuillBot tool to improve language and readability, with caution. After using this tool/service, the author(s) reviewed and edited the content as needed and took full responsibility for the content of the publication.

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# The Use of Chatgpt in Language Education

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## Abstract

*This study explores the multifaceted role of ChatGPT, an AI language model, in language teaching and learning contexts. Drawing upon a comprehensive review of literature and empirical studies, the benefits and disadvantages of integrating ChatGPT into language education are examined. Findings reveal that ChatGPT offers personalized feedback, facilitates customized lesson planning, and enhances language proficiency through individualized learning experiences. However, concerns regarding misinformation, lack of human connection, and ethical implications necessitate careful consideration. Implications for language teaching underscore the importance of strategic integration and educator training, while recommendations for further research highlight the need for addressing ChatGPT's limitations and exploring its potential in-depth. By addressing these considerations, educators can harness ChatGPT's capabilities to enhance language instruction and foster more effective learning outcomes.*

**Key words:** *Artificial intelligence, AI, ChatGPT, Language learning and teaching*

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## Introduction

Artificial intelligence (AI) Effective communication is crucial when interacting with individuals of different language proficiency levels. In the present era of globalization, proficiency in multiple languages holds significant importance. It is vital to recognize the importance of language proficiency and its potential to enhance both personal and professional growth. Learning different languages is important to broaden cultural awareness, improve communication, and create new career opportunities. It helps to understand diverse cultures, develop intercultural communication skills, and build relationships with people from various backgrounds. Consequently, the ability to be proficient in multiple languages is an asset that should be prioritized in today's competitive environment. By recognizing this need and taking steps to develop language skills, individuals can broaden their horizons and enhance their communication abilities.

Technology has emerged as a pivotal component in the realm of education, essential to the teaching and learning processes. Educators can dramatically transform how knowledge is conveyed and assimilated by utilizing technological innovations. In the vast landscape of education, technology has unlocked a multitude of opportunities for both teachers

and students. It allows traditional teaching methods to become innovative, transforming classrooms into dynamic, interactive learning environments. From digital textbooks to online learning platforms, these technological advancements offer students a wealth of resources and diverse perspectives beyond the limitations of the physical classroom.

The evolution of technology paves the way for the emergence of Artificial Intelligence (AI), which has profoundly transformed various aspects worldwide (1). As Grassini (2) suggests the integration of AI into teaching and learning environments has substantial implications, offering considerable potential for enhancing educational outcomes. Studies have shown that AI technologies improve language learning experiences both cognitively and affectively, for example, by providing feedback (3) and reducing anxiety among L2 learners (4). On the other hand, a number of obstacles have also been identified in terms of the implementation of AI technologies for language learning and teaching including ethical and social concerns (5), reliability, and accuracy (6). As an AI language model, ChatGPT (Chat Generative Pretrained Transformer), a type of natural language processing (NLP) developed by OpenAI, has gained significant attention in the field of language teaching. Its ability to generate coherent and

contextually appropriate responses (7) makes it a promising tool for enhancing language learning experiences (6).

With the increasing integration of technology in education, understanding the role of AI language models like ChatGPT is crucial for language educators and learners. This review study aims to explore the various ways in which ChatGPT can be utilized effectively in language teaching, considering its potential benefits and drawbacks. The research questions are stated below:

RQ1. What are the benefits of ChatGPT in language teaching and learning?

RQ2. What are the disadvantages of ChatGPT in language teaching and learning?

### **Literature Review**

There has been a recent increase in systematic review studies on the use of AI in language learning and teaching. Review research on 516 papers on AI in language instruction from 2000 to 2019 was carried out by Huang et al. (8) who discovered that language learners used AI in speaking, writing, reading, vocabulary, and grammar. The study found that after 2015, there was a noticeable surge in AI research on language acquisition. Despite being thorough, the study avoided going into particular effects, approaches, or applications in teaching and

learning in favor of concentrating on broad trends in AI papers and research.

Ji et al. (9) investigated the influence of teachers on AI-integrated language instruction. They looked at twenty-four empirical studies done between 2015 and 2021 that investigated the collaboration of conversational AI and language teachers. The benefits of artificial intelligence (AI) in the classroom are well known, but real evidence on specific strategies for AI-human teacher collaboration is hard to come by. Further research on the integration of conversational AI in language learning is recommended by the researchers in order to enhance teaching effectiveness and provide evidence-based recommendations. They also recommend looking at how conversational AIs could help instructors in the classroom, relieve some of their workload, and improve students' understanding of various cultures.

AI has made significant advancements in recent years, leading to the creation of Chat GPT. Since its launch in 2022, ChatGPT has gained worldwide popularity. It is an OpenAI-based tool that can understand and generate appropriate responses to natural language used in communication. The utilization of ChatGPT in the educational realm has sparked significant enthusiasm owing to its capacity to enhance students' learning encounters. Through furnishing prompt and tailored responses, this

technology possesses the capability to cater to individual student requirements, provide instant feedback, and aid in grasping intricate ideas. Consequently, it emerges as a promising instrument fostering students' active engagement and cognitive development by adjusting to their learning tempo and delivering ongoing assistance in their acquisition of knowledge (10). Chat GPT can create text that closely resembles human language and provide feedback at a level of human comprehension (11). This form of language allows people to communicate with computers naturally and interactively. In essence, Chat GPT is a well-known AI-based tool that enables people to engage in natural communication and receive relevant and natural responses (12).

Its effects have recently resulted in an increase in interest in education. This cutting-edge tool is transforming the way students are educated, advanced, and assisted in academic settings as a disruptive technology. To improve the teaching and learning experiences of educational agents, academic institutions are re-evaluating how to incorporate technology into their curricula (13). As a result, teachers ought to make use of this instrument in the classroom and present it as an additional resource that improves the educational process. However, it is crucial to emphasize that this tool does not replace the cognitive exercises

required for learning or other resources like reading, writing, or interacting with people.

### **Materials and Methods**

Adopting a systematic review methodology, researchers sorted through relevant recent studies by using the Google Scholar database. Keywords including AI and ChatGPT in the context of language teaching and learning were searched such as "AI in language learning and teaching", "ChatGPT and language teaching and learning" and "AI and language". The titles and abstracts of the papers were reviewed for relevance. After a thorough assessment of the entire text, the papers that were going to be included were listed. The ones that (1) the content did not specifically address ChatGPT in language instruction; (2) they were not articles; and (3) the articles were not open-access were excluded. In order to address the research questions posed, a content analysis was carried out on the 15 research studies obtained.

### **Results and Discussion**

#### **RQ1. What are the benefits of ChatGPT in language teaching and learning?**

The studies on the use of ChatGPT in education have identified several significant benefits of using this technology. One of the key advantages is that it enables teachers to create more detailed and customized lesson plans that are better suited to the needs of their students (14). With the help of ChatGPT, teachers can generate lessons that



are tailored to the learning style, pace, and interests of each student, leading to a more engaging and effective learning experience. This technology also allows teachers to provide personalized feedback to students, which can help them improve their understanding of the subject matter and make better progress toward their learning goals. Overall, the use of ChatGPT in education has the potential to enhance the quality of teaching and learning and can benefit both teachers and students in a variety of ways. According to Mohamed (15), ChatGPT's benefits which include real-time feedback, individualized training, a large knowledge base, natural language processing, human-like responses, and cost-effectiveness-can significantly improve EFL learning.

The efficiency of EFL teachers can also increase with the incorporation of ChatGPT into EFL teaching strategies. ChatGPT can enable students to practice language outside of the classroom, provide individualized feedback and assistance, and facilitate personalized and interactive language learning experiences by offering innovative and efficient methods for language education and assessment. Correspondingly, Perkins (16) delves into the practical application of Chat GPT as a means to facilitate the generation of formal assessments. As an instrument that enables the generation of text, ChatGPT serves as a

valuable asset in supporting assessments through the production of coherent and systematic formal assessment materials.

The studies also showed that the use of ChatGPT enhanced students' language skills. Baskara and Mukarto (17) state that the incorporation of ChatGPT into the teaching process can offer educators an opportunity to generate authentic materials, personalized exercises, and lesson plans that cater to the language proficiency requirements of students across various competencies such as reading comprehension, writing, as well as foster their motivation (18). The integration of this AI-driven platform in classroom settings can lead to desirable outcomes for language learners, providing them with a more tailored and engaging learning experience. With the creation of customized exercises, teachers can leverage ChatGPT to promote self-directed learning and enhance students' language skills in a personalized manner. Correspondingly, Fırat (19) highlights that ChatGPT is capable of engaging in multiple ongoing conversations, comprehending and responding to natural language input, and providing personalized and interactive support. These qualities make ChatGPT a promising tool for open education, as it can enhance self-reliance and autonomous learners, while also being practical and versatile. In line with these studies, Fauzi et al. (20) also concluded that the use of

ChatGPT improves students' language skills, facilitates collaboration, increases time efficiency, and provides support and motivation.

Xiao and Zi (21) conducted a small-scale qualitative investigation aiming to delve into students' perceptions and encounters with ChatGPT in language learning. Their research revealed that ChatGPT acts akin to a learning companion or personal tutor, offering tailored, easily accessible, and adaptable feedback. Moreover, it aids in enhancing language proficiency when students employ critical thinking skills, such as adjusting prompts, refining the model through training, and scrutinizing and selectively accepting its outputs. Additionally, it facilitates idea generation for brainstorming purposes. Crucially, the study demonstrated students' capacity to engage in critical analysis of the information provided by ChatGPT, showcasing their ability to modify prompts, refine ChatGPT's performance, verify responses, and selectively incorporate the information provided.

Young and Shishido (22) conducted a study to evaluate the effectiveness of ChatGPT in generating high-quality dialogue materials that are suitable for English as a Foreign Language (EFL) students. Using multiple readability metrics, the researchers analyzed the suitability of the dialogue materials produced by ChatGPT and

determined the target audience that could benefit the most. The findings of the study indicated that ChatGPT's dialogues are well-suited for students at the elementary level of the Common European Framework of Reference for Languages (CEFR) A2 level. The dialogues are easily understandable, making it possible for students at this level to comprehend most of the vocabulary used. Additionally, a considerable portion of the dialogues intended for the intermediate level (CEFR B1) provide ample opportunities for learning new words. The integration of AI-powered chatbots in EFL education has the potential to overcome limitations and provide valuable learning resources to students.

Apart from the EFL context, there are also some studies conducted in different languages. For example, Senyaman (23) investigates the potential benefits of integrating ChatGPT into the Arabic language learning process, focusing on its suitability for individual learners. Directed questions were asked to ChatGPT to evaluate its effectiveness in teaching Arabic, considering its design for facilitating natural communication in users' native languages. These inquiries covered various aspects such as vocabulary, pronunciation, grammar at different levels, translation tasks, text generation on specific topics, and explaining idiomatic

expressions. The study concludes that ChatGPT offers significant advantages in language learning, particularly in terms of providing personalized feedback, support, and guidance irrespective of time and location, and enhancing motivation, which are crucial factors in individual language acquisition.

