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Complementary Use of Artificial Intelligence in Healthcare

Sağlık Hizmetlerinde Yapay Zekânın Tamamlayıcı Kullanımı

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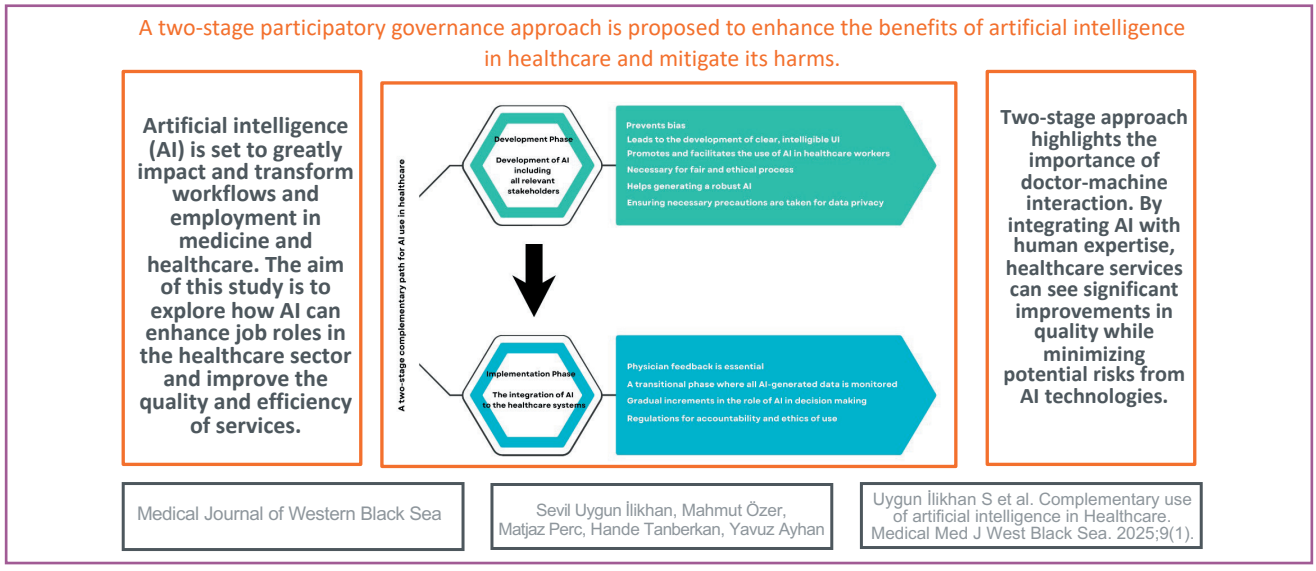
GRAPHICAL ABSTRACT



ABSTRACT

Artificial intelligence (AI) is set to greatly impact and transform workflows and employment in medicine and healthcare. This study explores how AI can enhance job roles in the healthcare sector and improve the quality and efficiency of services. A two-stage approach is proposed. In the first stage, doctors and healthcare workers are involved in developing AI systems. Their participation ensures ethical use, boosts effi-

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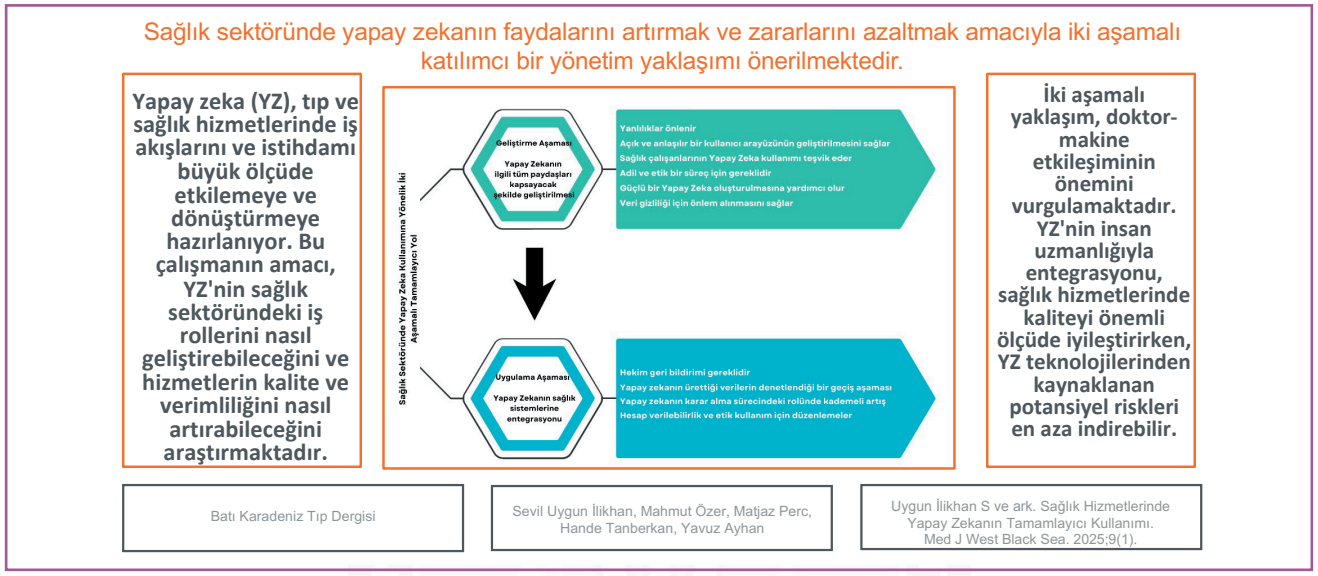
ciency, and prevents biases from the data or algorithms. In the second stage, continuous monitoring of AI systems by healthcare professionals is crucial. They act as filters for AI-generated results during decision-making processes. This ongoing oversight helps maintain accuracy and reliability. This two-stage approach highlights the importance of doctor-machine interaction. By integrating AI with human expertise, healthcare services can see significant improvements in quality while minimizing potential risks from AI technologies.

