Bangladesh Journal of Medicine (BJM)
ISSN : 1023 - 1986
eISSN : 2408 - 8366

REVIEW ARTICLE

ARTIFICIAL INTELLIGENCE IN MEDICINE: A NEW FRONTIER

MD. AZIZUL HAQUE[1], QUAZI TARIKUL ISLAM[2]

Abstract:

Artificial intelligence (AI) refers to the engineering and science of making intelligent machines through algorithms or rules, mimicking human cognitive functions, such as learning and problem-solving. AI has several branches, such as machine learning and deep learning, which can add intelligence to applications. Machine learning is the study of algorithms that allow computer programs to improve automatically through experience. Deep learning algorithms learn from an extensive, multi-layered collection of interconnected processes and expose these processors to many examples. In the coming years, the integration of AI in routine medical care is expected to revolutionize Medicine, potentially improving patient care and quality of life. The time required for a diagnosis can be greatly reduced, and diagnostic efficiency can be significantly enhanced when AI assists clinicians. Large language model chatbots are capable of clinical expert-level medical note-taking, consultation, and question-answering.Chatbotscan generate human-like text, may help diagnose diseases based on medical records, and may suggest treatment options or plans. Artificial intelligence algorithms, particularly deep learning, have demonstrated remarkable progress in radiological image analysis and diagnosis and may improve radiologists' efficiency. These algorithms may also improve diagnostic accuracy in dermatology, histopathology, fundoscopy, endoscopy, and other medical images. Natural language processing and ambient clinical intelligence automate administrative duties like recording patient visits in electronic health records, streamlining clinical workflow, and freeing up doctors to spend more time with patients. AI may also help with new drug discoveries, precision medicine, and clinical research. AI developments can revolutionize several healthcare-related fields and pave the way for a more individualized, accurate, predictive, and portable future.

Keywords: *Artificial intelligence, Medicine, machine learning, deep learning, convolutional neural network.*

Received: 18.04.2024 *Accepted: 22.04.2024*
DOI: https://doi.org/10.3329/bjm.v35i2.72811

Citation: *Haque MA, Islam QT. Artificial Intelligence in Medicine: A New Frontier. Bangladesh J Medicine 2024; 35: 54-60.*

Introduction:

Artificial intelligence (AI) is the intelligent behavior by computers with little to no human interaction. Alan Turing, considered to be the father of theoretical computer science and artificial intelligence, first described using computers to simulate intelligent behavior and critical thinking in 1950. Turing described a simple test, later known as the Turing test, to determine whether computers can achieve human-level performance in cognition-related tasks.[1]John McCarthy first used the phrase "artificial intelligence" (AI) in 1955, characterizing it as "the science and engineering of making intelligent machines."The discipline of artificial intelligence was officially established in 1956 during a conference held at Dartmouth College.[2]AI refers to the engineering and science of making intelligent machines through algorithms or rules, which mimics human cognitive functions, such as problem-solving and learning. [3]

With continued progress in electronicspeed, capacity, and software programming, computers continued to evolve. *Deep Blue* was the first chess computer to beat

1. Professor, Department of Medicine, Pabna Medical College, Bangladesh
2. Professor, Department of Medicine, Popular Medical College, Dhaka, Bangladesh
Address of Correspondence: Prof. Dr. Md. Azizul Haque, Professor, Department of Medicine, Pabna Medical College, Bangladesh. Email: drazadbd@gmail.com

Garry Kasparov, the reigning world champion, in a game under tournament conditions on February 10, 1996.It was a symbolic moment for AI because it demonstrated that AI can match or even surpass human intelligence. In the last few decades, the use of AI has been expanded in many scientific fields, especially healthcare. There are two branches of AI: virtual and physical. The virtual branch is represented by natural language processing, neural networks, and machine learning. In contrast, the physical branch is represented by intelligent medical devices and robots delivering care.