Additionally, a study by Athanassopoulos et al. (24) assessed the effectiveness of ChatGPT as a feedback tool for foreign language writing among students. The study involved eight 15-year-old migrant/refugee students learning German in Greece. ChatGPT enhanced the vocabulary and grammar of their first writing attempt, resulting in an increase in word count and average word count per sentence. Overall, ChatGPT proved to be a promising language-learning tool for students with language difficulties.

Furthermore, Zileli (25) conducted a study to investigate the potential use of ChatGPT chatbot in helping individuals learn Turkish as a foreign language. The study explored various applications of ChatGPT, including dialogue interactions, word and sentence meanings, text comprehension, translation of English text to Turkish with feedback, pronunciation, reading texts, providing feedback on written texts, explanation of topics with examples, and preparation of exercises. The research concludes that ChatGPT can provide valuable feedback to

Turkish language learners in multiple areas, making the language learning process easier and contributing to the acquisition of the target language.

## **RQ2. What are the disadvantages of ChatGPT in language teaching and learning?**

With the excessive use of the powerful AI language models, concerns have been raised regarding ChatGPT, and its legitimacy in the educational setting. It can provide false information and give inconvenient instructions on biased material. There are also moral concerns over the impact it will have on society given its capacity to combine information from various sources and produce unique responses to the same question. Using AI in education raises a number of ethical and legal concerns, including those related to privacy, data security, and intellectual property (14).

Mohamad (15) and Athanassopoulos et al. (24) have pointed out several drawbacks including the absence of human connection and personalized interaction, the potential for incorrect or unsuitable responses, difficulties in grasping context and meaning, limitations in providing feedback on pronunciation and intonation, cultural insensitivity, the possibility of being used as a tool for cheating, and various technical limitations. Additionally, he also emphasized that since ChatGPT cannot provide precise citations and references, it

might not be the most suitable or trustworthy tool.

Similarly, Perkins (16) examines the impact of Learning Management Systems (LMS) on academic integrity in Higher Education Institutions (HEIs) and students. It was suggested that the use of AI tools does not determine plagiarism or academic misconduct, but rather whether students make clear their use (13). The study suggests that the academic integrity policies of HEIs must be updated to consider future educational environments and determine if the specific use of LLMs constitutes academic misconduct. Başkara and Mukarto (17) highlight a few issues with using ChatGPT in EFL writing teaching, including ethical concerns, potential bias in AI and NLP technologies, and cautious design and implementation. Appropriate learning tasks and activities should be created, and students should be given clear directions, to ensure efficacy. The quality and accuracy of the text that AI and NLP systems, like ChatGPT, generate can be influenced by biases, which can have a detrimental effect on students' language acquisition and development.

Recent research has emphasized how crucial it is to provide educators and students with training in order to maximize the effective use of ChatGPT (19-21, 26). These results imply that although ChatGPT has the potential to be an important teaching

aid, its efficacy mostly depends on how well users comprehend its features and recommended usage procedures. Consequently, to ensure that educators and learners can fully utilize ChatGPT's potential to improve instruction, thorough training courses are essential. Through the provision of requisite skills and information, training programs can enable educators and learners to effectively utilize ChatGPT, hence promoting a more productive and enriching educational experience.

The studies reveal that ChatGPT struggles to aid language learners who are interested in any language different from English. For example, Arabic, ChatGPT ignores the Turkish translations of Arabic grammatical concepts and its pronunciation exercises follow English pronunciation guidelines (23). On the other hand, the tool misguides Turkish learners with extremely complicated constructs, improper sentence structures, and semantic errors (25). These findings show that ChatGPT needs to be further improved and modified to better meet the unique linguistic subtleties and educational needs of any language learners.

### **Conclusion**

The utilization of ChatGPT in language teaching and learning presents numerous benefits as well as challenges. While ChatGPT offers personalized feedback, customized lesson plans, and thus, enhances

language proficiency; concerns regarding its potential for misinformation, lack of human connection, and cultural insensitivity require particular attention. Moreover, the ethical implications surrounding its use, including issues related to privacy, data security, and academic integrity, necessitate careful consideration within educational settings. Despite these drawbacks, with adequate training and refinement, ChatGPT can function as a valuable tool for augmenting language instruction, provided its limitations are properly addressed. Being aware of both ChatGPT's advantages and disadvantages, comprehensive training programs should be given top priority. Furthermore, continuous research and improvement are necessary to enhance ChatGPT's functionality, boost its dependability and accuracy, and resolve moral dilemmas related to its application in educational settings.

The implications for language instruction stress how crucial it is to carefully incorporate ChatGPT into instructional methods. Teachers should receive thorough training in order to make the most of ChatGPT's benefits and minimize its drawbacks. Additionally, in order to promote a well-rounded and successful approach to language training, curriculum designers should create learning tasks that make use of ChatGPT's advantages while resolving its disadvantages. Through the

recognition and intentional integration of ChatGPT into instructional practices, educators can improve student learning outcomes and experiences in a variety of linguistic environments.

Implications for language teaching emphasize the importance of integrating ChatGPT strategically into educational practices. Educators should undergo comprehensive training to effectively utilize ChatGPT's features and mitigate its limitations. Additionally, curriculum developers should design learning tasks that leverage ChatGPT's strengths while addressing its weaknesses, promoting a balanced and effective approach to language instruction. By recognizing ChatGPT's potential and incorporating it thoughtfully into pedagogical strategies, educators can enhance the learning experience and outcomes for students across diverse linguistic contexts.

Further studies should concentrate on addressing ChatGPT's shortcomings, examining its possibilities and expanding on them in terms of precision, dependability and cultural differences. Besides, more research on the long-term effects of ChatGPT integration on learner autonomy and language proficiency is needed. Also, comparative analyses comparing various AI-driven language models in various educational situations may provide insightful viewpoints on the relative

benefits and drawbacks of various technologies. This study contributes to the field by examining ChatGPT's function in language instruction and calls all the stakeholders to put this tool into good use for improving language education methods and practices.

### Conflict of Interest

The authors declare that they have no conflicts of interest.

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# AI-Assisted English Language Learning for Cross-Cultural Medical Education in Multilingual Settings

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## Abstract

*In the interconnected world of global healthcare, proficiency in the English language serves as a crucial cornerstone for medical professionals as it facilitates access to a vast wealth of knowledge, collaborative research, and international dialogue. However, the challenge of developing not only linguistic proficiency but also cross-cultural competence within multilingual medical settings remains a significant challenge. This article investigates the innovative potential of artificial intelligence (AI) in transcending these barriers through AI-assisted English language learning, aimed at enriching cross-cultural medical education. It underscores the critical role of English in medical academia and practice by highlighting the consequential divide that language barriers can impose on non-native English speakers. Furthermore, it investigates the nuances of cross-cultural communication within healthcare by emphasizing the necessity for cultural competence amongst healthcare professionals to ensure comprehensive patient care across diverse cultural backgrounds. The investigation extends into an analysis of current AI technologies in language learning, evaluating their capacity to offer personalized, immersive learning experiences that go beyond mere linguistic acquisition to include cultural nuances and medical terminologies. Through an examination of case studies, the article presents successful integrations of AI-assisted language learning tools in medical education. And also, it illustrates their impact on improving English proficiency, cultural awareness, and ultimately, patient care in multilingual environments. Similarly, this article argues for a more inclusive approach to medical education. It proposes the utilization of AI technology, envisioning a future where AI-assisted English language learning becomes an integral component of medical curricula. This approach aims to foster a generation of healthcare professionals equipped with both the linguistic skills and cultural sensitivities required to negotiate the complexities of global healthcare.*

**Key words:** *Artificial intelligence, Multilingual medical education, English language learning, Cross-cultural competence, Global healthcare*

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## Introduction

Artificial intelligence (AI) In the ever-evolving context of global healthcare, proficiency in English language has emerged as a fundamental component for medical professionals worldwide. This linguistic skill not only facilitates access to a vast reservoir of medical knowledge and cutting-edge research but also paves the way for fruitful international collaborations and dialogues. As English continues to dominate the sphere of medical education and practice, the imperative for medical practitioners and students to attain high levels of English proficiency has never been more pronounced. However, achieving such linguistic prowess is accompanied by the equally challenging pursuit of cross-cultural competence, especially within the multilingual contexts that characterize today's medical settings (1). The advent of Artificial Intelligence (AI) in educational domains presents a promising avenue to address these dual challenges. AI-assisted language learning tools, with their capacity for personalized learning experiences and adaptive content delivery, offer significant potential to revolutionize English language acquisition among medical professionals (2). These technologies are not just transforming the way language is taught but are also redefining the parameters of cross-cultural medical education, providing

learners with immersive experiences that go beyond traditional classroom boundaries.

Moreover, the integration of AI in language learning is particularly pertinent in medical education, where the stakes are high, and the need for both linguistic and cultural fluency is paramount. The potential of AI to simulate complex medical scenarios, teach cultural nuances, and offer practice in medical terminologies in English further underscores its value (3). This dual focus on language and cultural competence is essential for preparing medical professionals to deliver patient-centered care in increasingly diverse societies (4). Nevertheless, the journey toward leveraging AI in medical English education is fraught with challenges, ranging from ethical considerations to technological limitations. As we stand on the brink of this educational revolution, it is crucial to negotiate these challenges with a keen awareness of the ethical implications and a commitment to equity and accessibility (5).

### **The role of english in medical education and practice**

The primacy of English in medical education and practice cannot be overstated, serving as the lingua franca that bridges knowledge across borders and cultures. This centrality of English facilitates unparalleled access to a comprehensive corpus of medical literature, cutting-edge research, and facilitates international

collaboration among healthcare professionals. The global dissemination of medical findings predominantly in English underscores the language's instrumental role in shaping the contours of medical knowledge and practice worldwide (6). However, the dominance of English also presents a paradox. While it democratizes access to knowledge for English-speaking medical communities, it inadvertently erects barriers for non-English speakers, potentially marginalizing a significant section of the global medical fraternity from engaging fully with the international medical discourse (7). This dichotomy raises critical questions about equity and inclusivity in the global medical landscape, compelling a reevaluation of linguistic policies and practices within medical education and practice (8).

Moreover, the impact of English proficiency on professional opportunities in the medical field is profound. English language skills are not just academic prerequisites but gatekeepers to international training programs, conferences, and publications in prestigious journals, which are pivotal for career advancement and professional development in medicine (9). Therefore, English proficiency transcends the realm of communication skills, embodying a critical professional asset that can significantly influence a medical practitioner's career

trajectory. Acknowledging the centrality of English necessitates innovative approaches to language education in medical settings. This includes integrating English language training within medical curricula and leveraging technology to provide immersive, context-specific language learning experiences that cater to the unique needs of medical professionals (2).

