Article published online: 2023-09-19

Artificial Intelligence: A Primer for the Radiologists

Harsimran Bhatia[1] Anmol Bhatia[1] Chirag K. Ahuja[1] Arnavjit Singh[2] Kushaljit S. Sodhi[1]

[1] Department of Radiodiagnosis and Imaging, Postgraduate Institute of Medical Education and Research, Chandigarh, India
[2] Department of Electronics and Computer Engineering, Thapar Institute of Engineering and Technology, Patiala, Punjab, India

Address for correspondence Kushaljit Singh Sodhi, MD, PhD, Department of Radiodiagnosis and Imaging, Postgraduate Institute of Medical Education and Research, Sector-12, Chandigarh, 160012, India (e-mail: sodhiks@gmail.com).

Indographics 2022;1:215–221.

Abstract

Artificial intelligence (AI) has revolutionized almost every sphere of life today by providing cutting-edge tools aimed at improving the quality of life. The term AI refers to any operating system or a software that mimics human intelligence and performs functions like the human mind with minimal human intervention. The present review article focuses on the basics of AI and the terminology used in the field of AI. Flowcharts and figures to facilitate easy understanding of its impact and its potential applications have also been provided. It is meant to serve as a primer for the beginner.

Keywords
- artificial intelligence
- learning
- machine
- deep

Introduction

Artificial intelligence (AI) has made giant strides in the last couple of decades and is expanding at exceptional pace currently. The term AI refers to any software or operating system that mimics human intelligence and performs functions like the human mind with minimal human intervention. Just like human minds, these systems have the capacity to learn and improve their functioning based upon various inputs and data acquired. Artificial neural networks, the AI techniques, are involved in complex data processing to produce data outputs that mimic human cognitive function.

The history of AI dates back to the year 1950 when Alan Turing developed the “Turing Test” where one could check a machine’s ability to exhibit intelligent behavior to achieve human level performance in cognition-related tasks.[1] The term “artificial intelligence” was first coined by American computer scientist John McCarthy at the Dartmouth Conference in the year 1956.[2] Since then, the field has made extensive progress over the decades, particularly in the health care sector.[3]

In its simplest form, the term AI refers to the functioning of computers using models that emulate or mimic human intelligence.[4] The term encompasses all the operations performed by the computer system using appropriate hardware and software to produce results in a way humans think. Human intelligence and decision making is unique in the sense of continuously adding knowledge gained from experiences and altering decisions, thereafter, thus constituting the learning process.[5,6]

AI also emphasizes on this concept of learning so that machines can work and make decisions on their own, exactly the way humans would do. Thus, machines can better represent and interpret complex data based on the knowledge gained while incorporating basic human functions like common sense, reasoning, and social behavior into the process.[7,8] It consists of a set of programs that make the software smarter to an extent of mimicking human cognitive functioning perfectly with the outside user assuming that the output was generated by a human.[6]

Classification

AI can be divided into two main types: Artificial narrow intelligence and artificial general intelligence.[6] The former is considered to be weak intelligence where a computer can perform a very specific task at par or better than humans. In this type, a trained algorithm can perform a very specific task

DOI https://doi.org/10.1055/s-0042-1759863.

Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

like read a chest X-ray for instance. Tasks for which training has not been provided cannot be computed using this form of AI.[6]

The second, general form is known as superintelligence or human level intelligence where the system possesses the ability to mimic human cognitive ability. It goes beyond specific tasks to perform higher order functions, emulating the human thought process.[9]

Common Terminology Used in AI

One must be familiar with the common terms used in AI.[10–13]

- *Algorithm* refers to step-by-step instructions that help a computer complete a calculation and form the starting point of the programming process.
- *Image feature* refers to a measurable characteristic or a specific property in each image of the data set.
- *Label* refers to the ground truth for every data point in the data set.