AI has several fields, such as machine learning and deep learning, that can add intelligence to many applications. Algorithms that allow computer programs to automatically get better through experience are called machine learning. Machine learning algorithms fall into three categories: (i) unsupervised (ability to identify patterns), (ii) supervised (classification and prediction algorithms based on prior examples), and (iii) reinforcement learning (use of reward and punishment sequences to form a strategy for operation in a particular problem space).[4]Deep learning (DL) algorithms use extensive, multi-layered collections of interconnected processes, and these processors are exposed to many examples.DL is the predominant method in AI today, driving improvements in speech and image recognition.[5]In the coming years, the integration of AI in routine medical care is expected to revolutionize Medicine, potentially improving patient care and quality of life.

AI in Medical Diagnosis:

The time required for a diagnosis can be greatly reduced, and diagnostic efficiency can be significantly improved when AI assists clinicians. Through the analysis of clinical data from radiology (such as X-ray, CT, and MRI), pathology, endoscopic, ultrasonographic, and biochemical examinations for relevant medical conditions, artificial intelligence (AI) can make a prompt and accurate conclusion, particularly for complex diagnoses.

Use of Large Language Model Chatbots in Medicine:

Chatbots such as GPT-4 (Generative Pre-trained Transformer 4) were released in March 2023, and they can perform several text-based tasks in Medicine. Early studies have shown that these models can facilitate clinical expert-level medical note-taking, consultation, and question answering. After listening to healthcare provider-patient interactions, automated medical note-taking by AI can significantly reduce the administrative burden.[6]ChatGPT and others can respond to case scenarios written as prompts and have impressive but mixed results.[7]

These models can generate human-like text, may assist in diagnosing diseases based on medical records, and even suggest treatment options or plans. Without any specialized training or reinforcement, ChatGPT performed at or near the passing threshold of 60% accuracy in the United States Medical Licensing Examination (USMLE) step 1, step 2 CK, and step 3 examinations. Furthermore, ChatGPT's explanations showed a high degree of insight and consistency. These findings imply that large language models can be helpful in clinical decision-making and medical education.[8]

Early studies of large language models for text-based tasks in Medicine have included chatbots such as GPT-4 (Generative Pre-trained Transformer 4) and have shown that these models are capable of clinical expert–level medical note-taking, question answering, and consultation. Chatbots can also be a source of healthcare information for patients and may help fight off medical myths and disinformation. A Bangla Chatbot developed by local biomedical engineers in collaboration with local physicians can have a massive impact on spreading authentic medical information to patients and caregivers.

Automation and Ambient Clinical Intelligence:

Artificial intelligence systems that use natural language processing (NLP) algorithms may be able to automate administrative duties like recording patient visits in electronic health records, streamlining clinical workflow, and freeing up doctors to spend more time with patients.[9]

AI's speech recognition software can recognize a patient's or doctor's spoken language, convert it to patient notes, and save them electronically, thereby reducing workload.[10]

AI in Radiology:

Artificial intelligence (AI) algorithms, particularly deep learning, have demonstrated remarkable progress in radiological image analysis and diagnosis. Radiologists can use AI to interpret images from various imaging methods, such as radiography, CT, MRI, and ultrasonography. Traditionally, radiologists visually assess medical images to diagnose, characterize, and monitor diseases. AI algorithms can automatically recognize complex patterns in imaging data and provide quantitative rather than qualitative assessments of radiographic characteristics.AI-based algorithms help the radiology workflow, including image acquisition, image reconstruction, visualization, analysis, diagnosis, and prognosis prediction. They also help non-radiologist doctors using medical-imaging AI.[11]