### **Cross-cultural communication in healthcare**

Cross-cultural communication within healthcare settings is a pivotal concern that significantly influences patient outcomes and satisfaction. The increasing globalization of healthcare services, coupled with the growing diversity in patient populations, underscores the urgent need for healthcare professionals to navigate cultural nuances effectively (10). This challenge is not merely about linguistic proficiency but extends to understanding and respecting the myriad cultural beliefs, values, and practices that patients bring into the healthcare environment. Effective communication in healthcare goes beyond the exchange of information. In other words, it involves building trust, demonstrating empathy, and establishing a rapport with patients. Poor cross-cultural communication can lead to misunderstandings, reduced patient satisfaction, and disparities in healthcare outcomes (11). For instance, cultural

differences in perceptions of illness, health practices, and decision-making processes can significantly affect how patients perceive their care, adhere to treatment plans, and engage with healthcare systems (12).

Strategies to enhance cross-cultural communication encompass comprehensive cultural competence training for healthcare professionals. Such training aims to equip medical staff with the skills to recognize and respect cultural differences, employ culturally appropriate communication strategies, and provide care that acknowledges and honors patients' cultural backgrounds (13). Additionally, the incorporation of interpreters and cultural mediators in healthcare settings can bridge language gaps and facilitate better understanding and engagement between healthcare providers and patients from diverse linguistic and cultural backgrounds (14). In this sense, research highlights the role of empathy in cross-cultural communication, where healthcare providers' ability to empathize with patients' perspectives can significantly enhance communication effectiveness (15). Empathy involves not only understanding patients' feelings and concerns from their cultural viewpoint but also responding in ways that convey respect and validation of those perspectives.

Moreover, the application of artificial intelligence (AI) and digital tools in healthcare offers innovative avenues for improving cross-cultural communication. AI-driven language translation services and culturally sensitive patient education platforms can provide tailored information and support to patients in their native languages, thus enhancing comprehension and engagement (16). Considering this, it is clear that cross-cultural communication is a cornerstone of effective healthcare delivery in our increasingly multicultural world. The development of cultural competence among healthcare professionals, coupled with the strategic use of technology, can significantly improve the quality of healthcare for diverse patient populations. As the field continues to evolve, ongoing research and innovation in communication strategies will be critical for meeting the complex needs of global healthcare.

### **AI in language learning: opportunities and challenges**

The integration of Artificial Intelligence (AI) in language learning represents a transformative shift in educational paradigms, particularly in the realm of medical education where the stakes are exceptionally high. The advent of AI technologies in language acquisition offers unprecedented opportunities for medical professionals to enhance their English language proficiency, a skill increasingly

recognized as crucial in the global healthcare context (17). AI-assisted platforms can deliver personalized learning experiences, adapt to the learner's pace and style, and provide immediate feedback, features particularly beneficial for busy medical practitioners and students striving to balance rigorous academic demands with language development (18).

One of the most promising aspects of AI in language learning is its ability to simulate real-life interactions and medical scenarios. Through sophisticated natural language processing and machine learning algorithms, learners can engage in dialogue, comprehend complex medical terminologies, and practice clinical communication within a risk-free, virtual environment (19). This immersive approach not only facilitates the acquisition of linguistic skills but also enriches learners' cultural understanding and empathy, key components of effective cross-cultural communication in healthcare settings (4).

Despite these opportunities, the deployment of AI in language learning is not without challenges. Data privacy concerns, algorithmic biases, and the digital divide pose significant hurdles to the equitable and ethical use of AI in education (5). Moreover, the reliance on AI technologies necessitates robust infrastructural support and digital literacy among users, prerequisites that may not be uniformly

available across different regions and institutions (14). Additionally, the efficacy of AI in language learning, while promising, requires ongoing empirical validation. Critics argue that the absence of human interaction in AI-assisted learning platforms could limit learners' ability to develop nuanced communication skills and cultural sensitivities essential in medical practice (20). Thus, while AI offers innovative tools for language acquisition, it should complement rather than replace traditional, instructor-led language education. In this regard, it is crucial that the development and implementation of AI in language learning are guided by pedagogical principles, ethical considerations, and empirical evidence. Collaborative efforts among educators, technologists, and policymakers are essential to harness the full potential of AI in enhancing language learning while mitigating its challenges (21).

### **AI-assisted english language learning in medical education**

Incorporating Artificial Intelligence (AI) into English language learning within the realm of medical education marks a significant leap towards addressing the linguistic and communicative challenges faced by healthcare professionals globally. AI-assisted language learning platforms have emerged as powerful tools that not only enhance English proficiency but also

bridge the gap between linguistic competence and professional medical practice (15). These innovative solutions offer personalized, flexible learning environments that can adapt to individual learners' needs, facilitating a more effective and engaging language acquisition process. A notable advantage of AI in medical education is its ability to simulate complex medical scenarios, allowing learners to practice language skills in contexts closely mirroring real-life situations (4). This contextual learning is crucial in medical settings where the precision of language can significantly impact patient outcomes. AI-driven simulations and interactive platforms enable learners to navigate through diverse medical conversations, diagnoses, and patient interactions, thereby enhancing their communicative competence and readiness for global healthcare environments. Moreover, AI-assisted programs are instrumental in teaching medical terminologies and jargon in English, which are often challenging for non-native speakers. These programs utilize sophisticated algorithms to introduce, practice, and reinforce specialized vocabulary, ensuring that learners are well-equipped to understand and engage in professional medical discourse (22). The inclusion of cultural nuances in language learning further prepares medical professionals to interact effectively with

patients and colleagues from diverse backgrounds, fostering a more inclusive and empathetic healthcare practice (20).

However, the integration of AI in language learning within medical education is not without challenges. Concerns regarding data privacy, the digital divide, and the potential depersonalization of education underscore the need for careful implementation and ongoing evaluation of AI technologies (5). To address these issues, educators and technologists must collaborate to develop AI tools that are ethical, accessible, and human-centered, thereby ensuring that technology enhances rather than detracts from the educational experience. As we move forward, the role of AI in language learning for medical education continues to evolve. In other words, future research should focus on assessing the long-term impact of AI-assisted language learning on medical professionals' careers and patient care outcomes. Additionally, exploring the potential for AI to support multilingual education could further democratize access to medical knowledge and opportunities for healthcare professionals worldwide (21).

### **Ethical considerations in ai-assisted language learning**

The implementation of Artificial Intelligence (AI) in language learning, especially in sensitive fields like medical education, brings to the forefront several

ethical considerations that must be meticulously addressed. One of the primary concerns revolves around data privacy and security. AI-assisted language learning platforms often require access to extensive amounts of personal and educational data to function effectively. This raises significant questions about how this data is collected, stored, and used (5). Ensuring robust data protection measures and transparency in data handling practices is paramount to safeguarding learners' privacy and maintaining their trust.

Moreover, the potential for algorithmic bias in AI systems is a critical ethical issue. If not carefully designed and monitored, AI algorithms can perpetuate or even exacerbate existing biases in educational content and language learning processes (23). For instance, biases in the training data can lead to unequal learning experiences or reinforce stereotypes, ultimately affecting the quality and fairness of education provided. Therefore, it is essential to adopt rigorous standards for algorithmic fairness and inclusivity, ensuring that AI systems support equitable language learning opportunities for all students, regardless of their backgrounds.

Another ethical challenge is the digital divide, which refers to the disparities in access to digital technologies and the internet among different populations. The effectiveness of AI-assisted language

learning depends heavily on reliable access to these technologies, which may not be uniformly available across all regions and socioeconomic groups (24). Addressing this divide is crucial to prevent further entrenchment of educational inequalities. Initiatives to expand digital infrastructure and provide affordable access to technology are essential steps towards ensuring that AI benefits a broad and diverse learner base.

Additionally, the ethical use of AI in language learning must consider the balance between automation and human interaction. While AI offers powerful tools for personalized and adaptive learning, it cannot fully replicate the nuanced, empathetic interactions that human educators provide. Therefore, AI should be seen as a complement to, rather than a replacement for, human teaching. Ensuring that learners continue to benefit from meaningful human engagement in their education is essential for fostering a holistic and well-rounded learning experience (20). Finally, the deployment of AI in language learning should be guided by principles of transparency, accountability, and inclusivity. Stakeholders, including educators, students, and policymakers, should be actively involved in the development and implementation of AI technologies to ensure that these tools align with educational goals and ethical standards. Ongoing monitoring and

evaluation are necessary to identify and address any emerging ethical issues promptly. In conclusion, while AI has the potential to revolutionize language learning in medical education, its implementation must be approached with careful consideration of ethical implications. By addressing these challenges proactively, we can harness the benefits of AI while upholding the values of equity, fairness, and human dignity in education (5).

### **Future directions and conclusion**

The future of AI-assisted language learning in medical education holds immense promise, driven by continuous advancements in technology and a growing recognition of the importance of linguistic and cultural competence in healthcare. As AI technologies evolve, they are likely to become even more sophisticated, offering more personalized and immersive learning experiences that can adapt to the specific needs and contexts of medical professionals (17). One potential direction for future research and development is the integration of AI with virtual and augmented reality (VR/AR) technologies. These combined tools could create highly realistic medical training environments where learners can practice both their language skills and clinical competencies in simulated scenarios that closely mimic real-world situations (25). Such immersive experiences could significantly enhance the

effectiveness of language learning, making it more engaging and relevant for medical professionals.

Furthermore, the potential for AI to support multilingual education should be explored more extensively. As global healthcare becomes increasingly interconnected, the ability to communicate in multiple languages can be a valuable asset for medical professionals. AI-driven platforms could facilitate the learning of multiple languages simultaneously, helping learners to develop the linguistic flexibility needed to navigate diverse healthcare settings (21). In addition to technological innovations, future efforts should also focus on addressing the ethical and practical challenges associated with AI-assisted language learning. Ensuring equitable access to AI technologies, mitigating biases, and safeguarding data privacy will remain critical priorities. Collaborative efforts among educators, technologists, policymakers, and healthcare professionals will be essential to develop and implement AI tools that are ethical, inclusive, and effective (5).

In conclusion, AI-assisted language learning offers transformative potential for enhancing English proficiency and cross-cultural competence among medical professionals. By leveraging AI technologies, we can create more effective, personalized, and engaging learning

experiences that prepare healthcare providers to meet the linguistic and cultural demands of global healthcare environments. However, realizing this potential requires careful consideration of ethical issues, equitable access, and ongoing collaboration among diverse stakeholders. As we look to the future, the continued evolution of AI in language learning promises to play a pivotal role in shaping the next generation of medical education and practice, ultimately contributing to better healthcare outcomes worldwide.

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# Cancer and Artificial Intelligence

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**Dear Editor,**

Cancer is a current problem that affects human life and quality of life worldwide. According to the 2019 data of the WHO (World Health Organization), it is among the first or second causes of death in individuals before the age of 70 in 112 out of 183 countries (1). In addition, according to GLOBOCAN (Global Cancer Observatory) data, 20 million new cancer cases were seen in 2022 (2). High mortality rates and high interaction power with the microenvironment of cancer reveal the importance of early diagnosis, effective treatment and monitoring of the disease.

The concept of Artificial Intelligence, which emerged in the middle of the 19th century, was based on the construction of machines that could analyze and reason complex data, and think and make inferences on complex situations like humans. Thanks to the groundbreaking ideas of scientists, artificial intelligence, which has become a reality by being included in research laboratories, has made many developments (3). Thanks to the rapidly developing technology in the last half century, its usage area has expanded considerably today and Artificial Intelligence, which is advancing more and more every new day, has become a tool used in many scientific fields by including different subgroups. Artificial Intelligence tools, which can be used for many purposes such as creating data banks, storing data, organizing information obtained from different sources and creating outputs, making predictions, etc., are also of great interest in clinical cancer research.