Keywords: Artificial intelligence, data bias, healthcare, human complementation, medicine

GRAFİKSEL ÖZET



ÖZ

Yapay zekâ (YZ), tıp ve sağlık hizmetlerinde iş akışlarını ve istihdamı büyük ölçüde etkilemeye ve dönüştürmeye hazırlanmaktadır. Bu çalışma, YZ'nin sağlık sektöründeki iş rollerini nasıl geliştirebileceğini ve hizmetlerin kalite ve verimliliğini nasıl artırabileceğini araştırmaktadır. Bu kapsamda iki aşamalı bir yaklaşım önerilmektedir. İlk aşamada, doktorlar ve sağlık çalışanları YZ sistemlerinin geliştirilmesine dahil edilmektedir. Doktorlar ve sağlık çalışanlarının katılımı, etik kullanımın sağlanmasını, verimliliğin artırılmasını ve verilerden veya algoritmalardan kaynaklanan önyargıların önlenmesini sağlamaktadır. İkinci aşamada ise, YZ sistemlerinin sağlık profesyonelleri tarafından sürekli izlenmesi kritik öneme sahiptir. Sağlık profesyonelleri, karar verme süreçlerinde YZ tarafından üretilen sonuçlar için bir filtre görevi görmektedir. Bu sürekli denetim, doğruluk ve güvenilirliği korumaya yardımcı olmaktadır. Bu iki aşamalı yaklaşım, doktor-makine etkileşiminin önemini vurgulamaktadır. YZ'nin insan uzmanlığıyla entegrasyonu, sağlık hizmetlerinde kaliteyi önemli ölçüde iyileştirirken, YZ teknolojilerinden kaynaklanan potansiyel riskleri azaltacaktır.

Anahtar Sözcükler: İnsanı tamamlama, sağlık hizmetleri, tıp, veri yanlılığı, yapay zekâ

INTRODUCTION

Artificial intelligence (AI) is rapidly spreading across all fields, from education to healthcare, economy to defense industry, with its significant advantages (1-6). The transformation brought about by AI technologies is occurring on a significantly different scale compared to previous major technologies, and an AI ecosystem is forming in a short period. Particularly, the widespread digitalization in all areas ensures the sustainability of AI systems.

Medicine is among the first application areas of AI technology. AI had already had its impact on different aspects of medicine, including the patient care (diagnostics and therapeutics), medical training and healthcare systems (7,8). Particularly, the prevalence of digitalization efforts, especially related to image processing, has accelerated the use of AI systems in diagnostics (9,10). As evidence of the benefits provided by AI systems, the advantages they offer, particularly in the healthcare sector, are highlighted (11-13). Beyond patient care, the incredible increase in the amount of digital data in healthcare and technological advancements, as well as significant investments by technology companies and governments in the application of AI, serves enormous potential to improving healthcare systems (14). Therefore, the spread of AI technologies in healthcare is expected to be much faster.

In this context, AI technologies particularly enhance efficiency and reduce costs in tasks related to clinical documentation, such as processing and recording requests by allied health personnel, or in support services like prescription renewal or appointment scheduling (14-16). On the other hand, it is also possible to identify and monitor patients in need of advanced healthcare services using big patient data (17). Thus, proper utilization of big data via AI may even have a significant impact on single individual level.

Concerns regarding AI technologies mainly revolve around how the transformations in the labor market will impact employment and how negatively they will affect professions (18-21). In other words, how AI systems will affect current employment, especially in the fields of health and medicine, is a major point of curiosity. In this context, it is expected that AI systems will transform existing skills and create new professions in the fields of medicine and healthcare (14,22). Similarly, the World Health Organization (23) also predicts that AI technologies will significantly change the workflows and jobs of health professionals such as doctors and nurses. Despite ongoing debates on this issue, findings regarding how AI technologies will affect employment often contradict each other (20). However, the most agreed-upon point is that the expected skill level will significantly increase with the use of AI technologies (24). Moreover, it is observed that even companies that do not directly use AI technologies now prefer individuals with AI skills in their employment (25).

AI systems are transforming processes in medicine and healthcare, taking over most tasks through automation (26). This shift has sparked discussions regarding the employment of healthcare workers. While AI can automate many routine tasks in healthcare, there are three main reasons it cannot replace doctors (27): First, there is still a need for doctors to give specific task instructions to AI systems and to evaluate their outputs. Second, the support provided by AI systems is extremely specific and limited according to the complexity of doctors' responsibilities. Third, while public data sets often contain biases, making the clinical applicability of algorithms trained on these data extremely limited, there is also a significant lack of accessible data formats needed by AI systems that require training data sets. Consequently, the alternative path that will be explained in the next section will not adversely affect employment and will increase efficiency in the field where it is used involves using AI to complement humans (28). We believe that the AI will not replace physicians but AI literacy will be a cardinal feature in medicine especially for healthcare workers in executive and administrative positions (27,29).

The discussion on how AI technologies will transform workflows in the healthcare sector, from education to diagnosis and treatment processes, and which skills will come to the forefront in this transformation is a hot topic. In this context, international initiatives to address the risks of artificial intelligence mentioned above have begun to increase, and steps towards multinational regulation, beyond national regulations, are also on the rise. For example, the European Union recently published the EU AI Act, which provides a framework for regulating artificial intelligence within the EU (30).

Therefore, this study explores how AI technologies can be used in a way that complements humans in the healthcare field. For this purpose, it is primarily recommended to increase AI literacy among all healthcare workers. Additionally, a two-stage solution is presented to complement human efforts. The first stage requires the active participation of healthcare professionals in the development process of AI technologies in the healthcare field, while the second stage necessitates these professionals to guide and filter the results produced during the implementation phase of AI technologies.

TWO PATHS FOR THE DEPLOYMENT OF AI: AUTOMATION AND COMPLEMENTARY PATHS

It is known that major technological transformations significantly reshape the skill sets of professions, forcing a restructuring of the labor market (31). In this process, while some professions disappear, the losses in the employment market are balanced by the new professions emerging from technological transformation. A similar expectation applies to AI technologies (18). However, recent studies indicate that this expectation may not be entirely accurate, suggesting that the number of new job positions created may not compensate for the ones eliminated (4-6,32,33). Therefore, there are warnings that if the automation trend enhanced by AI technologies is not addressed, significant waves of unemployment could occur. In this context, creating a sector that prioritizes employment for AI technologies is proposed as an alternative path that could increase efficiency by using AI technologies in a way that complements humans.

AI technologies are creating new opportunities in workplaces that support the alternative path. For instance, a study using GitHub Copilot at a workplace has shown that a test group with access to Copilot, a productive AI-powered programming assistant, completed programming tasks about 56% faster than the control group without access (34). Another study, using data from 5,179 customer support representatives, examined the effects of a productive AI-powered chat assistant on employee performance (35). It found that the AI-supported chat assistant increased productivity, measured by the number of problems solved per hour, by an average of 14%. However, the increase in productivity showed significant variations according to the skill levels of the employees. The study revealed that the AI-powered

chat assistant improved performance by 34% for newcomers and low-skilled workers, while it had a minimal impact on experienced and high-skilled workers.

Another study examining the impact of ChatGPT on writing tasks demonstrated that ChatGPT significantly improved the performance of the least skilled writers, leading to notable enhancements in writing speed and quality (36). In other words, the productivity gains caused by AI in workplaces predominantly benefit mid-skilled or novice low-skilled workers, significantly enhancing their productivity, with this contribution diminishing as the skill level increases. Similar findings from other studies show that the complementary contribution of AI technologies is realized by compressing the skill range among workers (37-40). Therefore, these findings suggest that the alternative path of using AI to complement humans could provide an opportunity to increase the overall productivity of the workplace by enhancing the efficiency of mid and low-skilled workers rather than displacing them from employment.