An important concept known as "*Machine Learning*" forms the basis of all AI-based systems. This term was coined by Arthur Samuel in the year 1959 and is defined as the process where computers learn automatically from the available data. Just like humans gain experience from the outside environment and improve their decision making, computers too, perform improvised tasks with increasing data accumulation.[10,11]

Machine learning has been divided into various subtypes (►**Fig. 1**), namely supervised learning and unsupervised learning or reinforcement learning.[12] In the first subtype, the developer teaches the machine that there are different variables, while the machine randomly defines variables without a developer in the second subtype. In reinforced learning, the machine is taught which variables are correct through a reward system. A notable example is the unsupervised protein-protein interactions that have successfully led to the development of novel therapeutic targets.[13]

AI-based systems primarily use two machine learning methods. The first or the traditional model is based upon predefined engineered features which have been established based on expert knowledge.[14] These are often used in quantifying radiographic data/parameters like tumor location, volume, intensity, and shape. The most relevant features are then used as data inputs into machine learning to be used as potential biomarkers in the future.[5] The second method is the deep learning method, which is of great interest today. This system is composed of algorithms that permit the software to perform tasks by itself. The machine can automatically learn to identify/interpret imaging features without prior definition by humans. This nondeterministic approach does not require explicit feature definition, thus making it more generalized and informative. Multiple interconnected algorithms, hidden layers, and neural networks are involved in generating output from this data.[15–17]

To simply differentiate the methods, the traditional method can well assess quantitative parameters of the lesions under consideration only after prior segmentation and placement of region of interest (ROI) have been done. Data-driven deep learning, on the other hand, functions like a human brain and can automatically identify diseased tissues and extract characters without prior segmentation by experts.[18,19] It weighs parameters based on their importance and then arrives at a conclusion improving the diagnosis and helping in better clinical decision making, akin to trained radiologists.

Convolutional neural networks are the most prevalent deep learning architecture used in medical imaging today.[20] The layered algorithms involved in deep learning form the artificial neural networks, which are utilized in generating