Cancer is a multifactorial group of diseases that are known to affect human life with incidence and mortality rates.

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This complex group of diseases includes treatment options such as surgery, chemotherapy, radiotherapy, individual treatment, etc., and/or if several of these are applied together (4).

Prolonging the survival time of patients, determining the effective treatment method, reducing recurrence and monitoring post-treatment conditions are among the main goals of clinicians. In addition to these, the susceptibility of individuals to the disease in cancer types, the accuracy of the diagnosis, the determination of the prognosis, the late appearance of symptoms in some cancer types, etc. are among the difficulties of this disease.

The treatment of cancer is improving itself every day, thanks to the constant increase in current information and developments in other fields of science. The development of new techniques is effective in determining and applying treatments for the patient. Artificial Intelligence and developments in its sub-branches are used in confirming the diagnosis, applying optimal treatment, combined drug therapy applications, predicting possible recurrence, and estimating survival times, and they produce scientifically satisfactory results (5, 6).

Artificial Intelligence and the development of new strategies in cancer treatment are of great importance in helping physicians apply optimized treatment tailored to the patient, overcoming both physical and psychological difficulties, and preventing the recurrence and spread of the disease. In addition, it is groundbreaking in shortening the treatment process, overcoming extra drug burden, accurate diagnosis and applicability of effective treatment method in a shorter time. Thanks to the field of health and Artificial Intelligence, which are integrated with current developments in coordination with each other, great advances have been made and continue to be made in the diagnosis, treatment and prognosis of cancer, one of the major problems of our age.

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# Artificial Intelligence in Clinical Applications for Infectious Diseases: Diagnosis, Treatment and Immunization

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## Abstract

*Despite scientific and technological advances in recent years, infectious diseases continue to pose a significant threat to public health. These diseases can cause serious health problems as they have the potential to spread rapidly. In addition, they occur in the form of epidemics and affect populations. The difficulty of rapid and accurate diagnosis and increasing antimicrobial resistance create difficulties in the treatment of infectious diseases. Artificial intelligence technology has developed useful applications in many areas such as the development of diagnosis and treatment methods, anti-infective drug and vaccine discovery, and prevention of increasing anti-infective drug resistance. In particular, AI-assisted clinical decision support systems can help predict disease outbreaks, support diagnosis of diseases, optimise treatment options and monitor epidemiological trends by analysing large datasets. It can also provide more accurate and faster results in analysing diagnostic images and identifying diseases. Advances in this field need to be supported by multidisciplinary studies and a strong ethical framework. In this review, we outline approaches to the application and use of artificial intelligence in infectious diseases, highlight the progress supported by artificial intelligence, and discuss how it can be used. We outline the applications and benefits of AI in infectious diseases. In this way, more effective intervention strategies can be developed to control infectious diseases and protect public health.*

**Key words:** *Artificial intelligence, Machine learning, Infectious diseases*

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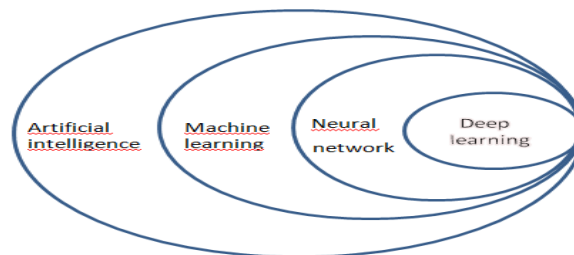
*Artificial intelligence is not a threat; it is about how we choose to use it*  
(Moedas, 2017)

## Introduction

In recent years, developments in the field of technology have been rapidly progressing, profoundly influencing and shaping societal life. Artificial intelligence (AI) studies have created a revolution by leading to radical changes in human life. In this context, just as in all other fields, efforts are being made to develop future-oriented designs in the field of medicine through AI applications. AI is a comprehensive branch of computer science that aims to create intelligent machines that can mimic human intelligence. At the same time, it is the

general name of technologies that can fulfil the tasks of prediction and decision-making; whether it uses machine learning or not is a factor affecting this process. The process of acquiring rules includes the processes of making logical inferences and self-correction using these rules and produces output as a result.

This learning method is capable of making inferences and decisions similar to or even better than humans. AI includes many disciplines such as machine learning, deep learning, neural networks (Figure 1).



**Figure 1:** Learning relationship.

The origins of the concept of AI started with Alan Turing's question "Can machines think?" (1). The first examples of AI applications in the field of medicine are a mechanical machine developed in 1954 to assist clinicians in symptom-based diagnosis and a Naïve Bayes-based digital

system developed in 1972 for the diagnosis of acute abdominal pain (2).

The first system used in health services was the MYCIN system developed in 1976. It is also one of the first attempts towards a computer-based clinical decision support system for infectious diseases.

This system utilised more than 500 rules to identify the bacterial species responsible for infection, make a diagnosis and recommend an antibiotic regime. The aim of the system was to recommend antibiotic treatment regimens for serious bacterial infections. However, the use of the system was limited due to the inability to integrate the system with clinical studies and the size of the data (3).

With the developed AI applications, more specialised programmes have started to be developed in health services as a result of interviews with medical specialists (4).

In the following years, especially after the 2000s, developments in the field of technology have revolutionised medical sciences in the field of artificial intelligence. The systematic recording of electronic health records and other medical data has provided a rich resource for the development of AI technologies. Different AI applications have been developed using medical data in many areas such as diagnosis and imaging, treatment planning and personalised medicine, drug discovery and development, patient monitoring and prediction, medical tissue and cell analysis, health systems and data management. Developments in the field of medicine aim to provide more accurate diagnoses, more effective treatments, better patient care and improve the overall quality of healthcare

services. At the same time, it finds an intensive use in the field of medicine due to its potential expectations and promising prospects (5). It is expected that the expenditures on this new developing technology in healthcare services will reach 45 billion US dollars by 2026 worldwide (6).

Despite advances in medical sciences in recent years, infectious diseases caused by pathogens such as bacteria, fungi and viruses still challenge scientists and clinicians. The difficulty of rapid and accurate diagnosis and increasing antimicrobial resistance create challenges in the treatment of infectious diseases. Joint interdisciplinary efforts are required to overcome these challenges. Interdisciplinary collaborative efforts are required to address these challenges.

The first applications of artificial intelligence in the field of infectious diseases were carried out with easily accessible medical data (demographic information, laboratory measurements, medical history and physical examination data) (7). In the following process, AI applications together with systems and synthetic biology aimed to reveal new approaches in diagnosis and treatment methods in the field of infectious diseases. In particular, biotechnological and medical innovations (including drug therapies and

modalities, vaccines and diagnostics) are aimed to overcome the challenges. In this review, we aim to understand the relationship between artificial intelligence applications and infectious diseases and to understand how artificial intelligence can be utilised.

The systematic recording of electronic health records and other medical data has significantly increased the availability of healthcare data (8). Clinical decision support systems (CDSS) software has started to be used to integrate and make sense of this large amount of data (9). These systems have the ability to provide patient-specific assessments and suggestions and solutions for the clinician (10). In the following process, interest in this system has increased since data can be analysed more effectively with Machine Learning-Clinical Decision Support Systems (ML-CDSS). With these systems, large amounts of data can be used, the logic system is automatically derived and most of the problems can be solved (11).

In a review by Peiffer-Smadja et al. in 2020, 60 different ML-CDSS applications were analysed (7). It was determined that structured and easily accessible medical data types, including vital signs, laboratory measurements, demographic information, medical history and physical examination data, were used in the first AI applications related to infectious diseases. In the review,

ML-CDSS applications were analyzed, revealing that 62% (37 applications) included bacterial infections, 17% (10 applications) included viral infections, 15% (nine applications) included tuberculosis, and 7% (four applications) included any type of infection. Among these applications, it was noted that 33% (20 applications) focused on diagnosing infections, 30% (18 applications) on predicting, early detecting, or classifying sepsis, 22% (13 applications) on predicting treatment response, 7% (four applications) on predicting antibiotic resistance, 5% (three applications) on selecting antibiotic regimens, and 3% (two applications) on selecting antiretroviral treatment combination.

### **1. AI Applications in Medical Diagnosis of Infectious Diseases**

It is important to take infectious diseases under control with early diagnosis and to prevent them from turning into epidemics or pandemics. Early diagnosis of infectious diseases is of vital importance (12). For this reason, studies are carried out in order to develop models for the diagnosis of diseases in the early stages.

Humans can usually easily interpret and integrate up to 4 variables at the same time (13). Computers, on the other hand, can process a wider range of variables simultaneously due to their ability to

recognize and process complex patterns invisible to the human eye.

Therefore, they do not share the limitations of variable interpretation and integration that humans have. Consequently, the development of predictive analytics through AI/ML will continue. With the developed AI, the spread of infectious diseases is classified and predictions are tried to be made (14).

When literature was reviewed, it was observed that different machine learning methods were used for modeling in various infectious diseases. In one study, clinical and laboratory data were used for early diagnosis and prediction of mortality rates of COVID-19, which created a global pandemic at the end of 2019. In another study, diagnosis and prognosis were predicted with different modelling types using many data, including images (15,16). Additionally, various applications have been used in areas such as drug and vaccine development (17). During the COVID-19 pandemic, contact tracing was performed using an AI application called FITAS (Filiation and isolation tracking system). The rate of case increase was reduced with the measures taken in line with the analysis of the filiation data (18).

In a study by Kar et al. it was stated that only clinical tests could be used for hepatitis (19). In another study, ML models were established using laboratory and pathology

scoring system data to predict the progression of chronic hepatitis C infection (20). The use of ML approaches to predict early virological relapse following cessation of treatment in chronic hepatitis B infection is promising. ML models have been established with the combination of interleukin-2, interferon gamma, T cell activation, stem cell factor and tumour necrosis factor-associated apoptosis-inducing ligand to determine the highest predictive values for early virological relapse (21). It was predicted that only signs and symptoms may be insufficient in the modelling to be performed in the detection of pneumonia, and the combination with imaging may detect more infections (22). For the diagnosis of tuberculosis, which is widespread globally, the combination of clinical signs, symptoms, and radiological images, or the use of only chest X-ray images, or the use of only clinical and laboratory data as inputs have been examined, and modeling has been performed using AI approaches (23,24).

For influenza A virus, which causes epidemics, genomic or proteomic inputs have been used for AI applications to predict the phenotypic characteristics of influenza virus in surveillance laboratories (25).

Using AI applications in the diagnosis of infectious diseases can help shorten the time required for medical diagnosis. Various



medical diagnostic tools such as clinical examination findings, biochemical data, and radiological images can be analyzed with the assistance of AI to predict rapid and accurate results and provide effective treatment planning.