In fact, the alternative path for AI technologies is not entirely new. Particularly in Germany, during the period when the first wave of automation led to significant shifts in labor market dynamics, the initial steps of the alternative path were taken using two different approaches: inclusive education and the application of innovations in workplaces in a way that supports mid-skilled or unskilled workers (41). Thus, on one hand, inclusive education ensures that all individuals receive education of the same quality, preventing the clustering of new jobs within the elite class. On the other hand, it prevents new investments in workplaces from favoring highly skilled workers, thereby helping to avoid job losses among mid-skilled or unskilled workers. Consequently, Germany's previous stance on handling the challenges posed by automation, now intensified by AI technologies, supports the significance of the alternative path for AI technologies in preventing profound disruptions in employment (42).

CURRENT SHORTCOMINGS OF AI

With the current status of AI, a system needs to be established in the healthcare field in which the generation and the use of AI-produced data is regulated. To build up a framework for this reasoning, below, first we will discuss the shortcomings of AI and the risks it may pose. Secondly we will explain why human supervision is necessary in healthcare decisions. We will then propose a two stage model of a complementary path to utilize AI in healthcare.

One of the significant challenges encountered in the use of AI technologies is the production of biased results based on biases in training data sets or erroneous assumptions in algorithms (2,4,43). Health systems serve a heterogeneous population that varies according to different environments, socioeconomic status, gender, religion, and race. Therefore, the use of AI technologies in healthcare can only contribute to the improvement of healthcare services if it produces unbiased results. Consequently, biased data or assumptions used in algorithms compromise the impartiality of AI technologies in healthcare (2). For example, it has been observed that a machine learning algorithm trained at a university hospital using data from wealthy, young, white patients to create a clinical report produces biased results when used in hospitals serving minorities and patients with low socioeconomic status (44). Similarly, an algorithm developed to predict Acute Kidney Injury (AKI), which primarily comprised data from white, older male patients, when used to predict AKI in young and female patients exhibited gender-based biases (45,46). It has been identified that AI applications actively used in health systems disadvantage individuals with darker skin tones in determining SpO2, and in dermatological imaging systems (17,47). The cause of this bias lies not only in the underrepresentation of different skin colors in the training data set but also in the low sensitivity of the scales used to determine skin tone (48,49). In particular, The Monk Skin Tone Scale (MST) (50) is recommended in AI algorithms rather than the Fitzpatrick scale which is the widely accepted in clinical settings, to provide more sensitive results and helps combat algorithmic injustice (48). We would like to emphasize that this intervention (using appropriate measurement protocol) is a significant strategy and an essential step in machine learning, addressing biases linked to the data set. Moreover, the MST scale was originally developed for social sciences. Thus AI-based systems may encourage an interdisciplinary approach to provide generalizable results (50). This approach not only enhances the fairness of AI applications but also underscores the need for cross-disciplinary contributions to improve AI's accuracy and ethical application in healthcare.

On the other hand, the assumptions made during the development of AI algorithms can inherently include biases, and this directly affects the outcomes they produce. In this context, a recent study highlighted the biases in an AI system used to identify patients needing advanced healthcare, which considered the amount of healthcare expenditures (17). The study demonstrated that the results were biased according to race and socioeconomic status. The criterion used by the algorithm assumes that everyone, regardless of their socioeconomic background, has equal access to the healthcare system. In reality, wealthy families, who have easier access to healthcare systems and thus higher healthcare expenditures, benefit more from advanced healthcare services as a result of the AI system's decision-making process, compared to individuals who may need similar or more advanced care but have already less access to healthcare services. This situation showcases a critical flaw in how AI systems evaluate and provide healthcare services, emphasizing the need for algorithms that ac-

curately reflect the diverse conditions and barriers different populations face in accessing healthcare. By addressing these biases, AI can truly enhance the equity and effectiveness of healthcare delivery.

Similarly, the lack of transparency in AI systems complicates the recognition of biases embedded in algorithmic assumptions. For instance, an algorithm which is used in hospitals to recommend treatments for cancer patients is known to make inappropriate treatment recommendations, such as the use of an anticancer drug which is associated with an increased risk of bleeding in a patient with severe bleeding. The 'black box' nature of these algorithms makes it impossible to explain why a medication unsuitable for the patient's history was prescribed, contradicting the principle of transparency in healthcare (51,52). Consequently, a flawed algorithm has the potential to commit medical errors and cause serious harm to patients.

One of the second-tier risks associated with the use of AI, particularly generative AI technologies like ChatGPT, in healthcare—from writing academic articles to preparing patient reports and treatment processes—is the phenomenon of hallucinations (53). Recently, it has been suggested that using the term "confabulation" rather than "hallucination" to describe this behavior would be more accurate (54). This term describes the issue where AI systems do not consistently produce accurate answers and can frequently generate incorrect or non-existent content. For example, it has been shown that some references created in research proposals or articles entirely prepared by ChatGPT neither appear in Google searches nor have an existing Digital Object Identifier (DOI) (55). Thus, while the responses produced by generative AI can seem reasonable, they may actually be nonsensical.

It is suggested that these hallucinations occur when AI systems either lose connection with the dataset they were trained on (source amnesia) or face difficulty and tension due to contradictory data in their training set, which drives this behavior (56). Even worse, once AI systems begin hallucinating, they can continue this behavior in a consistent manner in subsequent responses, potentially causing a snowball effect of hallucinations (57). In the healthcare setting, hallucinations can misdirect diagnosis and treatment processes, thus posing a high cost to human health.

On the other hand, AI systems' ability to generate meaningful outcomes from complex and large datasets can undesirably boost confidence in their results, making automation of healthcare processes appear attractive (58). However, this approach often fails to achieve the superior performance that could be realized by combining the unique strengths of humans and AI. Furthermore, studies have shown that AI has the potential to err in disease diagnosis, leading to a decline in the quality of healthcare services (58-60). For example, while AI can interpret acute neurological scans much faster than radiologists in diagnosing head trauma, its diagnostic accuracy remains lower (61). Similarly AI misled radiologists for interpreting chest radiography (62,63). Therefore, relying solely on the automation capabilities of AI technologies carries significant risks.

