Article Review

Artificial intelligence in medical practice: closing the gap for the present and creating opportunities for the future

[1]Adejumo AA, [2]Alegbejo-Olarinoye MI, [3]Akanbi OO, [1]Ajamu OJ, [1]Akims SM, [4]Koroye OF

[1]Department of Surgery, FMC Keffi, Nassarawa state, Nigeria
[2]Department of Surgery, University of Abuja Teaching Hospital, Gwagwalada, Abuja, Nigeria
[3]Department of Surgery, Ladoke Akintola University of Technology Ogbomoso, Oyo, Nigeria
[4]Department of Surgery, Niger Delta University, Olokobiri, Bayelsa State.

Corresponding author: Olusola O. Akanbi, *Department of Surgery, Ladoke Akintola University of Technology Ogbomoso, Oyo, Nigeria; drsolaakanbi@yahoo.com; +2348039540925*

Article history: Received 21 February 2023, Reviewed 21 June 2023, Accepted for publication 30 June 2023

How to cite this article:
Adejumo AA, Alegbejo-Olarinoye MI, Akanbi OO, Ajamu OJ, Akims SM, Koroye OF. Artificial intelligence in medical practice: closing the gap for the present and creating opportunities for the future. The Nigerian Health Journal 2023; 23(2): 580 - 586

Abstract

Background: Artificial intelligence (AI) is being incorporated into every aspect of human endeavour with benefits in diverse ways. Its application has brought a revolutionary dimension to healthcare delivery services across the globe. The aim of this study is to appraise the concept of artificial intelligence as it is applicable to contemporary medical practice and also looking into opportunities to come in its future application of AI.

Method: This is a narrative review article on AI, in which literatures were searched on AI using PubMed, Google Scholar, and MEDLINE. The search keywords were artificial intelligence concerning the basic theory, clinical and non-clinical applications, and future medical and global economic benefits. A critical review of the article was then undertaken.

Results: Eight-seven articles were screened of which, 46 articles were found to be relevant for the review. Artificial Intelligence has been found useful across various specialties of medicine through its precision, error-reduction ability and prediction of clinical outcomes. Despite this, AI-driven practice is still at a rudimentary stage and likewise the knowledge about AI in sub-Saharan Africa with a paucity of researches and publications on AI.

Conclusion: The use of AI in medical practice is increasing rapidly and has a great propensity to revolutionize patient care through better precision and reduction of medical errors. Despite this, AI in medical practice is still in the infancy stage in sub-Saharan Africa, we thus suggest the need to move from a position of a spectator to that of an active participant by embracing this innovation.

Keywords: Artificial intelligence, contemporary medical practice, benefits, the future

Introduction

In simple terms, artificial intelligence (AI) can be defined as the thinking behaviour by machines as opposed to that of the human innate thinking ability of natural intelligence.[1] Other terminologies being used to describe artificial intelligence include heuristic programming or machine intelligence. AI is designed to simulate cognitive behavior that is as close to that of the human brain in its ability to receive commands and perform various tasks.[1]

Print ISSN: 0189-9287 Online ISSN: 2992-345X

For more than 50 years since computer systems have been invented, efforts are being put in place to see how the computer can fit to undertake various simple to complex tasks in order to replace human efforts. As such, computer systems and programmes are being designed to vary in their capacities and dynamics and such are directed at a specific purpose.[1,2] These purpose-driven programmes (software)have been incorporated and in use to achieve efficiency and improve productivity in various aspects of our routine daily tasks such as navigation on land, sea and air, facial detection, recognitions for security checks for crime surveillance, voice recognition and commands, use of text editors and auto-correct functions on our phones and computers, electronic payment platforms, medical diagnoses, military operations, agricultural and pharmaceutical tasks etc.[2,3]