## **2. AI Applications in Imaging Methods in Infectious Diseases**

One of the auxiliary methods used in the diagnosis of infectious diseases is imaging systems. ML models are also used in the field of imaging methods. The first FDA approval for AI applications in this field was granted in 2018 for the detection of diabetic retinopathy in retinal fundus photographs (26). In the following period, the use of AI applications for the analysis of medical imaging techniques increased rapidly with the COVID-19 pandemic. However, it was realized that measuring more complex (unstructured) data types, especially three-dimensional (3D) and time-series images, would be difficult. Therefore, it was realised that further studies are needed to develop specialised AI applications for imaging systems.

Segmentation and classification of images are two main challenges in imaging applications for infectious diseases. Images have to be segmented manually and this process is time-consuming, especially for high field of view and high-resolution 3D images such as CT, MR and PET. Therefore, the development of reliable

automated segmentation methods was crucial for advancing infectious disease imaging research and improving clinical applications. In the following period, with the use of artificial intelligence techniques, images could be automatically segmented and utilized in the diagnosis of various infectious diseases.

In infectious diseases, it is crucial to address questions regarding the infection status, severity or stage of the disease, and predicting the response to therapeutic interventions.

AI approaches are employed across a broad spectrum of applications, ranging from simple algorithms to more complex deep learning algorithms. Convolutional neural networks (27) and image transducers (28), a special type of deep learning, have led to significant advances in this field. AI imaging methods have been extensively utilized in various contexts, including human immunodeficiency virus (HIV), tuberculosis, Ebola and Marburg virus infections, Lassa virus and Nipah virus infections, liver CT scanning, influenza, and throughout the COVID-19 pandemic (29).

Imaging data in infectious diseases are more complex due to uncontrolled and confounding factors. This complexity can adversely affect model performance because there can be spurious correlations between data. With the widespread use of

AI techniques, predictions based on imaging data can become more accurate.

### **3. AI Applications in Antibiotic Resistance and Treatment Methods**

Antimicrobial resistance is one of the greatest threats to global public health and development. In 2019, it is estimated that bacterial resistance directly caused 1.27 million deaths and contributed to 4.95 million deaths (30). The acquisition of resistance with the increasing use of anti-infective drugs leads to a decrease in treatment options. Therefore, the detection of resistant organisms is crucial. In vitro antimicrobial susceptibility testing (AST) can be determined by microdilution or molecular approaches. While the microdilution method determines the minimum inhibitory concentration, molecular approaches target specific genes to rapidly identify genotypic resistance.

In this field, AI applications are also utilized. ML models are used to make predictions with techniques such as gene expression and mass spectrometry. When performing AST, methods such as gene expression and mass spectrometry are also used. Typical culture-based AST can take at least a few days to complete. However, in acute systemic infections such as sepsis, accurate and early initiation of antimicrobial therapy is vital. AI technology has combined gene expression and structural mutation mapping with ML

(31,32). Bacterial proteins were used to predict MALDI-TOF mass spectra and antibiotic resistance profiles. Results can be finalised within 24 hours after sample collection (33). The creation of multidimensional data resistance profile clusters will enable ML to produce accurate predictions. Despite high-quality data sources like the PATRIC database (34), it remains unclear whether the antimicrobial resistance predictions generated from these data can be generalized to infections worldwide. With the advances in the field of ML, antibiotic resistance can be predicted accurately and rapidly using proteins, peptides and nucleic acids.

Antibiotic resistance is a global threat. Inappropriate use can be prevented with rational antibiotic use in our country as in the world. Drugs should be used in appropriate duration and dose by evaluating clinical findings and individual characteristics. Determining prescribing rules with AI applications requires the integration of broad and complex information. In a study conducted by Rawson et al., fifty-eight articles were reviewed and 38 CDSS applications were analysed. It was observed that the majority of systems aimed at prescribing antimicrobial drugs (76%), integrating with electronic medical records (74%), and having a rule-based infrastructure (76%). However, it was observed that CDSS

studies were unsuccessful when considering workflow. Additionally, clinicians were reluctant to use CDSS (10).

In the field of infectious diseases, the most significant challenge in antimicrobial prescription CDSS applications is that decision support is influenced not only by human factors but also by pathogen factors, the antibiotic prescribed in the context of individual polypharmacy, the evolution of resistance, symbiotic microbiome, and environmental factors. In the field of infectious diseases, AI applications are still in their early stages, and personalized treatment decision-making systems need to be developed to avoid undesired outcomes.

#### **4. AI Applications in Pharmaceutical and Vaccine Production**

Anti-infective drugs, including antibacterials, antivirals, antifungals and antiparasitics, have become less effective treatments as a result of the spread of drug resistance. The use of anti-infective drugs is increasing worldwide, leading to the development of resistance as a consequence. Every year, the diminishing number of effective anti-infective drugs presents a serious public health concern. In addition, some pathogenic microorganisms have developed resistance to all existing antibiotics and this situation causes difficulties in treatment processes (35).

Traditional drug production includes many stages such as drug ingredient design, drug

performance tests, clinical trials. Phase 0,1,2,3 and phase 4 studies are carried out for each drug and production is realised at the end of a long process. However, this process involves expensive, time-consuming, and labor-intensive stages that can decrease production performance. Moreover, due to the decrease in the share of research and development (R&D) expenditures, research for the development of new drug molecules cannot be supported adequately.

Artificial intelligence technologies contribute to drug development studies at molecular level by shortening the processes. Due to the extensive time and effort required for drug discovery, AI technologies have also been employed in this field. Using powerful logical inference and automatic learning capabilities, 3D printing technology enables the design of the most suitable drug size, shape, and combinations of different pharmaceutical components (36).

This technology has most recently been used for COVID-19 drug design and research, and more than 80 drugs have been discovered (37). Utilizing a deep learning-based model called Molecule Transformer-Drug Target Interaction (MT-DTI), which is one of the AI applications, research has been conducted to identify drugs among commercially available existing drugs that could be effective on the viral proteins of

SARS-CoV-2. Drugs such as atazanavir, remdesivir, efavirenz, ritonavir, and dolutegravir have been investigated, and it has been found that they have inhibitory potency against SARS-CoV-2 (38). By employing AI approaches such as fingerprint vectors, neural network models, and automatic descriptors, a deep neural network training has been completed to design new molecules with antibacterial activity. The c-Jun N-terminal kinase inhibitor SU3327 (Halicin) molecule, which exhibits bactericidal activity against many pathogens including carbapenem-resistant Enterobacteriaceae and Mycobacterium tuberculosis, was designed. Pan drug resistant Acinetobacter baumannii and Clostridioides difficile infections were treated in mouse strains with the designed molecule (38,39). In another study, oxidative damage caused by many drugs or nutritional supplements to human body cell components was tried to be prevented by hydrogen atom transfer and a model was created using machine learning to evaluate the results. In this way, the process and costs were reduced (40).

Despite the advantages provided by AI technologies in the development of anti-infective drugs, there are glaring problems in their application to drug discovery. One of the major challenges is that it is unclear how well ML models generalise to unexplored biomolecular domains. Another

major challenge is the need for advanced mechanical models to complement phenotypic approaches. Although drug-target interactions can be designed in AI models, more research is needed to accurately predict them (41).

AI applications have been used in vaccine development efforts during the COVID-19 pandemic. AI prediction models provided benefits to create vaccine design combinations, thereby reducing R&D costs and time (42). Throughout the COVID-19 pandemic, numerous vaccine studies have been conducted using AI technologies. ML models have provided utility in vaccine development efforts. However, low data quality, limited data availability and generalisability, and complex testing procedures are challenges encountered in this process. Furthermore, validation of vaccine candidates can be time-consuming and expensive. An adequate level of immunogenicity must be ensured by analyzing the level of the vaccine. Standardizing the quality of vaccine-related data could enhance the predictive power of next-generation machine learning approaches in vaccine development (41).

In the future, AI and ML will be used in new vaccine development researches and in the identification of existing or new chemical structures with antimicrobial activity. It offers predictions in the process of vaccine and anti-infective drug development. With

the models created, the results become transparent and interpretable. In this way, the future environment of trust may encourage the adoption and acceptance of systems based on AI and ML (43).

### Conclusion

With the advancement of science and technology, AI applications are a necessity of the age. The use of AI technologies in infectious diseases can provide significant advantages in the diagnosis and treatment of diseases. However, the ethical and legal challenges of these applications should not be ignored. In particular, it is crucial to establish and enforce the ethical and legal framework for AI-supported diagnosis and treatment applications to safeguard the safety and privacy of patients in medical practices. The rapid development and utilization of technologies such as artificial intelligence and machine learning during extraordinary situations such as pandemics can offer more effective and faster solutions in medical interventions. Therefore, it is essential to continue to researching on the role and impact of technology in healthcare. Effective management and implementation of these technologies is vital to achieve better outcomes in the healthcare system.

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# Artificial Intelligence in Diagnosis and Treatment

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## Abstract

*Artificial intelligence (AI) is a field within computer science that has vast applications and has transformed medical technologies. It is often regarded to be the branch of computer science that can handle complicated problems with minimal theory and many applications. AI is utilized to assist researchers in the analysis of large data sets, enabling precision medicine and assisting physicians in improving patient outcomes. New techniques in AI can bring together various types of data to make sense of new information obtained from multiomics datasets. Analyzing high-quality data combined with machine learning, a subset of AI, can help modify patients' unhealthy behaviors, predict risk or recurrence of chronic diseases after a surgical and curative treatment, prediction of progression and survival rates of patients with chronic diseases, therapeutic need, generation of improved clinical trial interpretations and identification of new targets. However, to effectively implement precision medicine in healthcare, a more user-friendly interface would be required. If AI technologies are applied correctly, fairly and robustly, in close cooperation with human intelligence, it is expected to open up new possibilities for effective and personalised healthcare services worldwide. In this review, the general outlines of AI technology, its application areas in healthcare and its future are overviewed.*

**Key words:** *Artificial Intelligence, Explainable Artificial Intelligence, Machine Learning, Medicine, Drug Discovery*

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## Introduction

The cost of healthcare is soaring everywhere. The rising prevalence of chronic illnesses, longer life expectancies, and the ongoing development of expensive new treatments all contribute to this trend. It is therefore not surprising that academics project a dismal future for the viability of healthcare systems globally. Artificial intelligence (AI) holds the potential to mitigate the effects of these advancements by enhancing and optimizing healthcare expenditures (1). When smartphones, wearables, sensors, and communication systems first appeared, medical technologies were primarily known as traditional medical devices (such as implants, stents, and prosthetic limbs). However, with the advent of these devices and their capacity to house AI-powered tools (like applications) in incredibly small forms, medical technology underwent a revolution. AI is a field within computer science that has vast applications and has transformed medical technologies. It is often regarded to be the branch of computer science that can handle complicated problems with minimal theory and many applications (2). AI is utilized to assist researchers in the analysis of large data sets, enabling precision medicine and assisting physicians in improving patient outcomes.