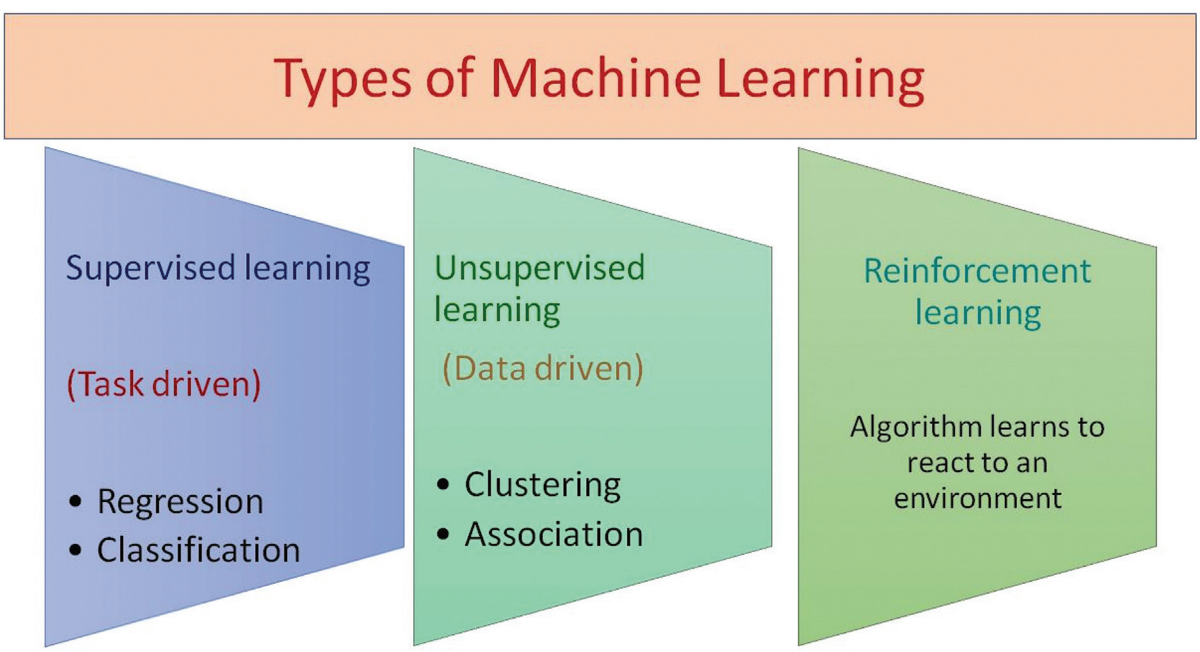

Fig. 1 Flowchart representing the various types of machine learning.

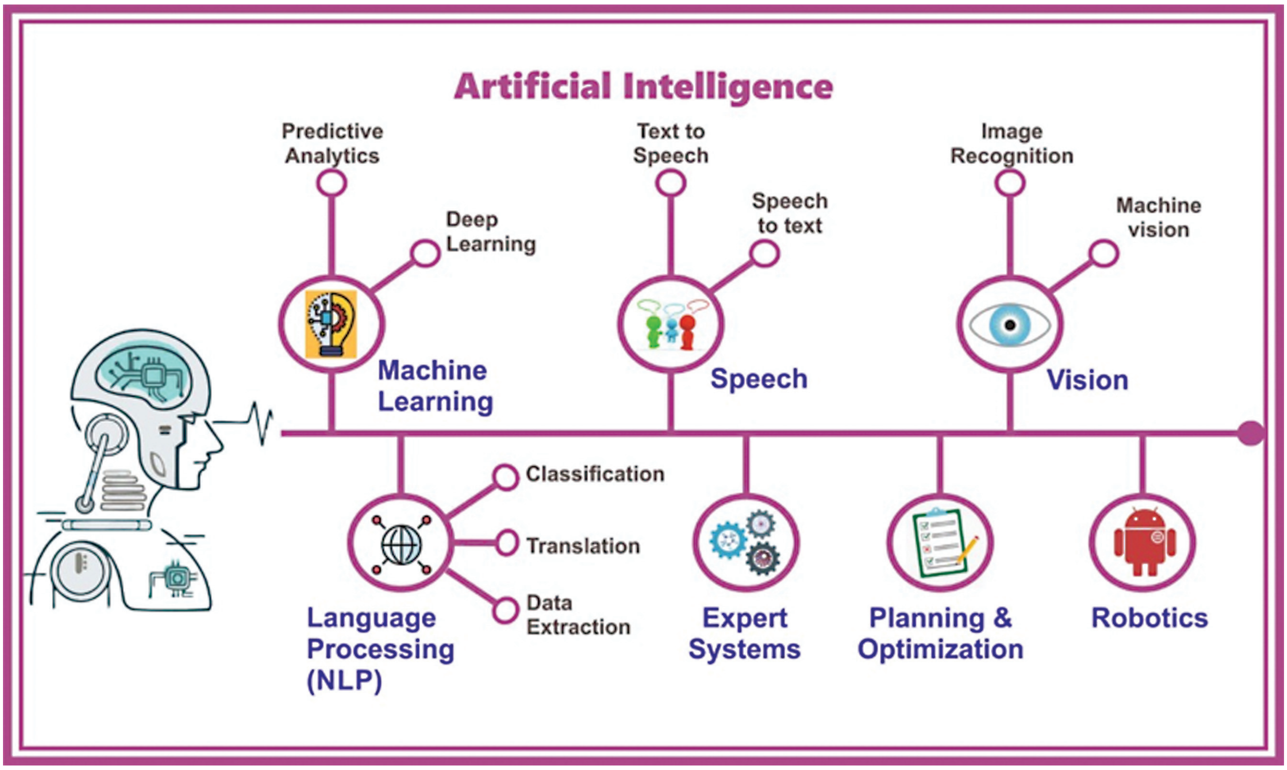

Fig. 2 Applications of artificial intelligence (AI) in medicine. Diagrammatic representation denoting the various applications of artificial intelligence in clinical practice.

an output.[10] These networks are made of thousands to millions of nodes or units, which are connected by links that propagate activation. The activated nodes connected by links work as feed forward networks or recurrent networks. Flow of information/connections is in one direction only in the former, while a loop is utilized in feeding the output back to the input in the latter. The answer/output must match the examination's label and is then considered correct.[6,10] These artificial neural networks must be trained so that the machine undergoes "learning" process.