Researchers compared the performances of AI with those of human radiologists in interpreting various radiological images. The AI-Rad Companion Chest X-ray (AI-Rad, Siemens Healthineers) was tested against two human radiologists' written reports. The AI-Rad offered better sensitivity for the detection of lung lesions (0.83 versus 0.52), consolidations (0.88 versus 0.78), and atelectasis (0.54 versus 0.43) compared to humans.[12]The performance of a DL algorithm for identifying chest radiographs with clinically relevant abnormalities in the emergency department setting was evaluated by Hwang et al. For the AI algorithm, a sensitivity of 88.7% and a specificity of 69.6% at the high-sensitivity cutoff was noted. Radiology residents showed lower sensitivity (65.6%; $p<0.001$) and higher specificity (98.1%; $p<0.001$) compared with the algorithm. After the reinterpretation of chest radiographs with the use of the algorithm's outputs, the residents' sensitivity improved.[13]WHO has recommended computer-aided Detection for Tuberculosis (CAD4TB) as an alternative to human reporting of digital chest X-ray (CXR) for screening and triage for TB. It takes 10 seconds to evaluate lung abnormalities. A study in Bangladesh showed that the sensitivity of CAD4TB v6 was close to 100%, whereas the human radiologist's sensitivity was 88.2%.[14]Not only in CXR, artificial intelligence systems have approached neuroradiologist-level differential diagnosis accuracy at brain MRI. For accuracy of the top three differential diagnoses, the AI system (91% correct) performed similarly to academic neuroradiologists (86% correct; $p = 0.20$) and better than radiology residents (56%; $p <0.001$), general radiologists (57%; $p < 0.001$), and neuroradiology fellows (77%; $p = 0.003$).[15]

Integrating AI into radiology offers possible advantages and difficulties for radiologists and the AI community. The majority of radiology residents and radiologists anticipate significant changes in the radiology field during the next decade, and they think AI should play the function of a "co-pilot," serving as a second set of eyes and streamlining workflow duties. AI is also a valuable tool for non-radiologist clinicians in resource-poor settings where round-the-clock radiology services are unavailable.[16]

In addition to the radiologic diagnosis, AI algorithms can accurately predict clinical outcomes based on CT data in cancer and traumatic brain injury cases.[17,18]Effective clinician-AI collaboration is essential for successfully applying AI in radiology, utilizing the complementary skills of both.

AI for Interpretation of Medical Images:

AI algorithms are remarkably successful in the interpretation of medical images. Their use has been extended to various medical imaging applications, including the diagnosis of dermatologic conditions and the interpretation of electrocardiograms, pathological slides, and ophthalmic images.[16]Google Net Inception or similar algorithms can be trained with millions of dermatological images. Subsequently, the patterns of submitted digital images can be analyzed at a pixel level, and a diagnosis can be made.[19]

A systematic review was done by OT Jones et al. to evaluate the role of artificial intelligence and machine learning algorithms in facilitating the early diagnosis of dermatologic malignancies, focusing on their application in primary and community care settings. It showed reasonable mean diagnostic accuracy for melanoma (89·5%), squamous cell carcinoma (85·3%), and basal cell carcinoma (87·6%).[20]Application of deep-learning convolutional neural networks, one of the most powerful artificial intelligence techniques, to the interpretation of electrocardiograms (ECG), is feasible and valuable. Neural networks trained with large numbers of digital ECGs can diagnose common cardiac conditions and help detect some atypical conditions like silent atrial fibrillation, asymptomatic left ventricular dysfunction, and hypertrophic cardiomyopathy based on the ECG alone.AI algorithms to detect other cardiac conditions, such as amyloid heart disease, and aortic valve stenosis are in the active stages of development.[21]

Accurate histopathological diagnosis is a prerequisite for the management of many diseases. However, even for experienced pathologists, visual observation and subjective interpretation can result in intra- and inter-observer disagreement. AI-aided computational pathology can improve the diagnostic accuracy of pathology slides. One of the other advantages of computational pathology is that it allows the simultaneous inspection of histopathology images along with patient metadata, such as demographic, gene sequencing, or expression data, and progression and treatment outcomes. Whole slide imaging can detect features that are difficult to detect by the human eye alone.[22]