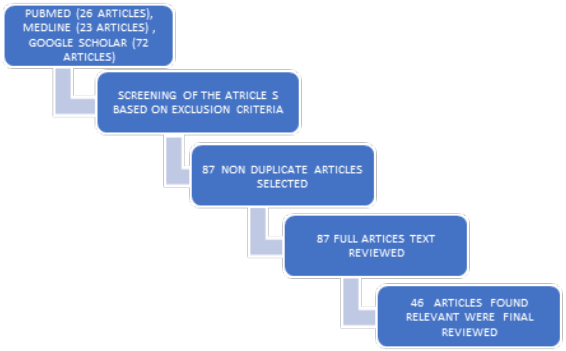
Over the decades, there have been tremendous improvements in computer systems to carry out various complex and complicated tasks as close to human ability with improved user experience, reduction in the margin of errors and increased speed. These attributes have been factored into the designing and upgrading of the computer system to function like the human brain hence, the concept of 'reproducing the man in the machine'. The basic objective of AI therefore is to enable computers perform such cognitive and intellectual tasks just like the human brain as well as undertake complex tasks and many more.[4,5]

The AI mechanisms has been undergoing several modifications to replicate or even perform more complex tasks in a safe and refined manner than humans hence; the technology of AI is focused on certain key and sensitive areas in which many researches have been conducted to understand the in-depth knowledge of how the complex cerebral neural network systems of the human brain function. Such refined areas include image and speech recognition, sensor technologies, cognitive decision support and robotics; all of which have direct links to contemporary medical practice and other spheres of life such as in the military, medical, agriculture, pharmaceutical and aviation industries.[6-8] On daily basis, complex tasks are being carried out on our mobile phones and computer systems using various applications that are AI-based.

AI in its applied form has been of tremendous benefit in carrying out many advanced information processing tasks aimed at producing "smart" systems which today have become invaluable in "expert" medical informatics and diagnosis.[5] Various algorithms for this technology have been developed to carry out programmed tasks with precision.[9] Various tasks can be programmed and re-programmed depending on the intent of the action. This could function in solving problems applicable to surgical scene analysis (context-aware system) or workflow analysis. The application of this could be appreciated in various aspects of the medical practice cutting across administrative, diagnostic and therapeutic fields with a significant reduction in possible human errors and also help in prognostication of some disease entities.[9-11]

Method

This is a narrative review article in which peer-reviewed published research articles focusing on artificial intelligence were reviewed from English literature. The following databases were used: Google Scholar, PubMed, and Medline. The key search term includes artificial intelligence, definition, application to healthcare delivery system, contemporary medical practice, the future trends. The articles were screened based on the title, abstract and full-text articles. One hundred and twenty-one non-duplicate citations were screened of which 34 were excluded after the title and abstract were screened. Eight seven articles were then retrieved for reading and after reading through, 46 articles were found to be relevant to the critical review process of this study. Review articles, editorials, letters to the editor, and commentaries were all excluded. A review on artificial intelligence in contemporary medical practice was carried out to highlight the benefits, clinical applications, the future expectation and also identify the gaps between our region and the developed climes.



PRISMA flow diagram for the article selection

Print ISSN: 0189-9287 Online ISSN: 2992-345X

Discussion

Clinical Benefits

The clinical application of AI has been found useful over the last two decades across various specialties of medicine. In radiology, it is now possible to view, identify and reconstruct human anatomical images in a 3-D or 4-D format. This has been in application in sonographic studies, magnetic resonance imaging (MRI), mammography studies, computed tomography scan (CT), and Positron emission tomography scans (PET scan). Interventional radiologists have also benefited from this gesture as well in carrying out some therapeutic procedures like angioembolization, endovascular stent insertion, vascular shunts, etc. Such anatomical reconstruction has helped in the definition of pathologies more accurately when assessing the extent of diseases (when compared to what was obtainable with conventional studies) and this has helped clinicians to improve the quality of care given.[12]