Clinical Applications

AI-based systems have revolutionized medicine in the present decade, with rapid progress being made in the field of radiology in particular. While virtual AI utilizes these softwares for better identification and characterization of disease process, ensuring a higher standard of clinical care by helping the physician, physical AI refers to the use of robotics to assist surgeons ►**Fig. 2**.[4]

- Analysis of single-photon emission computerized tomography or stress echocardiographic images with AI-based softwares has provided valuable information in cardiology.[21]
- AI has successfully identified structure of various protein particles and newer antibiotics contributing significantly to clinical care.[22,23]
- The role of deep learning methods is rapidly evolving in neuroradiology, with specific emphasis on stroke imaging. Automated softwares have been developed to calculate the Alberta Stroke Program Early CT Score and have been reported to perform better than trained neuroradiologists.[24] Automated detection of intracranial large vessel occlusion (LVO) on computed tomography angiography using these AI-based algorithms has been reported to have a high sensitivity, specificity, and negative predictive value in detecting intracranial LVO.[25] Many of these (RAPID AI, Brainomix AI, etc.) have found their way into clinical stroke practice and are being used in high-volume as well as primary care centers where timely and accurate LVO detection helps in prompt patient management (►**Fig. 3**). Convolutional neural and recurrent network-based algorithms have helped in better classifying Alzheimer's disease and prediction of conversion of prodromal stage of Alzheimer's into full-fledged disease.[26] Deep learning methods have also contributed substantially in the grading of gliomas by accurately predicting the O(6)-methylguanine-DNA methyltransferase methylation, 1p 19 q codeletion, and isocitrate dehydrogenase 1 mutation status.[27]
- Imaging in splenic and renal trauma has also been optimized using automated softwares that detect contrast extravasation with a higher sensitivity.
- Deep learning algorithms have revolutionized the field of oncology. AI has helped in detecting breast, prostate, and melanomas with high sensitivity and specificity, surpassing human experts in some scenarios.[28] Oncologic imaging basically utilizes a three-step process, including detection, characterization, and monitoring.