Internists in their daily clinical practice have to do fundoscopy to diagnose many systemic conditions affecting the eyes, like diabetic and hypertensive retinopathy, papilloedema, optic atrophy, Roth spots, choroid tubercle, retinitis pigmentosa, and many others. Machine learning algorithms can help immensely in diagnosing ophthalmic conditions from ophthalmic images. Conventional diagnostic methods relying solely on physicians' knowledge and professional experience can lead to a high rate of misdiagnosis and delayed ophthalmic referral, resulting in poor outcomes. Diabetic retinopathy is a potentially preventable cause of blindness, affecting millions of people worldwide. A deep convoluted neural network for automated detection of diabetic retinopathy was first used by Gulshan et al.[23]Keel and colleagues developed a deep learning-based diabetic retinopathy screening model for use in an endocrinology outpatient clinic, which resulted in 96% patient satisfaction.[24]

Lumineticscore (formerly IDX-DR) is the first medical device to be authorized by the US FDA to provide a screening decision for diabetic retinopathy without the oversight of a clinician, stratifying patients into those who require immediate ophthalmology review, and those that do not, who need 12 monthly screening[s. 25]

AI in Endoscopy:

AI-augmented endoscopy can significantly enhance the diagnosis of gastrointestinal diseases, including Barrett's esophagus (with or without dysplasia),early detection of carcinoma at different sites, small bowel angiodysplasia, colonic polyp, and assessment of mucosal healing in ulcerative colitis, by shorteningthe detection time and improving the diagnostic accuracy. The convoluted neural networks may also aid automated endoscopy reporting and triaging for endoscopy referral, thus reducing the administrative workload of a busy endoscopy unit.[26]

The current guidelines propose endoscopic surveillance in Barrett's esophagus (BE) patients with random four-quadrant biopsies obtained every 1-2 cm to detect dysplasia. This is because only experts can accurately perform the visual diagnosis of early dysplasia related to BE. Furthermore, 10% of upper gastrointestinal malignancies are overlooked during endoscopy. AI-aided diagnosis is expected to help endoscopists minimize these shortcomings of conventional endoscopy.[27]A convolutional neural network (CNN)pre-trained and fine-tuned on a dataset of thousands of endoscopic images, either positive or negative for H. pylori, may help in the diagnosis of Helicobacter pylori gastritis based on endoscopic images alone with higher accuracy compared to manual diagnosis by endoscopists.[28]

AI in Diabetes Care:

The global diabetes prevalence in 20–79-year-olds in 2021 was estimated to be 10.5% (536.6 million people), rising to 12.2% (783.2 million) in 2045.[29]AI-based technologies may lead to data-driven actions and improve outcomes for patients with diabetes. Machine learning (ML) is particularly suitable for clinical applications to diabetes, where it will increasingly be used to predict the risk of developing diabetes, optimize treatments for patients with diabetes, and diagnose diabetic complications in their early, treatable stages.ML algorithms have already been used to predict a person's risk of developing diabetes by analyzing lifestyle activities, physiologic sensor data, and genomic data.[30]Clinical decision support tools based on supervised machine learning have been created to predict short- and long-term HbA1c response following insulin introduction in patients with type 2 diabetes mellitus. With guidance from AI, patients with diabetes can now make everyday decisions about their food and exercise. Apps can allow patients to assess the quality and calorie value of their food intake.[31]

Deep learning (DL) is a subset of machine learning that relies on more complex algorithms called artificial neural networksto imitate how a human brain processes data and recognizes patterns. DL is more powerful than ML and has been adapted to diagnose long-term, resource-intensive complications of diabetes, such as diabetic retinopathy and diabetic macular edema.[32]The One Drop Mobile app can help patients with type 1 and type 2 diabetes schedule medication reminders, view statistics, set goals, track health outcomes, and get data-driven insights. The use of this app for tracking self-care was associated with improved HbA1c in patients with diabetes.[33]

AI in Precision Therapeutics:

AI will broaden the horizons of precision Medicine in the near future through developments in synthetic biology and AI-guided drug discovery. Synthetic biology has led to advancements in the last ten years, including personalized cancer medicines and CRISPR gene editing. Nevertheless, creating such sophisticated treatments is still incredibly costly and inefficient.