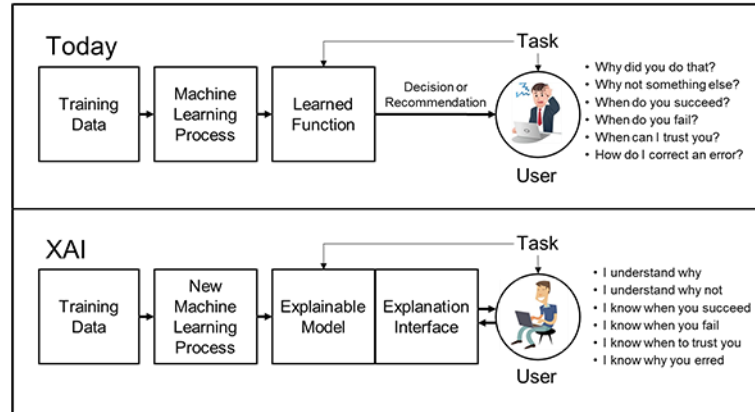
AI algorithms can help doctors to make better decisions (“clinical decision support”, CDS), localize tumors in magnetic resonance (MR) images, read and analyze reports written by radiologists and pathologists, and much more. In the near future, reports that are legible by humans may also be produced with the aid of generative AI and natural language processing (NLP) systems like Chat Generative Pre-trained Transformer (ChatGPT) (3). AI includes various techniques such as machine learning (ML), deep learning (DL), and NLP. AI was still in its infancy and mostly the focus of scholarly research at the time. John McCarthy first used the phrase "Artificial Intelligence" in 1956 at the Dartmouth Conference. The modern AI era began with this occurrence. Expert and rule-based systems were the main topics of AI research in the 1960s and 1970s. But the lack of additional data and processing power made this strategy impractical. Artificial intelligence (AI) research turned to ML and neural networks in the 1980s and 1990s, enabling machines to learn from data and gradually improve their performance (4). New techniques in AI can bring together various types of data to make sense of new information obtained from multiomics datasets. Analyzing high-quality data combined with machine learning, a subset

of AI, can help modify patients' unhealthy behaviors (5), predict risk or recurrence of chronic diseases after a surgical and curative treatment (6), prediction of progression and survival rates of patients with chronic diseases (7), therapeutic need, generation of improved clinical trial interpretations and identification of new targets (8). The application of AI models for diagnostic and prognostic assessments is widely accepted in the context of some cancers (9). The ability of AI models to discover nonlinear patterns embedded within complex multivariate datasets could potentially lead to a better understanding of the complex mechanisms underlying carcinogenesis and cancer progression (10). In the last decade, there has been a massive increase in the number of large and complex omics datasets, especially thanks to large-scale consortium projects such as the Cancer Genome Atlas (TCGA), which has sampled multiomics measurements from more than 30,000 patients and dozens of cancer types (11, 12, 13). These rich omics data provide unprecedented opportunities to systematically characterize the underlying biological mechanisms in cancer evolution and understand how the tumor microenvironment (TME) contributes to this evolution (12, 14). However, the idea that AI is essentially an opaque "black box" that cannot be mechanically interpreted and therefore cannot meet the required high

level of accountability, transparency and reliability in medical decision-making has led to major criticism of the incorporation of AI, especially deep learning, into medical fields. "Black box" AI models produce results with remarkable accuracy, but no one can understand and analyze how the algorithms arrive at their predictions (15). When AI suggests a decision, decision makers need to understand the underlying reasons. In recent years, AI researchers have been conducting extensive research to open this "black box" concept and transform it into a transparent system. At the forefront of this research is Explainable Artificial Intelligence (XAI), also referred to as the "white box" (16) (Figure 1). Explainability is the ability to explain AI decision-making in terms understandable to humans about how a decision is made (17). This system aims to achieve more transparent, more reliable and interpretable results by explaining to users what it has done, what it is doing and what it will do thanks to its developed algorithm (18). In the XAI method, the whole process can be analyzed retrospectively (15). Although studies on the use of AI in medicine have increased in recent years, XAI system studies using explainable algorithms have just started. Breast cancer is the leading cause of cancer-related deaths worldwide and is the most common type of cancer among women (19). Amoroso et al. used an

XAI modeling for breast cancer treatments and showed that XAI can summarize the most important clinical feature for

oncological treatments designed for the patient and the patient (20).



**Figure 1.** AI concepts (21).

In this review, the general outlines, application areas, future and possible ethical problems of artificial intelligence technology in healthcare are discussed.

## Artificial Intelligence Applications in Medicine

### AI in Pathology image processing

Digital pathology is becoming an increasingly important technological requirement in the laboratory setting and plays a crucial role in contemporary clinical practice (22). Histopathologists can now handle digital slide photos with greater ease and flexibility than they could ten years ago. They can also exchange images for telepathology and clinical use because to advancements in processing power, more rapid networks, and less expensive storage. Whole slide imaging (WSI), which enables total slides to be photographed and

permanently saved at high resolution, has evolved during the last 20 years in pathology digital imaging (23). The FDA has approved digital pathology's WSI system, ushering in a new era for digital image analysis in the field (24, 25). AI has primarily been utilized in radiology and cardiology for image-based diagnosis up to now. With multiple research organizations and committed businesses, the field of active research on its application to pathology is growing. The images produced by WSI are an abundant supply of information; their size (100k x 100k is not uncommon) makes them more complex than many other imaging techniques; they also have color information (H&E and immunohistochemistry); there is no obvious anatomical orientation as in radiology; information is available at multiple scales (e.g., 4x, 20x); and there are multiple z-

stack levels (each slice contains a limited thickness and depending on the plane of focus, it will result in various images). It is obvious that an ordinary reader cannot possibly extract all visual information (23, 24). WSI is currently in use for training at tumor boards, conferences, online seminars, and presentations (22). With WSI capabilities, AI tools can aid in the continued education of the upcoming generation of pathologists by offering standardized, interactive digital slides that are available for sharing at anytime, anywhere, to numerous users (22, 26).

Based on histological characteristics, AI can be utilized to forecast prognosis and treatment outcomes. Important information might be succinctly provided by directly connecting images of various tumor characteristics, the surrounding microenvironment, and genetic data with survival outcomes as well as response for adjuvant/neoadjuvant therapy (27). Wang et al. used H&E stained tissue microarray slides to build a machine learning model that predicted recurrence in early-stage non-small cell lung cancer (NSCLC) based on nuclear orientation, nuclear shape, texture, and tumor architecture. In two validation cohorts, the prediction of their model proved to be an independent prognostic factor, with 82% and 75% accuracy for recurrence prediction, respectively (28). In 2018, Saltz et al. brought attention to the

prognostic implications of AI tools. They employed a convolutional neural network to enhance pathologist feedback for the automated identification of the spatial organization of tumor-infiltrating lymphocytes in images obtained from The Cancer Genome Atlas. According to their research, this characteristic can predict the course of 13 different cancer subtypes (29). Similar research by Yuan et al. provided a model to examine the lymphocytes' spatial distribution in relation to tumor cells on triple-negative breast cancer white matter irradiation. They discovered a clear relationship between the spatial distribution of immune cells in ER-positive breast tumors and late recurrence, in addition to identifying three distinct types of lymphocytes (30).

### **Commentation of Biochemical and Clinical Tests with Artificial Intelligence**

Artificial intelligence (AI) has been also more and more empiercing into the world of health science applications. The foremost areas are biochemical and clinical tests. Because both the patients and clinicians always expect to get the most accurate and smooth results from the laboratories, the hand of AI could provide not only an opportunity for accelerating the process for obtaining results, but also annihilate the erroneous laboratory results at the best. Moreover, AI has been also being used for proper selection of sample in clinical trials

and detection of very early signs of adverse effects or toxicity (31).

Biochemical tests have been displaying a great diversity and there are lots of parameters which could be handled successfully by AI software. For instance, oxidative stress parameters and anti-oxidative capacity have been attempted to commit in order to predict certain neurodegenerative diseases such as Alzheimer's and Parkinson diseases (32). In clinical tests, as we mentioned that AI could be very useful for contemplating a clinical trial at the very beginning, there also have been lots of ventures to be able to use the AI for interpretation of biochemical or clinical test results. For instance, according to the one of previous studies, software algorithms are proved to have been producing more rapid and precise diagnosis in comparison to pathologists themselves (33).

### **Artificial Intelligence in Precision Medicine and Genomics**

Precision medicine, also known as personalized medicine, is an innovative approach to prevent or treat diseases by taking into account differences in an individual's genetic history, environment and lifestyle. Precision medicine recognises the critical fact that not all patients respond in the same way to the same treatment. It takes a patient-centred approach by analysing clinical, genomic and pharmacogenomic data, rather than a

symptom-centred approach. In the conventional healthcare system, clinicians tend to plan treatment on the basis of symptoms. Since the symptoms can vary greatly among individuals, genomic, metabolic and clinical data should be utilized together in order to create a more personalised treatment plan. In this way, the quality of healthcare services can be improved through the application of personalised precision medicine approaches rather than the symptom-based approach of the traditional healthcare system.

Artificial intelligence can be used in medicine in two different ways: virtual and physical. The virtual use of AI includes applications ranging from electronic health records to neural networks that guide patient treatment. Physical machines, such as artificially intelligent prosthetics for the disabled and robots that assist in surgery, are the physical subset of artificial intelligence. The most common applications of precision medicine are genetic screening for disease prediction and diagnosis, and pharmacogenomics for drug response prediction (34). Artificial intelligence and machine learning techniques have been shown to be useful in calculating genetic risk for diseases and in determining 'polygenic risk scores' to identify individuals at high genetic risk for certain diseases. Predictive algorithms can identify disease groups not recognised by

clinicians and can guide the selection of personalised treatment options for these patients. Another option is to monitor people with a genetic predisposition to the disease on an ongoing basis, allowing early diagnosis at the onset of the disease. This would avoid the need for complex treatments. By applying artificial intelligence techniques to new generation sensors, such monitoring can be further developed.

Genomic studies and the next-generation sequencing have progressed at an exponential rate from the first descriptions of DNA by Watson, Crick and Franklin in 1953. Sequencing technologies have reached a stage where the entire genome can be sequenced in one day. While whole genome sequencing (WGS) covers the entire genome, whole exome sequencing (WES) focuses only on the protein-coding regions and both produce massive amounts of genomic data to analyse. It is important to help scientists understand how genetic variation is linked to a disease by affecting critical cellular processes such as cell development, cell differentiation, metabolism and DNA repair (35). Several deep learning models have been developed to analyse large genomic datasets and identify genetic variants within a whole genome, for example DeepVariant is an analysis pipeline, a deep convolutional neural network model (36). DeepVariant

can call genetic variants from next-generation DNA sequencing data, enabling patient stratification based on statistically significant variants associated with a disease phenotype.

DeepSEA is another deep learning algorithm that can specifically identify functional effects of non-coding variants with single-nucleotide sensitivity, which is a difficult task due to the large number of these variants throughout the genome. DeepSea has been trained on regulatory sequences, chromatin profiles that play an important role in epigenetics and gene regulation at the transcriptional level, to predict changes, especially SNPs with a functional difference that are associated with a particular disease or phenotype (37). Epigenomics is responsible for the regulation of gene expression without altering the DNA sequence, adding another layer of complexity to the genome. Recently, machine learning models have emerged to identify epigenetic changes. For example, DeepBind has been developed to analyse disease-associated genetic variants that can alter transcription factor binding and alter gene expression. It is based on deep convolutional neural networks and is designed to predict the sequence specificity of DNA and RNA binding proteins (38). Other tools for identifying histone protein modifications are DeepHistone and DeepChrome (39, 40). These tools were

developed to predict epigenetic changes, specifically histone modifications that regulate gene expression (41).