As with all technological advancements, equitable use is a serious concern in AI. There is economical and geographical discrepancy for the development of technology and the data availability (9). A recent review of AI life science publications demonstrated that Northern America, Western Europe and Oceania countries produced the highest number of publications and also the highest number of high-quality and with clinical relevance (64). The lack of equitable and inclusive use of AI is not only a problem for the disadvantaged countries but also constitutes a major hurdle for generalizability of AI-generated data in HIC and HMIC with a heterogeous population structure. In the HIC and HMIC, the available health data may be biased for certain socioeconomic, racial or ethnic groups which results in flawed AI-generated predictions (65). The already evident disparities in healthcare may reflect itself onto AI -based diagnostic systems (66). However fair use of big data and AI may provide significant improvements in detecting and eliminating these disparities. In addition, there are numerous other opportunities that AI can provide to the healthcare systems of LICs. AI can support the use of telemedicine to reach out to rural disadvantaged populations, enhance healthcare supply systems and support management systems in the LIC (67). Thus, it is pivotal to include unbiased data preferably representing all strata of the target population to acheive the most accurate results from AI and capitalize its benefits on global health.

THE NECESSITY OF HUMAN INVOLVEMENT

The shortcomings of AI underscore the necessity for continuous monitoring of AI in autonomous systems that oversee patient health (68). Hence, the focus should not solely be on AI's capacity to fully automate medical processes but rather on the potential to enhance healthcare professionals' expertise concerning AI technologies (59). Emphasis should be placed on using AI to complement human capabilities, thereby improving the quality of healthcare services (9,69). In this manner, while AI technologies can analyze large datasets that humans may struggle to assess independently, the interpretation of these data should be performed in collaboration with healthcare personnel, leading to more accurate and reliable solutions.

Thus, a facilitator role for AI can be instituted. A study consulting experts on the use of AI in healthcare shows that all experts agree AI will take over time-consuming, repetitive routine activities not requiring completion by doctors, thus facilitating daily work in healthcare services and becoming

an indispensable part of clinical routine (27). In a study on how ChatGPT affects doctors' decision-making processes and biases in health systems, doctors were asked to assess chest pain in patients with different demographic features (gender, race), and then they used ChatGPT to question their own assessments (70). The study found that ChatGPT increased the accuracy of the doctors' decisions and reduced biases related to gender and race. Similarly, in studies examining ChatGPT's advice to doctors on cardiovascular diseases and hypertension, it was highlighted that ChatGPT could accelerate doctors' decision-making processes in diagnosing hypertension (71,72). However, viewing ChatGPT not as a replacement but as a complementary tool to decision-making processes enhanced accuracy (71).

The platforms developed with AI support and providing diagnostic assistance based on patients' complaints, enhances its diagnostic capability by allowing for online consultations with doctors. Consequently, to keep the platform up-to-date and ensure medical accuracy, doctors provide medical consultancy to this AI application (73). The interaction between robots and doctors in surgical areas is another example of how AI can enhance the complementary role of humans and ultimately provide healthcare services of higher quality (74).

A COMPLEMENTARY PATH FOR AI IN HEALTH CARE

The establishment of complementary path of AI use in healthcare systems consists of two stages as shown in Figure 1 (27, 75). The first stage is the development phase of AI systems, which involves the adoption of a society-in-loop approach. This approach not only includes AI experts but also involves doctors and health administrators, and all relevant healthcare stakeholders (2,76). Active participation at this stage allows for measures to be taken against biased outcomes and ensures ethical use of AI. Particularly, the participation of healthcare workers' unions is critical in this context.

As we mentioned above, awareness of biases stemming from the training data sets or algorithmic assumptions by doctors and cautious interpretation of the results will enhance the quality of healthcare services. Moreover, particularly in healthcare, adopting a participatory governance approach during the development phase of AI systems that allows involvement of healthcare stakeholders will likely reduce the likelihood of generating these biases. This engagement not only fosters transparency but also ensures that the algorithms are more aligned with the nuanced needs of diverse patient populations.

The second stage involves healthcare workers approaching the results produced by AI systems with caution, providing human input to correct any biases or deficiencies. This approach not only prevents AI systems from misleading doctors but also supports doctors in managing complex health data that they might not easily analyze on their own (77). Thus, AI systems enhance the capability of healthcare professionals to manage processes more effectively by providing them with insightful analyses of extensive health data.

Current studies suggest low diagnostic accuracy of chatbots, possibly due to 'hallucinations' and other factors that affect the algorithm output (78). Therefore, it is crucial for healthcare professionals to approach the results produced by AI technologies cautiously, enabling the detection and

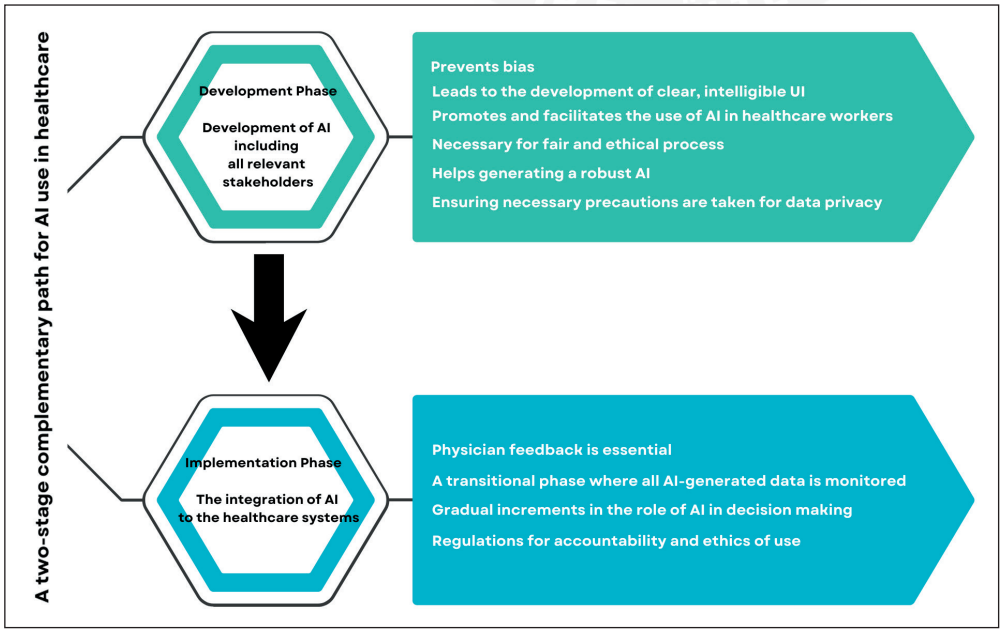


Figure 1. A two-stage complementary path for AI use in healthcare.

correction of errors. This vigilance is essential to minimize the adverse effects and safeguard patient outcomes.

CONCLUSION

Healthcare and medicine are among the primary fields impacted by AI technologies. AI holds significant potential for improving the quality of healthcare services. Indeed, the fact that the initial applications related to AI primarily started in the healthcare sector points to this potential. The digitalization of healthcare and the rapid accumulation of big data provide significant opportunities for the development of AI technologies. AI can help surpass human limitations in collecting, processing, and analyzing these vast datasets quickly and accurately, thereby substantially enhancing the quality of healthcare services (27, 79). Therefore, the focus of this study is not on the potential applications of AI technologies in healthcare, but on how they should be utilized to enhance the quality of healthcare services.