Future advances in data access (genomic, proteomic, glycomic, metabolomic, and bioinformatic) will enable AI to handle a much greater degree of systematic complexity, revolutionizing our understanding of, contributions to, and influence on biology. This will assist in better estimating which agents are more likely to be effective early on and also better anticipate undesirable drug effects, which will increase the efficiency of the drug discovery process.[9]

Use of AI in Conducting Clinical Research:

Through more effective participant matching and recruiting, as well as more thorough data analysis, artificial intelligence, and machine learning hold the potential to enhance, streamline, and expedite clinical trials. Furthermore, by comparing past data to target trial enrollment criteria, synthetic control groups might be able to be created. Additionally, AI and machine learning may improve understanding and prediction of potential adverse events and patient subpopulations.[34]

Remote Patient Monitoring Using Artificial Intelligence:

AI-augmented remote patient monitoring (RPM) is one of the common healthcare applications that assist doctors in monitoring patients with acute or chronic illnesses at remote locations, older adults in-home care, and even hospitalized patients.RPM is commonly used to measure vital signs or other physiological parameters that can assist with clinical judgments or treatment plans. RPM can be used to monitor blood sugar levels in diabetes, epilepsy, cardiac arrhythmias, mental health monitoring, monitoring of patients in ICU, etc.[35]

Priorities for Bangladesh:

The following developments and applications in the field of AI may have a significant impact on the improvement of healthcare delivery in Bangladesh: AI-enhanced electronic health records, AI speech-to-text software, Bangla chatbot, widespread availability and use of clinical-decision assistance, development of open-source AI software to minimize cost, and development of local AI platforms using Bangladeshi demographic data.

Areas of Concern:

One primary concern about using AI in Medicine is that it will "dehumanize" Medicine by reducing human touch, compassion, and patient empathy. This concern is countered by the argument that ambient clinical intelligence (ACI) and natural language processing (NLP) will reduce administrative burden and help clinicians focus more on the patient. A study by Sinsky et al. showed that physicians spent only 27% of their office day on direct clinical interaction with the patient but spent 49.2% of their office day on electronic health records and paperwork.[36]The use of AI technologies might make Medicine more "humanized."

Another concern is about patient confidentiality and data security; ongoing monitoring and privacy violations through medical devices and the Internet of Things can increase the stigma around chronically ill or more disadvantaged citizens. To prevent this, the issue of data protection and data ownership must be handled carefully; laws and regulations are likely to emerge that will also safeguard these issues.

AI replacing physicians is another concern raised by some healthcare workers, but it is an improbable event.AI is and will be complementary to physicians, and 4P model of Medicine (predictive, preventive, personalized, and participatory) is best delivered when AI acts in concert with the physicians.[37]American philosopher Hubert Dreyfus argued that human problem-solving and expertise depend on our intuition and background sense of the context. These unconscious skills can never be fully captured by AI.[38]

Another concern is that automation bias-the tendency to over-rely on automation and to ignore contradictory, non-automated information (even if it is correct), may weaken the clinical skills of a physician. To address this issue, we must emphasize that AI is not fault-proof, and doctors should critically evaluate the information provided by automated systems and trust their judgment when necessary.[39]

Medical mistakes by AI are also a possibility and must be carefully addressed. Close collaboration between physicians and biomedical engineers, use of local demographic data in the locally-developed AI tools, and extensive validation of AI tools before clinical application might help to reduce errors by AI.[40]

Conclusion:

AI developments have the potential to revolutionize several healthcare-related fields and pave the way for a more individualized, accurate, predictive, and portable future. For practical application of AI in Medicine, we need tech-savvy doctors with both clinical experience and digital expertise. Our medical curriculum may need to be updated to produce the "augmented" doctors who can adapt to the widespread use of AI in Medicine. Finally, we need to customize AI in our national context to meet the needs of our population.