While AI is being used to develop personalised medicine, there are limitations to consider. When predicting trends in a target individual's health data that may indicate a change in health status, based on data collected from a large number of individuals, it is important to remember that the data collecting from each individual is not ergodic. It has been argued by Fisher et al. important individual-level relationships are often missed by big data analyses, which combine information about many individuals to identify patterns that reflect population-level relationships between data points (42). Inferences based on group-level data can only be generalised to individual experience or behaviour for ergodic processes. However, medical data are unlikely to be ergodic as they vary between individuals and change over time. Therefore, in order to predict the target individual's health trajectory, more data points should be collected for each individual and the prediction should rely more on the existing data points for that target person rather than the population level data. It has been suggested that researchers across the medical sciences should clearly test the equivalence of processes at the individual and group levels (42).

## **Machine Learning In Pharmacogenomics**

Pharmacogenomics (PGx) involves understanding how a patient's genetic profile affects how they respond to drugs, predicting how an individual metabolises drugs and potential side effects. It is well known that genetic variations can affect drug response, particularly variations in genes involved in the absorption, distribution and metabolism of drugs, all of which affect the pharmacodynamics and pharmacokinetics of a drug. The aim of the pharmacogenomics is to prescribe the most effective drug at the correct dose, minimising the risk of side effects, increasing treatment efficacy and enabling personalised medicine by identifying a patient's genetic variations. FDA released a guidance in 2013 for pharmaceutical industry and the researchers engaged in drug development to provide recommendations on when and how genomic information should be utilised (43). Pharmacogenomics assessment is recommended to implement in early phase clinical trials to identify populations based on genetic effects on drug exposure, dose-response, common adverse reactions and early efficacy should receive lower or higher doses of a drug or longer titration intervals. Although this approach has not yet been widely adopted by pharmaceutical companies, applications of artificial

intelligence methods for patient stratification using clinical and genomic data are emerging and are expected to grow rapidly. Patient stratification involves the complex integration of heterogeneous sociometric, demographic and biomedical data to classify patients into subpopulations for clinical practice and clinical trial design. In order to identify better treatment options, electronic health records-linked DNA biorepositories have successfully used in predictive modeling with the integration of pharmacogenomic and sociometric data such as gender, age etc. Here are the some examples of recently published open source deep learning softwares applying artificial intelligence to patient stratification and healthcare coordination: Deep Patient is an unsupervised deep learning method for augmenting clinical decision systems and deriving patient representations. Hierarchical regularities and dependencies have been captured in the aggregated electronic health records of approximately 700,000 patients. Deep Patient can predict the likelihood of patients developing various diseases (44). DeepCare is another deep dynamic memory model for predictive medicine. This model uses electronic health record data, including medication codes, diagnoses and procedures, to predict unplanned readmissions and high-risk patients for mental health and diabetes patient cohorts (45).

## **Drug Discovery and Repurposing**

Drug design is generally recognised as a specific stage in the drug discovery process. It focuses on the development, optimisation and refinement of potential drug compounds. Drug repurposing is a faster and more cost-effective process than developing new medicines from scratch. It is focused on the discovery of novel pharmaceutical uses for drugs that were originally developed for specific medical indications. In silico studies involve many tasks performed on computer to assist drug screening, drug design and repurposing via investigating the interactions between targets and drugs. Computational drug design is not a new concept. However, with advances in hardware and software, the use of computational approaches, AI and machine learning models has increased rapidly. Deep learning models, including neural networks, have been developed to study drug-drug interactions, drug-target interactions, protein-protein interactions, DNA-protein interactions and examining disease mechanisms. Experimental methods for studying these interactions are labour-intensive, time-consuming and expensive. AI models have great potential to reduce the time and cost required for such analysis and subsequently for drug discovery. Studies focusing on drug-drug interactions try to understand how a drug works when it's given simultaneously with another drug and



how this might change the way the drug works. A detailed examination of all AI-based software and tools used for drug discovery is beyond the scope of this review. However, we can give AlphaFold2 developed by Google DeepMind, DeepChem, DeepBind as examples of the most commonly used AI-based softwares for drug development, discovery and analysis (46, 47, 48). Interested readers are referred to the excellent review by Qureshi et al. (49).

### **Concluding Remarks and Future Perspectives**

Healthcare is moving towards more personalised and targeted approaches to diagnosis, treatment and prevention. Artificial intelligence, clinical genomics, big data and pharmacogenomics are therefore critical to the future development of precision medicine. By harnessing the power of genomic and molecular data, precision medicine will help healthcare professionals and researchers access larger amounts of medical data and make more accurate diagnoses. There is currently no system that can simultaneously compare multi-omics data to predict more accurate and personalised outcomes. To effectively implement precision medicine in healthcare, a more user-friendly interface would be required. If AI technologies are applied correctly, fairly and robustly, in close cooperation with human intelligence,

it is expected to open up new possibilities for effective and personalised healthcare services worldwide.

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# Artificial Intelligence and Microbiology

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## Abstract

*The concept of Artificial Intelligence (AI) is increasingly important in the healthcare sector today. Components of AI such as machine learning and deep learning are being utilized in various applications within the field of microbiology. This study examines the uses of AI in microbiology and its role in healthcare applications.*

*Machine learning enables computer systems to analyze data using algorithms that mimic human intelligence, while deep learning processes information through multi-layered artificial neural networks. These technologies are used in many areas such as microbiological diagnosis, drug discovery, infection control, and patient monitoring.*

*For instance, AI-supported systems are used in microbiological diagnosis to shorten diagnosis times and increase accuracy compared to traditional methods. Additionally, smart systems developed for preventing hospital-acquired infections alert hospital staff, thus reducing the risk of infection.*

*AI also plays a significant role in the diagnosis of microorganisms such as viruses and fungi. Especially, AI-supported image analysis methods are utilized for rapid and accurate diagnosis. However, there are some challenges in the use of AI. Issues related to data privacy and ethics are among the factors limiting the applications of AI in microbiology and healthcare. Furthermore, the cost and complexity of algorithm implementation pose additional challenges. By discussing the applications of AI in microbiology and its potential in the future, this study sheds light on innovative developments in the healthcare sector.*

**Key words:** Artificial Intelligence, Healthcare, Medical microbiology

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## Introduction

The concept of Artificial Intelligence (AI), which first emerged in 1956, refers to digital systems that attempt to solve problems using algorithms that mimic human intelligence and continuously improve themselves with processed information. Today, with the increase in the amount of data entered, the use of more powerful coding languages, and the utilization of advanced algorithms, AI has spread to a wide range of sectors and begun to benefit many industries. In addition to its presence in various fields such as tourism, real estate, public services, navigation, facial recognition, smart cars, chatbots, search engines, and social media, its significance in healthcare applications is increasing day by day (1).

An AI system, composed of many components, is advanced with machine learning and further enhanced in problem-solving ability through deep learning. These components can be examined under the main headings of machine learning, deep learning, natural language processing, neural networks, image processing, and cognitive computing. In fact, machine learning lies at the core of these intertwined components.

## Machine Learning

Machine learning is the fundamental component of AI systems, teaching computers to process data like how humans

learn and think. The basic aim of machine learning is to teach the computer to make predictions and inferences. The first step in machine learning is to create a model with algorithmic data. Then, this model is trained and integrated into the application to be used. Subsequently, the suitability of the output data of the model is checked. In machine learning, there are two main components used to create these models: supervised learning, which involves example data containing the algorithm's input and output, and unsupervised learning, which involves algorithms scanning new data to establish connections between unknown inputs and predefined outputs (2).

## Deep Learning

Deep learning is a subset of machine learning that learns information by using multi-layered artificial neural networks, processing data in a way very similar to how neurons in the human brain function. Each artificial neuron uses software packages called nodes that perform mathematical calculations. When these neuron networks receive a data input, they pass it on to lower layers. With each new data passed through these hidden layers, the information is processed at different levels. This processed information emerges as a response from the output layer, which is the final layer (2).

## **Applications of Artificial Intelligence in Healthcare**

With the advancement of technology, AI has become highly integrated into the field of healthcare. Examples include the development of medical diagnoses, acceleration of drug discovery, management of health data, robotic surgery, patient monitoring, and imaging.

Artificial intelligence-supported image technology also holds significant utility in the field of radiology. AI, such as Aidoc, employs deep learning algorithms to store data entirely in cloud servers, eliminating the need for a physical device outside the imaging device itself (3). In addition to radiology, AI is also utilized in the field of surgery, with robotic surgery serving as a prime example. Robotic-assisted surgery, also known as the da Vinci system, facilitates complex techniques with multiple arms, provides clearer images with high-resolution cameras, and offers advantages such as minimal invasive intervention resulting in less blood loss, faster recovery, and reduced risk of infection (4).

The increasing frequency of emerging infections and the concomitant rise in drug resistance necessitate the acceleration of new drug discovery. Selecting the right target is crucial for the successful development of a drug molecule. In the disease process, numerous proteins are

involved, with some being overexpressed. Artificial intelligence-supported programs like AlphaFold analyze the three-dimensional structures of target proteins in drug discovery, accurately delivering the drug molecule to the correct target, thereby contributing to the success of this process (5).

Pandemics caused by infectious diseases such as the Spanish flu, Ebola, and Corona Virus Disease (COVID-19) have resulted in millions of deaths. It is known that the Spanish flu infected one-third of the world's population in the 20th century, and it is indicated that the Influenza A viruses seen today are different variants of this pandemic (6). Therefore, the control, prevention, and treatment of epidemic diseases are crucial for the future of humanity. AI-based applications play an important role in monitoring infectious diseases.

One of these applications involves the use of a relatively new data class called the Internet of Things (IoT). IoT is an internet network that can be installed on devices such as smartphones and smartwatches that we use in our daily lives, allowing them to collect data. The collected data is used to better understand infectious diseases, the mechanisms of infections, treatment resistance, transmission, and to develop vaccine designs (6).

One useful application is the deployment of thermal cameras in airports. These cameras

can detect individuals with elevated body temperatures, thereby identifying potentially infected individuals (6).

### **Usage in Microbiology**

The history of tests related to the detection of microorganisms dates back to before the publication of Koch's postulates in 1890. These tests have evolved from simple culture methods such as Petri dishes to serological tests, matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOF), and modern molecular methods like next-generation sequencing, and continue to advance (7). However, human limitations in processing capacity and the consequent use of a limited range of parameters also restrict interpretation and observation abilities. In this context, AI can provide more precise and versatile results without being subject to any limitations (1, 8). It can help minimize the risk of misdiagnosis in the laboratory, such as due to similarities in colony color and shape (9). Moreover, it aids in saving labor and time while ensuring more accurate and reliable results (1).