For the gastrointestinal physicians and surgeons, the narrow band imaging (NBI) function on endoluminal scopes has brought a paradigm shift to the field of endoscopy by characteristic features it displays when in doubt if an endoluminal lesion is suspected to be malignant (Image 1).[13-15] Also, the scope guide system with AI-dependent function gives a 3-D image on the monitor help the endoscopists to navigate the colonoscope safely during colonoscopy. AI-dependent systems in its various forms have been found useful in laparoscopic and other minimal access surgeries, including robotic surgeries (robotic-assisted minimally invasive surgeries- RAMIS) [Image 2]. Robotic surgeries with their attendant super smart systems and software, currently have been found to have surmounted some of the challenges associated with conventional minimally invasive procedures like poor depth perception, poor haptic feedback, improved accuracy and dexterity thereby opening up a new horizon in the concept of tele-robotic surgeries.[15,16]

Fluorescence-guided surgery, which is based on emission properties of certain chemical agents (indocyanine green, pafolacianine) when viewed with light below the infra-red ray spectrum is now becoming more popular and accepted in diverse surgical specialties. This is particularly useful in carrying out surgical procedures like sentinel lymph node surveillance, detection of metastatic spread of tumours, and outlining the hepatobiliary tract during laparoscopic procedures to minimize or prevent attendant injuries to vital structures such as the common bile duct or hepatic arteries (Image 3).In physical and rehabilitation medicine, there has been a lot of improvement of the use of robotic and hybrid joint control systems for upper and lower limb exoskeletons in patients that had suffered limb loss (Image 4). AI-dependent thermo-sensor devices have been found to be an invaluable non-contact tool in temperature measurement; such is relayed to an instant surveillance system for immediate attention and follow-up.[17,18] This has become invaluable recently in ensuring little or no contact in the wake of coronavirus disease and other contagious diseases.

In Cardiology, AI-based software and applications have been adopted on some smartphone devices and such had been approved and are being in used in the United States. Such software and applications could detect cardiac arrhythmias and fibrillations and such can be remotely shared with the attending Physicians.[19,20] Other related AI-dependent software have also been found useful in the early detection of cardiac diseases.[21,22] In like manner, AI-dependent applications have found its way into other sub-specialties of medical practice. For example, in neurology, it has helped in early detection and alertness of an impending seizure. In endocrine medicine, AI-based software has been found useful in close continuous monitoring of plasma glucose using a specialized Guardian system that is being evaluated to curb the occurrence of hypoglycaemic spells among diabetic patients).[23-26]

Clinical outcome-predicting tools that encompass both clinical, radiological and laboratory parameters of the patient have been designed for use and some of these applications are still at trial phases. Examples of such predictive technologies are being applied to surgery (in predicting the occurrence of surgical site infection), prediction of post-hepatic surgery organ failure, survival after pancreatic surgeries, and recurrence of incisional hernia after repair.[27-33] Hechi and his colleagues have also reported AI-dependent outcome predictors that has been employed in the management of trauma patients.[34] Context-aware system designed to enhance surgical scene workflow has been found useful in operative procedures to reduce the margin of error and also avert disastrous complications. This system actually guides the surgeon through the operative steps for that particular procedure highlighting any deviation from the normal anatomy. This system has been deployed in the operative procedure of laparoscopic cholecystectomy in the identification of delicate structures and achievement of the critical view of safety.[35-37]

Print ISSN: 0189-9287 Online ISSN: 2992-345X

The Expectations

With all these innovations currently at use in diverse medical specialties, it becomes germane therefore that the much-awaited future is already here with us. As medical practitioners, we need to get acquainted with these technologies and their mode of operation because many 21st century manufacturing companies are already aligning with the global trend of incorporating AI – dependent functions onto their equipment.

As for practitioners in Nigeria and by extension to the sub-Sahara region, AI-driven medical practice is still at a rudimentary stage and likewise the knowledge about this. This may be attributed on one hand to the fact that many of us did not encounter such technological revolution during our medical training and on the other hand, confounding socio-economic factors such as lack of stable electricity, and poor technological infrastructure that currently confront Nigeria and other Sub-Saharan countries are limiting factors. We need to take conscious efforts to catch up with this technological advancement in order to bridge the gap and align with the current global technology of the 21st century where virtually every aspect of our daily life including healthcare service delivery is tending towards dependence on smart systems.