References:

1. Turing, Alan. Computing Machinery and Intelligence. Mind, LIX October 1950; 236: 433-460, doi:10.1093/mind/LIX.236.433. https://doi.org/10.1093/mind/LIX.236.433
2. Hamet P, Trembley J. Artificial intelligence in Medicine, Metabolism 2017;69:36-40. https://doi.org/10.1016/j.metabol.2017.01.011. PMid:28126242
3. McCarthy J. What is artificial intelligence? John McCarthy, 1998
4. Ayodele TO. Types of machine learning algorithms. New advances in machine learning. 2010 Feb 1;3(19-48):5-1.
5. LeCun Y, Bengio Y, Hinton G. Deep learning. Nature 2015;521:436-44. https://doi.org/10.1038/nature14539. PMid:26017442
6. Lee P, Bubeck S, Petro J. Benefits, limits, and risks of GPT-4 as an AI chatbot for Medicine. N Engl J Med 2023;388:1233-1239. https://doi.org/10.1056/NEJMsr2214184. PMid:36988602

7. Thirunavukarasu AJ, Ting DSJ, Elangovan K, Gutierrez L, Tan TF, Ting DSW. Large language models in Medicine. Nat Med. 2023 Aug;29(8):1930-1940. doi: 10.1038/s41591-023-02448-8. PMid:37460753

8. Kung TH, Cheatham M, Medenilla A, Sillos C, De Leon L, et al. (2023) Performance of ChatGPT on USMLE: Potential for AI-assisted medical education using large language models. PLOS Digital Health 2(2): e0000198. https://doi.org/10.1371/journal.pdig.0000198. PMid:36812645 PMCid:PMC9931230

9. Bajwa J, Munir U, Nori A, Williams B. Artificial intelligence in healthcare: transforming the practice of Medicine. Future Healthc J. 2021 Jul;8(2):e188-e194. doi: 10.7861/fhj.2021-0095. https://doi.org/10.7861/fhj.2021-0095. PMid:34286183 PMCid:PMC8285156

10. Zhang J, Wu J, Qiu Y, Song A, Li W, Li X, Liu Y. Intelligent speech technologies for transcription, disease diagnosis, and medical equipment interactive control in smart hospitals: A review. Comput Biol Med. 2023 Feb;153:106517. doi: 10.1016/j.compbiomed.2022.106517. PMid:36623438 PMCid:PMC9814440

11. Hosny A, Parmar C, Quackenbush J, Schwartz LH, Aerts HJWL. Artificial intelligence in radiology. Nat Rev Cancer. 2018 Aug;18(8):500-510. doi: 10.1038/s41568-018-0016-5. PMid:29777175 PMCid:PMC6268174

12. Niehoff, J.H., Kalaitzidis, J., Kroeger, J.R. et al. Evaluation of the clinical performance of an AI-based application for the automated analysis of chest X-rays. Sci Rep 13, 3680 (2023). https://doi.org/10.1038/s41598-023-30521-2. PMid:36872333 PMCid:PMC9985819

13. Hwang EJ, Nam JG, Lim WH et al. Deep Learning for Chest Radiograph Diagnosis in the Emergency Department. Radiology October 2019; 293 (3): 1-8. DOI: https://doi.org/10.1148/radiol.2019191225. https://doi.org/10.1148/radiol.2019191225. PMid:31638490

14. Qin ZZ et al. Comparing different versions of computer-aided detection products when reading chest X-rays for tuberculosis. PLOS Digit Health. 2022 Jun 14;1(6):e0000067. PMid:36812562 PMCid:PMC9931298