It is well known that every major technological transformation leads to significant changes in the skill sets required for various professions. With these transformations, a considerable number of existing jobs disappear while new professions that require new skills emerge. A similar situation applies to AI technologies. However, while technological transformations post 1970s have spread automation and had the potential to transform existing professions and create new ones, warnings are issued that AI technologies might not have the same potential (28). In other words, if the current path of automation continues, the AI ecosystem might eliminate the need for many professions without demonstrating the same performance in creating new ones. Consequently, significant fluctuations in employment are expected. On the other hand, the professions emerging from AI technologies are expected to require a high level of skill, necessitating advanced education that may include graduate studies. This indicates a shift towards more specialized and higher educational requirements for the workforce engaged with emerging AI-driven sectors.

The rapid development of AI technology in the medical field and its increasingly advanced capabilities in diagnosis and treatment have highlighted the necessity of integrating AI into medical education without delay (80). It is also known that medical school students are willing to take courses related to AI (81). When examining the curricula of different universities offering medical education (such as Stanford University and Harvard University), it is observed that courses on topics like “AI in healthcare, data science, fair AI, human-machine interaction, etc.” have been added to the curriculum to enhance AI literacy (82, 83). In this context, a study exists in the literature that serves as a guide for the integration of AI into medical education curricula, which defines the necessary competencies for medical students to understand the workings of AI, use it responsibly, and develop AI literacy (including clinical applications, ethical and legal frameworks, data analytics, statistics, etc.) (84).

This study proposes a two-stage complementary approach for the use of AI technologies in healthcare. The development phase of AI applications should ensure the fair participation of all healthcare stakeholders. This cooperative approach is crucial for integrating diverse perspectives and expertise, which enhances the robustness and applicability of AI systems in healthcare settings.

The second stage of integrating AI technologies in healthcare is the implementation phase, where a cautious approach to these systems is essential. Despite all precautions taken during the first stage, AI systems might still produce biased outcomes or exhibit hallucinatory behavior during application. Detecting these errors, which can negatively affect diagnosis and treatment processes, and making the necessary corrections is critical. Healthcare workers should act as a ‘filter behind the AI’ (27).

Finally, considering that generative AI systems particularly enhance the productivity of individuals with medium and low skills and shorten training periods for this group (35-37), the use of AI in all training within the healthcare sector could improve the quality of healthcare services by enhancing the quality of human capital in the field. Furthermore, it would also enable the training of a new generation of doctors and healthcare professionals with AI literacy.

AI systems are seen to significantly facilitate doctors’ work by taking over routine tasks and simplifying more complex jobs. In this context, the field of radiology offers significant potential for this collaboration (85). Thus, AI-human interaction can create greater collective intelligence in healthcare (86). This integrated approach ensures that AI supports healthcare professionals without replacing the critical human judgment necessary in medical practice.

The use of AI in healthcare, as outlined, necessitates an enhancement of AI literacy among doctors and other healthcare professionals. Given the rapid development in AI technologies, continuous updating of detailed training specific to AI usage in each healthcare domain is imperative. This requirement for continuous education can trigger significant transformations in decision-making processes within the medical field. At this stage, even if AI systems are not replacing doctors in healthcare, doctors proficient in AI will be preferred over those who lack such skills (27,29). Therefore, AI literacy in healthcare is no longer an option but a necessity.

A similar situation exists in discussions about the use of AI in scientific research and writing scientific papers (87). The opportunities presented by generative AI technologies, especially ChatGPT, have started to be actively utilized by scientists, and papers with ChatGPT as a co-author have even

been published. As in the field of healthcare, the ethical dimension of using AI technologies in this field, particularly regarding who will take responsibility for its contributions, is a topic of ongoing debate (88). While some journals, such as Science, take a firm stance that text, figures, images, or graphics generated by AI can never be used in articles (89), many journals have policies stating that AI cannot be a co-author, but its contributions can be significant and must be explicitly acknowledged in the article (90,91). This approach implies that, similar to the significant contributions of AI in diagnosis and treatment processes in the healthcare field, medical AI systems cannot replace doctors due to the lack of accountability.

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Author Contributions

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The authors have no conflicts of interest to declare.

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REFERENCES

1. Harari YN. Reboot for the AI revolution. Nature. 2017; 550:324-327. https://doi.org/10.1038/550324a
2. Ilikhan S, Ozer M, Tanberkan H, Bozkurt V. How to mitigate the risks of deployment of artificial intelligence in medicine? Turk J Med Sci. 2024;54:483-492. https://doi.org/10.55730/1300-0144.5814
3. Ozer M. Potential benefits and risks of artificial intelligence in education. BUEFD. 2024;13:232-244. https://doi.org/10.14686/buefad.1416087
4. Ozer M, Perc M, Suna HE. Artificial intelligence bias and the amplification of inequalities in the labor market. JECS. 2024; 69:159-168. https://doi.org/10.26650/JECS2023-1415085
5. Ozer M, Perc M, Suna HE. Participatory management can help AI ethics adhere to the social consensus (Internet). Istanbul University Journal of Sociology. 2024 Apr 04 (cited 2024 May 06). Available from: https://doi.org/10.26650/SJ.2024.44.1.0001
6. Perc M, Ozer M, Hojnik J. Social and juristic challenges of artificial intelligence. Palgrave Commun. 2019;5:61. https://doi.org/10.1057/s41599-019-0278-x
7. Erdoğan S. Integration of Artificial Intelligence and Genome Editing System for Determining the Treatment of Genetic Disorders. Balkan Med J.; 2024; 41(6):419-20.
8. Sarıkaya Solak S, Göktay F. The Promising Role of Artificial Intelligence in Nail Diseases. Balkan Med J.; 2024; 41(4):234-5.
9. Rajpurkar P, Chen E, Banerjee O, Topol EJ. AI in health and medicine. Nat Med. 2022;28:31-38. https://doi.org/10.1038/s41591-021-01614-0
10. Zhang J, Zhang Z. Ethics and governance of trustworthy medical artificial intelligence. BMC Med Inform Decis Mak. 2023;23:7. https://doi.org/10.1186/s12911-023-02103-9
11. Albert IL, Mercolli L, Pyka T, Prenosil G, Shi K, Afshar-Oromieh A. Large language models (LLM) and ChatGPT: what will be the impact on nuclear medicine be? Eur J Nucl Med Mol Imaging. 2023;50:1549-1552. https://doi.org/10.1007/s00259-023-06172-w
12. Ardila D, Kiraly AP, Bharadwaj S, Choi B, Reicher JJ, Peng L, Tse D, Etemadi M, Ye W, Corrado G, Naidich DP, Shetty S.. End to-end lung cancer screening with three-dimensional deep learning on low-dose chest computed tomography. Nat Med. 2019;25:954-961. https://doi.org/10.1038/s41591-019-0447-x
13. Huynh E, Hosny A, Guthier C, Bitterman DS, Petit SF, Haas-Kogan DA, Kann B, Aerts HJWL, Mak R.. Artificial intelligence in radiation oncology. Nat Rev Clin Oncol. 2020;17:771-781. https://doi.org/10.1038/s41571-020-0417-8
14. Tursunbayeva A, Renkema M. Artificial intelligence in healthcare: implications for the job design of healthcare professionals. Asia Pacific Journal of Human Resources. 2023;61:845-887. https://doi.org/10.1111/1744-7941.12325
15. Apornak A, Raissi S, Keramati A, Khalili-Damghani K. Human resources optimization in hospital emergency using the genetic algorithm approach. Int J Healthc Manag. 2020;14:1441-1448. https://doi.org/10.1080/20479700.2020.1763236
16. Davenport T, Kalakota R. The potential for artificial intelligence in healthcare. Future Healthc J. 2019;6:94-98. https://doi.org/10.7861/futurehosp.6-2-94
17. Obermeyer Z, Powers B, Vogeli C, Mullainathan S. Dissecting racial bias in an algorithm used to manage the health of populations. Science. 2019;366:447-453. https://doi.org/10.1126/science.aax2342
18. Acemoglu D, Restrepo P. Artificial intelligence, automation, and work. Cambridge: National Bureau of Economic Research NBER Working Paper; 2018: 24196. Available from: https://www.nber.org/system/files/working_papers/w24196/w24196.pdf.
19. Arntz M, Gregory T, Zierahn U. The risk of automation for jobs in OECD countries: A comparative analysis. OECD Social, Employment and Migration Working Papers 2016; 189. Available from: https://doi.org/10.1787/1815199X