A big concern however, is the safety of some classified information and patients' privacy protection in the event of cyberattack. This has led to global discussion and in 2019, the World Health Organization (WHO) established an expert group to put in place mechanisms to ensure patient and data safety, to be considered within ethico-legal framework in order to achieve safety to hospital-related information so as not to violate patients' fundamental human rights.[38]

The future

From various researches and information currently available, the future and application of AI in medical practice is a wide horizon endowed with hidden opportunities which is yet to be comprehensible to the human mind and which over time will deliver tons of unimaginable feats that the present scientific world is yet to unravel. The benefits of this hopefully will help to look into diverse areas of disease epidemiology, analysis of population-based medical mega-statistics that may help to look at the trend of disease entities, molecular and genetic typing of diseases as well as the possibility of propounding some specific and targeted treatment modalities for some ailments.[5] Virtual medical consultations and diagnostics (including virtual reality surgeries) are also coming up and hopefully, an improvement in this aspect of clinical practice will yield better outcomes in climes where human resources are limited wherein by this technology, patients can access the services of specialists from a remote location (telemanipulation).

With population explosion threatening the globe, it is becoming evident that human computerization on the industrial scale will soon become inevitable hence; every individual with statutory social security /national identification number could be tagged to all his credentials in hospitals, banks, and other areas of everyday socio-economic life.[39]

In the event of another global pandemic, robotic-assisted minimal invasive surgery (RAMIS) modality could be employed to undertake surgeries under precarious situations thereby negating the need for elective surgeries to be suspended as we experienced during the 2020 COVID-19 pandemic.[40] Other complex applications that are still undergoing research currently include AI-assisted robotic procedures using thermo-sensors. Smart Tissue Autonomous Robots (STAR) is another innovation that was designed at John Hopkins University to carry out complex surgical tasks without the input/assistance of the surgeon. This modality of smart systems is still at the experimental phase with prospects and potential applications in various surgical specialties in the nearest future.[41,42] Although still in the experimental phase, an autonomic robotic system has been designed with successful bowel anastomosis in the porcine specimen. Hopefully, we look forward to having this technology deployed in our climes in the nearest future.

The use of nanoparticles with LASER-enhanced technology in the treatment of malignant diseases is still at its elementary stage. This nanotechnology which has AI being incorporated into its use is currently undergoing trials in oncology. This system is being designed to have the maximal drug delivered at the tumour site while reducing the systemic toxicity that is usually associated with the conventional chemotherapy and radiotherapy treatment protocols[43-45] If successful and found to be safe with an attendant satisfactory cure rate, this technology might revolutionize cancer treatment. Another interesting and upcoming area of the application of AI in medicine is the concept of ambient clinical intelligence (ACI). This aspect is expected to create a digital adaptive and responsive environment for the clinician to extract and analyze relevant clinical information with respect to the patient and process such for eventual institution of treatment /intervention

Print ISSN: 0189-9287 Online ISSN: 2992-345X

accordingly.[46] These and many more are the horizons yet to be conquered in the medical parlance and we hope that with ongoing research, more feats will be achieved in the nearest future.

Recommendation

We suggest the need for the stakeholders, policymakers, and curriculum developers to consider the inclusion of AI as applicable to medical practice into the medical curriculum both at undergraduate and postgraduate levels to give medical practitioners the basic knowledge of these newer smart systems. Despite the benefits and sophistication of AI, it should be of note that AI is not devoid of limitations such as system malfunction, risk of cyberattack, lack of innate human qualities like empathy, and emotional care among others. Therefore, in whatever capacity AI is desired, we must not underestimate the role of sound clinical judgment and innate human quality in the appraisal and final decision-making as far as patient management is concerned as such quality cannot be replaced by machines. And with further reaches and innovations into AI such limitations are expected to be resolved in the nearest future.

Limitation of the review: Review articles were mainly from publications in English literature

Strength of the review: Most of the review article were less than five years.