15. Rauschecker AM, Rudie JD, Xie L et al. Artificial Intelligence System Approaching Neuroradiologist-level Differential Diagnosis Accuracy at Brain MRI. Radiology. 2020 Jun;295(3):626-637. doi: 10.1148/radiol.2020190283. https://doi.org/10.1148/radiol.2020190283. PMid:32255417 PMCid:PMC7263320

16. Rajpurkar P. Lungren MP. The Current and Future State of AI Interpretation of Medical Images. N Engl J Med 2023;388:1981-90.DOI: 10.1056/NEJMra2301725. https://doi.org/10.1056/NEJMra2301725. PMid:37224199

17. Jiang Y, Zhang Z, Yuan Q, et al. Predicting peritoneal recurrence and disease-free survival from CT images in gastric cancer with multitask deep learning: a retrospective study. Lancet Digit Health 2022;4(5):e340-e350. https://doi.org/10.1016/S2589-7500(22)00040-1. PMid:35461691

18. Pease M, Arefan D, Barber J, et al. Outcome prediction in patients with severe traumatic brain injury using deep learning from head CT scans. Radiology 2022;304:385-394. https://doi.org/10.1148/radiol.212181. PMid:35471108 PMCid:PMC9340242

19. Esteva A, Kuprel B, Novoa RA et al. Dermatologist-level classification of skin cancers with deep neural networks. Nature 2017; 542:115-118. https://doi.org/10.1038/nature21056. PMid:28117445 PMCid:PMC8382232

20. Jones OT, Matin RN, van der Schaar M et al. Artificial intelligence and machine learning algorithms for early detection of skin cancer in community and primary care settings: a systematic review. Lancet Digit Health. 2022 Jun;4(6):e466-e476. doi: 10.1016/S2589-7500(22)00023-1. PMid:35623799

21. Siontis KC, Noseworthy PA, Attia ZI, Friedman PA. Artificial intelligence-enhanced electrocardiography in cardiovascular disease management. Nat Rev Cardiol. 2021 Jul;18(7):465-478. https://doi.org/10.1038/s41569-020-00503-2. PMid:33526938 PMCid:PMC7848866

22. Kim I, Kang K, Song Y, Kim TJ. Application of Artificial Intelligence in Pathology: Trends and Challenges. Diagnostics (Basel). 2022 Nov 15;12(11):2794. doi: 10.3390/diagnostics12112794. PMid:36428854 PMCid:PMC9688959

23. Gulshan V, Peng L, Coram M, Stumpe MC, Wu D, Narayanaswamy A, et al. Development and validation of a deep learning algorithm for detection of diabetic retinopathy in retinal fundus photographs. JAMA. 2016;316(22):2402-10. https://doi.org/10.1001/jama.2016.17216. PMid:27898976

24. Keel S, Lee PY, Scheetz J, Li Z, Kotowicz MA, MacIsaac RJ, et al. Feasibility and patient acceptability of a novel artificial intelligence-based screening model for diabetic retinopathy at endocrinology outpatient services: a pilot study. Sci Rep. 2018;8(1):4330. https://doi.org/10.1038/s41598-018-22612-2. PMid:29531299 PMCid:PMC5847544

25. Anand E. Rajesh, Oliver Q et al. Artificial Intelligence and Diabetic Retinopathy: AI Framework, Prospective Studies, Head-to-head Validation, and Cost-effectiveness. Diabetes Care 1 October 2023; 46 (10): 1728-1739. https://doi.org/10.2337/dci23-0032. PMid:37729502

26. Gulati S, Emmanuel A, Patel M, et al. Artificial intelligence in luminal endoscopy. Ther Adv Gastrointest Endosc, 2020,13:2631774520935220. https://doi.org/10.1177/2631774520935220. PMid:32637935 PMCid:PMC7315657