One of the threats to human health is nosocomial or hospital-acquired infections. Many pathogens that cause nosocomial infections are naturally resistant to empirical drugs, making them untreatable with routine treatment protocols. Most individuals affected by nosocomial infections are elderly, newborns, or

individuals with immunodeficiency. Fortunately, when correct treatment and prevention protocols are applied, these diseases can be prevented by up to 70%. A software called AITSM (Artificial Intelligence Thermal Sensing Monitor) has been developed to monitor whether these protocols are correctly implemented. AITSM tracks hospital staff's protective clothing via cameras and can be installed on smartphones, providing alerts through voice commands. It serves as an example of AI used for monitoring and ensuring compliance with infection control protocols in healthcare settings (10).

AI integrated into molecular diagnostic methods also finds applications in whole genome sequence analysis. AI capable of detecting antibiotic resistance genes in a sequenced bacterial genome can inform us about which antibiotics the bacterium is resistant to and which ones it is susceptible to, without the need for conducting antibiotic resistance tests on the bacterial species. This capability helps save time and labor by providing insights into the bacterium's antibiotic resistance profile directly from its genome sequence (8).

MALDI-TOF (Matrix-Assisted Laser Desorption/Ionization Time-of-Flight) is another laboratory technique where smart software applications are used. In MALDI-TOF, biomolecules such as proteins, sugars, peptides, and large polymers are ionized

after which they are passed through an electric field to extract protein profiles. These profiles are then compared with reference profiles in the system to identify species and genera (11).

MALDI-TOF can also be used for predicting antibiotic resistance. In a study, machine learning algorithms such as decision tree, k-nearest neighbors, random forest, and support vector machine (SVM) were able to distinguish between hospital-acquired infections caused by vancomycin-intermediate *Staphylococcus aureus* (VISA) and heterogenous VISA from vancomycin-sensitive strains (12). Another resistance study focused on hospital-acquired infections caused by vanB positive vancomycin-resistant *Enterococcus faecium* (VRE). With high specificity (98.1%) and sensitivity (96.7%), the study successfully differentiated VRE from susceptible strains. Additionally, the study measured the similarity degrees of 66 VRE isolates that could not be distinguished using PFGE (Pulsed-Field Gel Electrophoresis) method (8).

### **Artificial Intelligence for Bacteria**

Bacteria are single-celled prokaryotic microorganisms, typically ranging in size from 0.1 to 10 micrometers, with most having a cell wall made of peptidoglycan. They can be found in various forms, including cocci (spherical), bacilli (rod-shaped), cocobacilli (oval-shaped), vibrio

(comma-shaped), and spiral. To differentiate between bacteria, their microscopic shapes, colony morphologies, staining and biochemical properties, as well as differences in genetic sequences, are utilized.

In a study conducted by Glasson et al. (13), traditional plate reading and digital imaging were compared. An Automated Plate Assessment System (APAS) was utilized for urine samples, and differences between the traditional methods were evaluated. APAS demonstrated a sensitivity and specificity of 99% and 85%, respectively, in diagnosis. It was able to detect 99% of colonies on blood agar plates and 99.5% on MacConkey agar plates. Additionally, APAS showed agreement with microbiologists in 92.1% of plate interpretations, with a sensitivity of 90.8% and specificity of 92.8% for case definition (13).

In a similar study, Ma et al. (14) employed AI for the detection of bacteria on food, focusing on the analysis of morphological differences in microcolonies. Using the YOLOv4 (You Only Look Once) algorithm, it was found that the detection of *Escherichia coli* (*E. coli*) was 30 frames per second faster compared to the basic microscopic detection method. Additionally, the study showed that the YOLOv4 algorithm could distinguish *E.*



*coli* from other bacteria in mixed bacterial cultures (14).

One of the applications combining AI with clinical practice is computerized tomography (CT) and X-rays. In studies on the diagnosis of pulmonary tuberculosis (PTB) caused by *Mycobacterium tuberculosis*, AI-assisted chest X-rays were reported to provide results close to those of clinicians. In a comparative study, the performance of an automated AI image reader and manual image reading was evaluated on 47 PTB-positive patients. While expert doctors misdiagnosed 14 cases, AI only misidentified 5 cases (15).

#### **Artificial Intelligence for Viruses**

Viruses are obligate intracellular parasites that are so small that they can only be seen with an electron microscope. They contain single or double-stranded DNA or RNA surrounded by a protein coat called a capsid. Some species additionally possess an envelope and harbor surface antigens along with adhesion proteins. Due to the difficulty in their cultivation, requiring cell culture in vitro, much like bacteria and fungi.

Although viruses exhibit distinctive features in terms of their different structures and shapes, difficulties in isolation and imaging have led to the widespread preference for studying the effects of viruses on cells (cytopathic effect) for diagnosis.

After the COVID-19 pandemic, which affected the entire world in 2019 and led to 774,834,251 cases and 7 million deaths according to the World Health Organization (WHO) by 2024, the early diagnosis of viruses has become even more crucial (16). For early diagnosis of COVID-19, Widodo et al. (17) developed an application that can diagnose the disease based on clinical symptoms such as fever, fatigue, cough, shortness of breath, sore throat, chest pain, nasal congestion, runny nose, and diarrhea. Researchers can input the encountered symptoms into the system and fill in the remaining systemic information to obtain results. The application achieved a high accuracy rate of 94.2% in diagnosing COVID-19 (17).

In another study by Sitaula et al. (18), symptoms of the monkeypox virus were taught to the Xception DL AI software with images. Subsequently, a group consisting of a total of 1754 individuals including those with measles, monkeypox virus, avian influenza, and healthy individuals had their photographs entered into the system. The software accurately predicted and classified the sick individuals from these photos with an accuracy rate of 86% (18).

#### **Artificial Intelligence for Fungi**

Fungi, unlike viruses and bacteria, have eukaryotic cell structures. They have cell walls like bacteria, but these walls are composed of chitin. They contain ergosterol

instead of cholesterol in their cell membranes, distinguishing them from other eukaryotes. Morphological distinctions are made based on colony shape and sporulation. They can be unicellular or multicellular, existing in mold or yeast forms.

Although fungal diseases may not receive much attention from the general public or scientists, they can cause serious infections, especially with the increasing number of individuals with underlying serious illnesses and immunodeficiency conditions (such as transplant patients, AIDS (Acquired Immune Deficiency Syndrome) patients, cancer patients, and those undergoing chemotherapy).

Diagnosing fungal diseases is challenging due to the similarity in their morphologies, making it difficult to make definitive and rapid diagnoses. AI shortens this diagnostic process, particularly contributing to survival rates in immunosuppressed patients (1, 19, 20).

In a study utilizing AI, fungal colonies stained using a simple staining method were identified with the help of a camera capable of distinguishing their morphologies. A database was created containing species from the *Candida* genus (*Candida albicans*, *Candida glabrata*, *Candida tropicalis*, *Candida parapsilosis*, and *Candida lusitanae*), the *Saccharomyces* genus (*Saccharomyces cerevisiae* and

*Saccharomyces boulardii*), and the *Basidiomycetes* genus (*Malassezia furfur* and *Cryptococcus neoformans*). The study shortened the diagnosis time of the disease by 2-3 days (19).

In a similar study, a database was created introducing sporulation shapes. Cultures of *Penicillioides*, *Restrictus*, *Versicolor*, *Cladosporium*, and *Eurotium* fungal species were photographed using a microscope and camera after sporulation. The system was trained with 30,000 photos, and 10,800 photos were used for testing. In this study utilizing convolutional neural networks (CNNs), the accuracy rate was found to be 94.8% (20).

In a study focused solely on *Aspergillus* species (*A. clavatus*, *A. flavus*, *A. terreus*, *A. niger*, *A. fumigatus*, and *A. nidulans*), the Xception software was trained with images taken with a stereo microscope. Original colony photographs of a total of 8995 colonies from seven species were used for training. From these photos, 17,142 images showing conidiophore and colony morphologies of each species were obtained and introduced to the software. The Xception software demonstrated a classification success rate of 99.8% (21).

### **Artificial Intelligence for Parasitology**

Parasites, with a more advanced structure compared to other microorganisms, are invertebrate animals that can cause diseases in humans and other animals. They are often

considered tropical and, therefore, have not been of great importance to physicians in colder and more developed countries. However, with an increasing number of tourists, Peace Corps volunteers, businessmen, and others visiting exotic regions of the world and staying for extended periods, these individuals are at risk for infections that are rare in developed countries. Therefore, the diagnosis of parasites is as crucial as other diseases.

Parasites are classified into four classes: Protozoa, Animalia, Fungi, and Stramenopila. They are categorized based on their nuclei and motile organs, morphologies, and reproduction methods, and distinctions are made according to these characteristics. Although the stool test (O&P) is a significant standard practice for detecting pathogens, it is costly in terms of time and labor (1).

Especially prevalent in Africa, malaria (malaria) caused by the *Plasmodium* genus is one of the most common parasitic diseases, with over 200 million cases annually. To facilitate the detection of this parasite, Liu et al. (22) developed software called AIDMAN. Using a more advanced version of the YOLOv4 algorithm called YOLOv5, AIDMAN accurately detected *Plasmodium* in thin blood smears with a high rate of 98.44% (22).

In a study analyzing the growth of pathogens and host defense behaviors, an

AI software called HRMan (host response to microbe analysis) was used, which utilized convolutional neural networks (CNNs). HRMan 2.0 version evaluated the growth rates of intracellular infection agents such as *Toxoplasma gondii*, *Plasmodium spp.*, and *Salmonella spp.* The algorithm also assisted in studying host-parasite interactions such as pathogen killing, extracellular behavior, and invasion rate (23).

Artificial intelligence-assisted telemedicine applications are also used in parasitology. With the AI-based application named TechCyte, remote diagnosis is possible. Stool samples on Kato-Katz slides were examined under a light microscope, photographed, and sent to the platform for diagnosis. This application also eliminates negative samples, thus increasing sensitivity (24).

### **Conclusion**

In conclusion, as AI continues to advance in today's technology, it becomes more integrated into our lives. It enhances our quality of life by saving labor and time, ultimately raising our standards of living. However, alongside the positive outcomes enabled by AI, there are also challenges and limitations to be faced.

While AI systems offer accurate data and image analysis, the generated results are only beneficial when they are clinically meaningful and interpreted correctly.

Therefore, in the current state of AI, it should not be viewed as a definitive diagnostic tool. For instance, the Xception software's 86% accuracy in virus studies and 99.8% accuracy in fungal studies indicate that the same software may yield different results in different studies, highlighting that no single application should be considered an absolute safe method.

Additionally, with the increase in big data, resolving ethical issues related to unauthorized and non-consensual use of

patient data requires the implementation of necessary regulations.

AI modules and algorithms should be made more accessible and user-friendly for everyone. However, due to the rapid data processing and special computing requirements of these algorithms, their usage and installation can be costly.

Despite facing certain limitations, it is evident that once these challenges are overcome through necessary regulations, AI will offer us a bright future in both clinical applications and our daily lives.

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