Conclusion

The use of AI in medical practice is increasing rapidly and has a great propensity to revolutionize patient care through better precision and reduction of medical errors. Despite the benefits of AI, its use is also faulted by some factors such as malfunction, lack of data privacy, and bias among others. However, such flaws are expected to be resolved in the nearest future with further research and innovation in AI. Despite the current trend towards the use of AI in many developed nations, AI in medical practice is still at the infancy stage in sub-Saharan Africa, and thus there is a need to move from the position of the spectator to that of an active participant by embracing this innovation.

Qualities that are unique for humans such as compassion, empathy, and emotional care will decide the professional success of future physicians even more than today. Today we are using artificial intelligence in diagnosis and prediction to help clinicians. Clinical algorithms and human experience cannot be replaced by machines. It will take many years to completely merge or replace humans with machines. However, we need to modify our medical education system in order to prepare the medical community and sensitize society well in advance for a smooth transition.

Declarations

***Authors' contribution*:** Adejumo, Alegbejo-Olarinoye, Akanbi and Koroye conceived the idea of writing this paper. All authors were all involved at different stages of this manuscript (literature search, proof-reading and review of this manuscript).

Conflict of Interest: None

Source of funding: None

References

1. Madhusudana GS, Kolin P, Senthil K, Nirmal KG. Artificial Intelligence and Deep Learning: The Future of Medicine and Medical Practice. J Assoc Physicians India. 2019; 67(4):71-73.
2. Luxton DD. Ethical challenges of conversational agents in global public health. Bull World Health Organ. 2020; 98 (4): 285-287.
3. Esteva A, Robicquet A, Ramsundar B, Kuleshov V, DePristo M, Chou K, et al. A guide to deep learning in healthcare. Nat Med. 2019;25(1):24–9.
4. Topol EJ. High-performance medicine: the convergence of human and artificial intelligence. Nat Med. 2019;25(1):44-56. doi: 10.1038/s41591-018-0300-7.
5. Goodman K, Zandi D, Reis A, Vayena E. Balancing risks and benefits of artificial intelligence in the health sector. Bull World Health Organ. 2020; 98 (4): 230-230A. doi:10.2471/BLT.20.253823.
6. Eli-Chukwu NC. Applications of artificial intelligence in agriculture: A review. Eng. Technol. Appl. Sci. Res. 2019; 9(4): 4377-4383.
7. Hadlington L. Binder J, Gardner S, Karanika-Murray M, Knight S. The used of artificial intelligence in a military context: development of the attitudes towards AI in defense (AAID) scale. Front Psychol. 2023; 14: 1164810. doi:10.3389/fpsyg.2023.1164810.
8. Sahu A, Mishra J, Kushwaha N. Artificial intelligence (AI) in drugs and pharmaceuticals. Comb Chem High Throughput Screen. 2022; 25