20. Frank MR, Autor D, Bessen JE, Brynjolfsson E, Cebrian M, Deming DJ, Feldman M, Groh M, Lobo J, Moro E, Wang D, Youn H, Rahwan I. Toward understanding the impact of artificial intelligence on labor. PNAS. 2019;116(14):6531-6539. https://doi.org/10.1073/pnas.1900949116
21. Septiandri AA, Constantinidies M, Quercia D. The impact of AI innovations on US occupations. 2023. Nokia Bell Labs, UK. https://doi.org/10.48550/arXiv.2312.04714
22. He J, Baxter SL, Xu J, Xu J, Zhou X, Zhang K. The practical implementation of artificial intelligence technologies in medicine. Nat Med. 2019;25:30-36. https://doi.org/10.1038/s41591-018-0307-0
23. World Health Organization. Transforming and scaling up health professionals' education and training: World Health Organization. Guidelines 2013. World Health Organization, Geneva. Annex 1, Definition and list of health professionals. Available from: https://www.ncbi.nlm.nih.gov/books/NBK298950/
24. Pitukhina MA, Gurtov VA, Belykh AD. The review of Chinese artificial intelligence labor market: Both in figures and skills. J Sib Fed Univ Humanit Soc Sci. 2024;17(3):580-591.
25. Bian Z. Research on the impact of artificial intelligence on the labor market. Highlights in Business, Economics and Management. 2024;24:1036-1041. https://doi.org/10.54097/48ra4c10
26. Reddy S, Fox J, Purohit MP. Artificial intelligence-enabled healthcare delivery. J R Soc Med. 2019;112(1):22-28. https://doi.org/10.1177/0141076818815510
27. Mosch L, Fürstenau D, Brandt J, Wagnitz J, Klopfenstein SAI, Poncette AS, Balzer F. The medical profession transformed by artificial intelligence: Qualitative study. Digit Health. 2022;8:1-13. https://doi.org/10.1177/20552076221143903
28. Ozer M, Perc M. Human complementation must aid automation to mitigate unemployment effects due to AI Technologies in the labor market. Reflektif J Soc Sci. 2024;5:503-514. https://doi.org/10.47613/reflektif.2024.176
29. Mesko B, Hetenyi G, Gyorffy Z. Will artificial intelligence solve the human resource crisis in healthcare? BMC Health Serv Res. 2018;18(1):545. https://doi.org/10.1186/s12913-018-3359-4
30. EU AI Act. 2024; The EU Artificial Intelligence Act.
31. Acemoğlu D, Restrepo P. The race between machine and man: implications of technology for growth, factor shares and employment. NBER Working Paper 22252; 2017. Available from: https://www.nber.org/papers/w22252
32. Acemoğlu D, Autor D, Johnson S. Can we have pro-worker- AI? Choosing a path of machines in service of minds. CEPR Policy Insight, 2023;123:1-12.
33. Capraro V, Lentsch A, Acemoglu D, Akgun S, Akhmedova A, Bilancini E, Bonnefon JF, Branas-Garza P, Butera L, Douglas KM, Everett JAC, Gigerenzer G, Greenhow C, Hashimoto DA, Holt-Lunstad J, Jetten J, Johson S, Kunz WH, Longoni C, Lunn P, Natale S, Paluch S, Rahwan I, Selwyn N, Singh V, Suri S, Sutcliffe J, Tomlinson J, van der Linden S, Van Lange PAM, Wall F, Van Bavel JJV, Viale R. The impact of generative artificial intelligence on socioeconomic inequalities and policy making. PNAS Nexus. 2024;3:pgae191 https://doi.org/10.1093/pnasnexus/pgae191
34. Peng S, Kalliamvakou E, Cihon P, Demirer M. The impact of AI on developer productivity: Evidence from GitHub Copilot. arXiv: 2302.06590v1.2023. https://doi.org/10.48550/arXiv.2302.06590
35. Brynjolfsson E, Li D, Raymond LR. Generative AI at work. NBER Working Paper 31161; 2023. https://doi.org/10.3386/w31161. (https://www.nber.org/system/files/working_papers/w31161/w31161.pdf. Erişim trihi:01.01.2025)
36. Noy S, Zhang W. Experimental evidence on the productivity effects of generative artificial intelligence. Science. 2023;381(6654):187-192. https://doi.org/10.1126/science.adh2586
37. Alam MF, Lentsch A, Yu N, Barmack S, Acemoglu D, Hart J, Johnson S, Ahmed F. From Automation to Augmentation: Redefining Engineering Design and Manufacturing in the Age of NextGen-AI. An MIT Exploration of Generative AI (Internet). 2024 Mar 27; Available from: https://mit-genai.pubpub.org/pub/9s6690gd
38. Choi JH, Schwarcz D. AI assistance in legal analysis: An empirical study (Internet). 73 Journal of Legal Education. Forthcoming, 2024. Available from: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4539836
39. Dell'Acqua F, McFowland E, Mollick ER, Lifshitz-Assaf H, Kellogg K, Rajendran S, Krayer L, Candelon F, Lakhani KR. Navigating the jagged technological frontier: Field experimental evidence of the effects of AI on knowledge worker productivity and quality (Internet). Harv Bus Sch Technol Oper Mgt Unit Working Paper 24-013; 2023. Available from: https://ssrn.com/abstract=4573321
40. Korinek A. Generative AI for economic research: Use cases and implications for economists. Journal of Economic Literature. 2023;61:1281-1317.
41. Markovitz D. The Meritocracy Trap: How America's Foundational Myth Feeds Inequality, Dismantles the Middle Class, and Devours the Elite. New York: Penguin Press; 2019.
42. Ozer M. Dynamics of the meritocracy trap and artificial intelligence. International Journal of Manegement Economics and Business. 2024; 20(3):845-869.
43. Korkmaz S. Artificial Intelligence in Healthcare: A Revolutionary Ally or an Ethical Dilemma?. Balkan Med J.; 2024; 41(2):87-8.
44. Gianfrancesco MA, Tamang S, Yazdany J, Schmajuk G. Potential biases in machine learning algorithms using electronic health record data. JAMA Intern Med. 2018;178(11):1544-1547. https://doi.org/10.1001/jamainternmed.2018.3763
45. Nazer LH, Zatarah R, Waldrip S, Ke, JXC, Moukheiber M, Khanna AK, Hicklen RS, Moukheiber L, Moukheiber D, Ma H, Mathur P. Bias in artificial intelligence algorithms and recommendations for mitigation. PLOS Digit Health. 2023;2(6) https://doi.org/10.1371/journal.pdig.0000278
46. Tomašev E, Glorot X, Rae J W, Zielinski M, Askham H, Saraiva A, Mottram A, Meyer C, Ravuri S, Protsyuk I, Connell A, Hughes C O, Karthikesalingam A, Cornebise J, Montgomery H, Rees G, Laing C, Baker C R, Peterson K, Reeves R, Hassabis D, King D, Suleyman M, Back T, Nielson C, Ledsam J R, Mohamed S. A clinically applicable approach to continuous prediction of future acute kidney injury. Nature. 2019;572(7767):116-119. https://doi.org/10.1038/s41586-019-1390-1
47. Charpignon ML, Byers J, Cabral S, Celi LA, Fernandes C, Gallifant J, Lough ME, Mlombwa D, Moukgeiber L, Ong BA, Panitchote A, William W, Wong AI, Nazer L. Critical bias in critical care devices. Crit Care Clin. 2023;39(4):795-813. https://doi.org/10.1016/j.ccc.2023.02.005