27. Mori Y, Kudo SE, Mohmed HEN, Misawa M et al. Artificial intelligence and upper gastrointestinal

endoscopy: Current status and future perspective. Dig Endosc. 2019 Jul;31(4):378-388. doi: 10.1111/den.13317. https://doi.org/10.1111/den.13317. PMid: 30549317

28. Shichijo S, Nomura S, Aoyama K et al. Application of Convolutional Neural Networks in the Diagnosis of Helicobacter pylori Infection Based on Endoscopic Images. EBioMedicine. 2017 Nov;25:106-111. doi: 10.1016/j.ebiom.2017.10.014. PMid:29056541 PMCid:PMC5704071

29. Sun H et al. IDF Diabetes Atlas: Global, regional and country-level diabetes prevalence estimates for 2021 and projections for 2045. Diabetes Res. Clin. Pract. 183 (2022) 109119. https://doi.org/10.1016/j.diabres.2021.109119. PMid:34879977

30. Dagliati A, Marini S, Sacchi L, et al. Machine learning methods to predict diabetes complications. J Diabetes Sci Technol. 2018;12(2):295-302. doi: 10.1177/1932296817706375. PMid:28494618 PMCid:PMC5851210

31. Frøisland DH, Arsand E. Integrating visual dietary documentation in mobile-phone-based self-management application for adolescents with type 1 diabetes. J Diabetes Sci Technol 2015;9(3):541-8. https://doi.org/10.1177/1932296815576956. PMid:25901020 PMCid:PMC4604541

32. Ellahham S. Artificial intelligence: the future for diabetes care. Am J Med. 2020;133(8):895-900. doi: 10.1016/j.amjmed.2020.03.033. PMid:32325045

33. Osborn CY, van Ginkel JR, Rodbard D, et al. One drop | mobile: an evaluation of hemoglobin a1c improvement linked to app engagement. JMIR Diabetes 2017; 2(2):e21. https://doi.org/10.2196/diabetes.8039. PMid:30291059 PMCid:PMC6238886

34. Cruz Rivera S, Liu X, Chan A-W, Denniston AK, Calvert MJ; SPIRIT-AI and CONSORT-AI Working Group. Guidelines for clinical trial protocols for interventions involving artificial intelligence: the SPIRIT-AI extension. Lancet Digit Health 2020;2(10):e549-e560. https://doi.org/10.1136/bmj.m3210. PMid:32907797 PMCid:PMC7490785

35. Shakik T, Tao X, Higgins N et al. Remote patient monitoring using artificial intelligence: Current state, applications, and challenges. WIREs Data Mining Knowl Discov.2023;13:e1485. https://doi.org/10.1002/widm.1485

36. Sinsky C, Colligan L, Li L, Prgomet M, Reynolds S, Goeders L, et al. Allocation of physician time in ambulatory practice: A time and motion study in 4 specialties. Ann Intern Med. 2016;165:753-60. https://doi.org/10.7326/M16-0961. PMid:27595430

37. Verghese A et al. What this computer needs is a physician: humanism and artificial intelligence. JAMA. (2018) 319:19-20. https://doi.org/10.1001/jama.2017.19198. PMid:29261830

38. Dreyfus, Hubert; Dreyfus, Stuart (1986), Mind over Machine: The Power of Human Intuition and Expertise in the Era of the Computer, Oxford, U.K.: Blackwell.

39. Goddard K et al. Automation bias: a systematic review of frequency, effect mediators, and mitigators. J Am Med Inform Assoc. 2012 Jan-Feb;19(1):121-7. https://doi.org/10.1136/amiajnl-2011-000089. PMid:21685142 PMCid:PMC3240751

40. Khan B et al. Biomedical Materials & Devices. 2023; 1:731-738. https://doi.org/10.1007/s44174-023-00063-2. PMid:36785697 PMCid:PMC9908503.