Print ISSN: 0189-9287 Online ISSN: 2992-345X

(11): 1818-1837. doi: 10.2174/1386207325666211207153943.
9. Davenport T, Kalakota R. The potential for artificial intelligence in healthcare. Future Healthc J. 2019; 6(2):94-98. doi: 10.7861/futurehosp.6-2-94. PMID: 31363513; PMCID: PMC6616181.
10. Padoy N, Blum T, Ahmadi SA, Feussner H, Berger MO, Navab N. Statistical modeling and recognition of surgical workflow. Med Image Anal. 2012;16(3):632–41.
11. LeCun Y, Bengio Y, Hinton G. Deep learning. Nature. 2015;521(7553):436–44.
12. Choy G, Khalilzadeh O, Michalski M, et al. Current Applications and Future Impact of Machine Learning in Radiology. 2018; Radiology 171820. doi: 10.1148/radiol.2018171820.
13. Urban G, Tripathi P, Alkayali T, Mittal M, Jalali F, Karnes W et al. Deep Learning Localizes and Identifies Polyps in Real Time with 96% Accuracy in Screening Colonoscopy. Gastroenterology. 2018; 155(4): 1069-1078. doi: 10.1053/j.gastro.2018.06.037.
14. Misawa M, Kudo S, Mori Y, Cho T, Kataoka S, Yamauchi A et al. Artificial Intelligence-Assisted Polyp Detection for Colonoscopy: Initial Experience. Gastroenterology. 2018; 154: 2027–2029.
15. Mori Y, Kudo S, Berzin TM, Misawa M, Takeda K. Computer-aided diagnosis for colonoscopy. Endoscopy.2017; 49: 813–9.
16. AtashzarSF, Patel RV. Teleoperation for minimally invasive robotics-assisted surgery. Biomed. Eng. 2018; 4: 341–372. doi:10.1142/9789813232266_0012.
17. Zemmar, A, Lozano AM, Nelson BJ. The rise of robots in surgical environments during COVID-19. Nat. Machine Intelligence. 2020; 2(10): 566–572. doi:10.1038/s42256-020-00238-2.
18. Gopichandran V, Ganeshkumar P, Dash S, Ramasamy A. Ethical challenges of digital health technologies. Bull World Health organ. 2020; 98(4): 277-281.
19. Halcox JPJ, Wareham K, Cardew A, Gilmore M, Barry JP, Phillips C, et al. Assessment of remote heart rhythm sampling using the AliveCor heart monitor to screen for atrial fibrillation: the REHEARSE-AF study. Circulation. 2017; 136:1784–94. doi: 10.1161/CIRCULATIONAHA.117.030583.
20. Turakhia MP, Desai M, Hedlin H, Rajmane A, Talati N, Ferris T, et al. Rationale and design of a large-scale, app-based study to identify cardiac arrhythmias using a smartwatch: the apple heart study. Ame Heart J. 2019; 207:66–75. doi: 10.1016/j.ahj.2018.09.002
21. Huang Z, Chan TM, Dong W. MACE prediction of acute coronary syndrome via boosted resampling classification using electronic medical records. J Biomed Inform. 2017; 66:161–70. doi: 10.1016/j.jbi.2017. 01.001.
22. Mortazavi BJ, Downing NS, Bucholz EM, Dharmarajan K, Manhapra A, Li SX, et al. Analysis of machine learning techniques for heart failure readmissions. Circ Cardiovasc Qual Outcomes. 2016; 9:629–40.doi: 10.1161/CIRCOUTCOMES.116.003039.
23. Regalia G, Onorati F, Lai M, Caborni C, Picard RW. Multimodal wrist-worn devices for seizure detection and advancing research: focus on the Empatica wristbands. Epilep Res. 2019; 153:79–82. doi: 10.1016/j.eplepsyres.2019.02.007.
24. Bruno E, Simblett S, Lang A, Biondi A, Odoi C, Schulze-Bonhage A, et al. Wearable technology in epilepsy: the views of patients, caregivers, and healthcare professionals. EpilepBehav. 2018; 85:141–9. doi: 10.1016/j.yebeh.2018.05.044.
25. Lawton J, Blackburn M, Allen J, Campbell F, Elleri D, Leelarathna L, et al. Patients' and caregivers' experiences of using continuous glucose monitoring to support diabetes self-management: qualitative study. BMC Endocrine Disord. 2018; 18:12. doi: 10.1186/s12902-018-0239-1.
26. Christiansen MP, Garg SK, Brazg R, Bode BW, Bailey TS, Slover RH, et al. Accuracy of a fourth-generation subcutaneous continuous glucose sensor. Diabet Technol Therapeut. 2017; 19:446–56. doi: 10.1089/dia.2017.0087.
27. da Silva DA, ten Caten CS, dos Santos RP, FogliattoFS, Hsuan J. Predicting the occurrence of surgical site infections using text mining and machine learning. PLOS ONE 14(12): e0226272. https://doi.org/10.1371/journal.pone.0226272
28. Poplin R, Varadarajan AV, Blumer K, Liu Y, McConnell MV, Corrado GS, et al. Prediction of cardiovascular risk factors from retinal fundus photographs via deep learning. Nat Biomed Eng. 2018;2(3):158–64.
29. Esteva A, Kuprel B, Novoa RA, Ko J, Swetter SM, Blau HM, et al. Dermatologist-level classification of skin cancer with deep neural networks. Nature. 2017;542(7639):115–8
30. McKinney SM, Sieniek M, Godbole V, Godwin J, Antropova N, Ashrafian H, et al. International

Print ISSN: 0189-9287 Online ISSN: 2992-345X

evaluation of an AI system for breast cancer screening. Nature. 2020; 577(7788):89–94.