48. Heldreth CM, Monk EP, Clark AT, Schumann C, Eyee X, Ricco S. Which skin tone measures are the most inclusive? An investigation of skin tone measures for artificial intelligence. ACM J Responsible Comput. 2024;1(1):1-21. https://doi.org/10.1145/3632120

49. Monares M, Tang Y, Raina R, de Sa VR. Analyzing Biases in AU Activation Estimation Toward Fairer Facial Expression Recognition. 2023.

50. Monk E. The Monk Skin Tone Scale (Internet). SocArXiv; 2023. Available from: osf.io/preprints/socarxiv/pdf4c.

51. Topol EJ. High-performance medicine: the convergence of human and artificial intelligence. Nat Med. 2019;25(1):44-56. https://doi.org/10.1038/s41591-018-0300-7

52. Ross C, Swetlitz I. IBM's Watson supercomputer recommended 'unsafe and incorrect' cancer treatments, internal documents show. In Stat News. 2018. Available from: https://www.statnews.com/2018/07/25/ibm-watson-recommended-unsafeincorrect-treatments/

53. Ji Z, Lee N, Frieske R, Yu T, Su D, Xu Y, Ishii E, Bang Y, Madotto A, Fung PN. Survey of hallucination in natural language generation. ACM Comput Surv. 2023;55(12):1-38. https://doi.org/10.1145/3571730

54. Ozer M. Is artificial intelligence seeing hallucination? Turkish Journal of Psychiatry. 2024; 35(4): 333-335. https://doi.org/10.5080/u27587

55. Athaluri S, Manthena S, Kesapragada V, Yarlagadda V, Dave T, Duddumpudi RTS. Exploring the Boundaries of Reality: Investigating the Phenomenon of Artificial Intelligence Hallucination in Scientific Writing Through ChatGPT References. Cureus. 2023;15(4):e37432. https://doi.org/10.7759/cureus.37432

56. Berberette E, Hutchins J, Sadovnik A. Redefining "Hallucination" in LLMs: Towards a psychology-informed framework for mitigating misinformation. arXiv:2402.01769. 2024. https://doi.org/10.48550/arXiv.2402.01769

57. Zhang M, Press O, Merrill W, Liu A, Smith NA. How language model hallucinations can snowball. arXiv:2305.13534 (Preprint).2023. https://doi.org/10.48550/arXiv.2305.13534

58. Hemmer P, Schemmer M, Kühl N, Vössing M, Satzger G. Complementarity in Human-AI collaboration: Concept, Sources, and Evidence. arXiv:2404.00029 (Preprint). 2024 https://doi.org/10.48550/arXiv.2404.00029

59. Lai Y, Kankanhalli A, Ong D. Human-AI collaboration in healthcare: A review and research agenda. Proceedings of the 54th Hawaii International Conference on System Sciences; 2021 Jan 5-8; Hawaii, USA.

60. Tschandl P, Rinner C, Apalla Z, Argenziano G, Codella N, Halpern A, Janda M, Lallas A, Longo C, Malvehy J, Paoli J, Puig S, Rosendahl C, Soyer H P, Zalaudek I, Kittler H. Human-computer collaboration for skin cancer recognition. Nat Med. 2020;26(8):1229-1234. https://doi.org/10.1038/s41591-020-0942-0

61. Titano JJ, Badgeley M, Schefflein J, Pain M, Su A, Cai M, Swinburne N, Zech J, Kim J, Bederson J, Mocco J, Drayer B, Lehar J, Cho S, Costa A, Oermann E K. Automated deep-neural-network surveillance of cranial images for acute neurologic events. Nat Med. 2018;24:1337-1341. https://doi.org/10.1038/s41591-018-0147-y

62. Bernstein MH, Atalay MK, Dibble EH, Maxwell AWP, Karam AR, Agarwal S, Ward RC, Healey TT, Baird GL. Can Incorrect Artificial Intelligence (AI) Results Impact Radiologists, and If so, What Can We Do about It? A Multi-Reader Pilot Study of Lung Cancer Detection with Chest Radiography. Eur Radiol. 2023; 33 (11): 8263-69. https://doi.org/10.1007/s00330-023-09747-1.