31. Maier-Hein L, Vedula SS, Speidel S, Navab N, Kikinis R, Park A, et al. Surgical data science for next-generation interventions. Nat Biomed Eng. 2017;1(9):691–6.
32. van Roessel S, Strijker M, Steyerberg EW, Groen JV, Mieog JS, Groot VP, et al. International validation and update of the Amsterdam model for prediction of survival after pancreatoduodenectomy for pancreatic cancer. Eur J Surg Oncol. 2019:105455.
33. Basta MN, Kozak GM, Broach RB, Messa CA, 4th, Rhemtulla I, DeMatteo RP, et al. Can We Predict Incisional Hernia? Development of a Surgery-specific Decision-Support Interface. Ann Surg. 2019; 270(3):544–53.
34. Hechi ME, Gebran A, Bouardi HT, Maurer LR, Moheb ME, Zhuo D et al. Validation of the artificial intelligence–based trauma outcomes predictor (TOP) in patients 65 years and older. SURGERY.2022;171(6): 1687–1694. doi: 10.1016/j.surg.2021.11.016
35. Lalys F, Jannin P. Surgical process modelling: a review. Int J CARS. 2014; 9(3):495–511.
36. Tokuyasu T, Iwashita Y, Matsunobu Y, Kamiyama T, Ishikake M, Sakaguchi S, et al. Development of an artificial intelligence system using deep learning to indicate anatomical landmarks during laparoscopic cholecystectomy. Surg Endosc. 2020 :1–8.
37. Twinanda AP, Shehata S, Mutter D, Marescaux J, de Mathelin M, Padoy N. Endonet: A deep architecture for recognition tasks on laparoscopic videos. IEEE Trans Med Imaging. 2017; 36(1):86–97.
38. Smith MJ, Axler R, Bean S, Rudzicz F, Shaw J. Four equity considerations for AI in public health. Bull World Health organ. 2020; 98(4): 290-292.
39. Paul AK, Schaefar M. The real safeguard for artificial intelligence and machine learning in global health systems. Bull World Health organ. 2020; 98(4): 282-284.
40. Bogue, R. Robots in a contagious world. Industrial Robot. 2020; 47 (5): 673–642. doi:10.1108/IR-05-2020-0101.
41. Panesar S, Cagle Y, Chander D, Jose Fernandez-Miranda, J, Kliot M. Artificial Intelligence and the Future of Surgical Robotics. Annals of Surgery.2019; 270 (2): 223-226. doi: 10.1097/SLA.0000000000003262.
42. Hademan A, Decker RS, Opfermann JD, Leonard S, Krieger A, Kim PC. Supervised autonomous robotic soft tissue surgery. Sci Transl Med. 2016;8(337):337ra64.
43. Yao Y, Zhou Y, Liu L, Xu Y, Chen Q, Wang Y et al. Nanoparticle-based drug delivery in cancer therapy and its role in overcoming drug resistance (Review article). Front. Mol. Biosci. 7:193. doi: 10.3389/fmob.2020.00193.
44. Acharya S, Sahoo SK. PLGA nanoparticles containing various anti-cancer agents and tumour delivery by EPR effect. Adv Drug Deliv. Rev.63:170-183. doi: 10.1016/j.addr.2010.10.008.
45. Yu Z, Gao L, Chen K, Zhang W, Zang Q, Li Q et al. Nanoparticles: a new approach to upgrade cancer diagnosis and treatment. Nanoscale Res Lett. 2021; 16:88.
46. Acampora G, Cook DJ, Rashidi P, Vasilakos AV. A survey on ambient intelligence in healthcare.Proc IEEE Inst Elect Electron Eng. 2013; 101: 2470-94. doi:10.1109/JPROC.2013.2262913.

Print ISSN: 0189-9287 Online ISSN: 2992-345X