63. Prinster D, Mahmood A, Saria S, Jeudy J, Lin CT, Yi PH, Huang C. Care to Explain? AI Explanation Types Differentially Impact Chest Radiograph Diagnostic Performance and Physician Trust in AI. Radiol. 2024; 313 (2): e233261.

64. Schmallenbach Leo, Bärnighausen TW, Lerchenmueller MJ. The Global Geography of Artificial Intelligence in Life Science Research. Nature Communications. 2024; 15 (1): 7527.

65. Gurevich E, El Hassan B, El Morr C. Equity within AI Systems: What Can Health Leaders Expect? Healthc Manage Forum. 2023; 36 (2): 119-24. https://doi.org/10.1177/08404704221125368

66. Ibrahim SA, Pronovost PJ. Diagnostic Errors, Health Disparities, and Artificial Intelligence: A Combination for Health or Harm? JAMA Health Forum. 2021; 2 (9): e212430. https://doi.org/ 10.1001/jamahealthforum.2021.2430

67. Khan MS, Umer H, Faruqe F. Artificial Intelligence for Low Income Countries. Humanities and Social Sciences Communications. 2024; 11 (1): 1422. https://doi.org/10.1057/s41599-024-03947-w.

68. Tommarello ND, Deek RA. The Convergence of the Internet of Things and Artificial Intelligence in Medicine: Assessing the Benefits, Challenges, and Risks. Computer. 2024;57(2):95-99. https://doi.org/10.1109/MC.2023.3321188

69. Sourati J, Evans J. Complementary artificial intelligence designed to augment human discovery. arXiv:2207.00902 (Preprint). 2022. https://doi.org/10.48550/arXiv.2207.00902

70. Goh E, Bunning B, Khoong E, Gallo R, Milstein A, Centola D, Chen JH. ChatGPT influence on medical decision-making, Bias, and equity: a randomized study of clinicians evaluating clinical vignettes. medRxiv. 2023. https://doi.org/10.1101/2023.11.24.23298844

71. Miao J, Thongprayoon C, Fülöp T, Cheungpasitporn W. Enhancing clinical decision-making: Optimizing ChatGPT's performance in hypertension care. J Clin Hypertens. 2024;26(1):588-593. https://doi.org/10.1111/jch.14822

72. Hayıroğlu Mİ, Altay S. The Role of Artificial Intelligence in Coronary Artery Disease and Atrial Fibrillation. Balkan Med J.; 2023; 40(3):151-2. https://doi.org/10.4274/balkanmedj.galenos.2023.06042023

73. Luo N, Zhong X, Su L, Cheng Z, Ma W, Hao P. Artificial intelligence-assisted dermatology diagnosis: from unimodal to multimodal. Comput Biol Med. 2023;107413. https://doi.org/10.1016/j.compbiomed.2023.107413

74. Fosch-Villaronga E, Khanna P, Drukarch H, Custers BH. A human in the loop in surgery automation. Nat Mach Intell. 2021;3(5):368-369. https://doi.org/10.1038/s42256-021-00349-4

75. Krzywdzinski M, Gerst D, Butollo F. Promoting human-centred AI in the workplace. Trade unions and their strategies for regulating the use of AI in Germany. Transfer: European Review of Labour and Research 2023;29(1):53-70. https://doi.org/10.1177/10242589221142273

76. Rahwan I. Society-in-the-loop: programming the algorithmic social contract. Ethics Inf Technol. 2018;20(1):5-14. https://doi.org/10.1007/s10676-017-9430-8

77. Mello MM, Guha N. Understanding Liability Risk from Using Health Care Artificial Intelligence Tools. N Engl J Med. 2024; 390 (3): 271-78.

78. Barile J, Margolis A, Cason G et al. Diagnostic Accuracy of a Large Language Model in Pediatric Case Studies. JAMA Pediatr. 2024; 178 (3):313-315. https://doi.org/10.1001/jamapediatrics.2023.5750

79. Usta U, Taştekin E. Present and Future of Artificial Intelligence in Pathology. Balkan Med J.; 2024; 41(3):157-8.

80. van der Niet AG, Bleakley A. Wheremedical education meets artificial intelligence: 'Doestechnology care?'. Med Educ. 2020;55:30-36. https://doi.org/10.1111/medu.14131

81. Sun L,Yin C, Xu Q, Zhao W. Artificial intelligence for healthcare and medical education: a systematic review. Am J Transl Res. 2023;15(7):4820-4828

82. Stanford School of Medicine (Internet). (cited 2025 Jan 12). Available from: https://med.stanford.edu/education.html

83. Harvard Medical School (Internet). (cited 2025 Jan 12). Available from: https://courses.my.harvard.edu/dw_course/hvrd_crse_cat.pdf

84. Calışkan SA, Demir K, Karaca O (2022) Artificial intelligence in medical education curriculum: An e-Delphi study for competencies. PLoS ONE 17(7): e0271872. https://doi.org/10.1371/journal.pone.0271872

85. Chen Y, Stavropoulou C, Narasinkan R, Baker A, Scarbrough H. Professionals' responses to the introduction of AI innovations in radiology and their implications for future adoption: a qualitative study. BMC Health Serv Res. 2021;21(1):813. https://doi.org/10.1186/s12913-021-06861-y

86. Topol E. Preparing the healthcare workforce to deliver the digital future (Internet). NHS Health Education England; 2019 Feb. Available from: https://topol.hee.nhs.uk/wp-content/uploads/HEE-Topol-Review-2019.pdf. Accessed date:01.01.2025.

87. Ekmekçi PE. Reflections on the "Ethics Guideline for using Generative Artificial Intelligence in Scientific Research and Publication Process of Higher Education Institutions". Balkan Med J. 2024; 41:1-2. https://doi.org/10.4274/balkanmedj.galenos.2024.2024-6-72

88. Ozer M. Impact of ChatGPT on scientific writing. İnsan ve Toplum Dergisi. 2024;3(14):210-217. https://doi.org/10.12658/E0002

89. Thorp HH. ChatGPT is fun, but not an author. Science. 2023;379(6630):313. https://doi.org/10.1126/science.adg7879

90. Lund BD, Naheem KT. Can ChatGPT be an author? A study of artificial intelligence authorship policies in top academic journals. Learned Publishing. 2023;37(1):13-21. https://doi.org/10.1002/leap.1582

91. Tang A, Li KK, Kwok KO, Cao L, Luong S, Tam W. The importance of transparency: Declaring the use of generative artificial intelligence (AI) in academic writing. J Nurs Scholarsh. 2024;56(2):314-318. https://doi.org/10.1111/jnu.12938