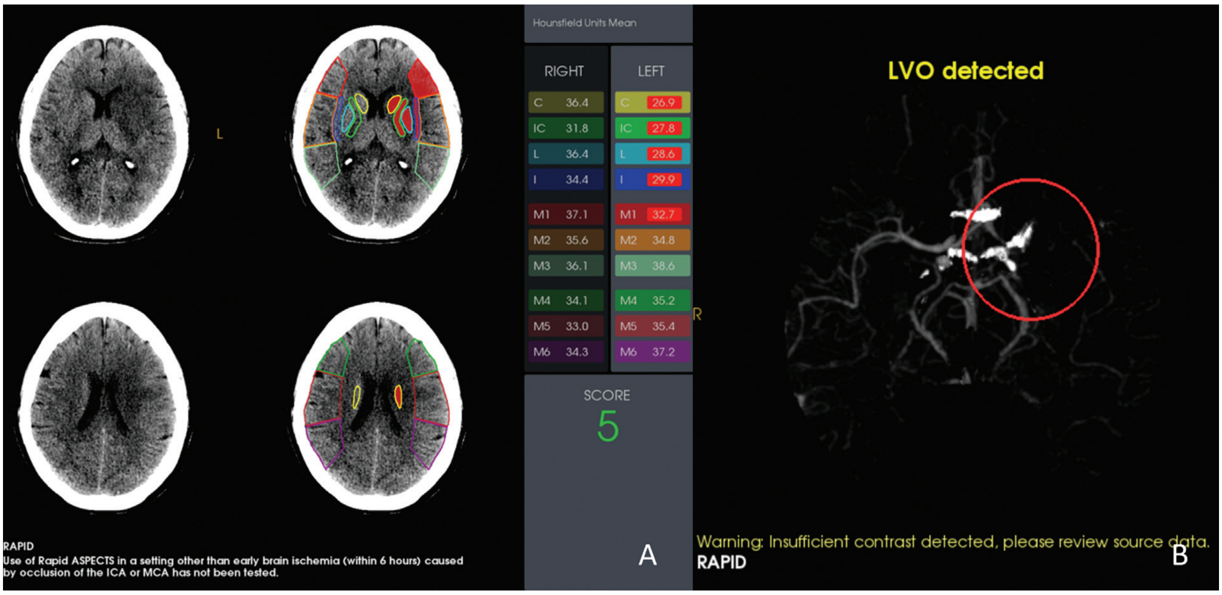

Fig. 3 Artificial intelligence (AI)-based algorithm automatically performs Alberta Stroke Program Early CT Score (ASPECTS) scoring (**A**) and detects the site of occlusion (**B**) in acute stroke.

Traditionally, the radiologists identify the abnormalities on imaging first followed by acceptance or rejection of findings based on cognitive skills. Machines are also being trained to detect abnormalities in a similar way.

Computer-Aided Detection

Computer-aided detection (CAD) has long been in practice in the last two decades aiding detection of breast, lung, and colon cancers.[29–31] While CAD is based on the detection of lesions based only on preset algorithms, True AI using deep learning algorithms is based on autonomous learning utilizing networks and connections. CAD algorithms are task-specific and cannot be generalized leading to subhuman performance. These has thus been superseded by deep learning-based CAD that are being increasingly used in the detection of pulmonary nodules and prostate cancer on multiparametric magnetic resonance.[32,33]

Characterization includes segmentation, diagnosis, and staging of disease. Multiple radiological features are easily quantified using AI. Disease classification into low or high risk using deep learning-based AI softwares is being used in multiple sclerosis and grading of gliomas.[34,35] Automated segmentation techniques are also being used to provide vital functional information in assessing disease extent and burden.[36–39]

TNM staging in oncology requires predefined criteria in assessing the stage based on information acquired through segmentation and diagnosis.[40] Deep learning helps in assessing the tumor size, lymph node status, and distant metastasis based on joint learning[41] (►**Fig. 4**). Deep learning methods are being extensively used in detection of primary tumor and assessing the lymph nodal status in patients of endometrial as well as cervical carcinomas.[42]

Monitoring is essential in determining treatment response and assigning the correct response category based on RECIST (Response Evaluation Criteria in Solid Tumors) and World Health Organization tumor response systems. Deep learning using recurrent networks helps in correctly assessing the temporal evolution of tumors, in particular, tumor size.[6,43] However, subtle change in characteristics like cavitation, change in heterogeneity, and texture within the tumor still require human intelligence and need to be worked upon.

Apart from the abovementioned role in radiology involving lesion detection and characterization, AI has an important role in other fields of radiology too (►**Fig. 5**), which include:

Radiomics: Involves the extraction of features from diagnostic images to measure specific parameters. Hundreds of features can be analyzed by AI systems from a given ROI, far beyond human eye/capability, which remarkably increase the accuracy of diagnosis of a particular pathology. Many of these features also help in better prognosticating the patient.[44,45]

Imaging biobanks: The enormous amounts of representative data extracted from images of thousands of patients can be easily stored, owing to the large memory of computers. Data from various institutions and hospitals can be clubbed together to create large biobanks. Information stored can thus be used for analysis and in predicting the risk of disease in large populations.[46,47]

Dose optimization: AI can help the radiologist in assessing the cumulative risk of radiation and tailoring the protocols accordingly to ensure lowest radiation dose as possible.[6]

Structured reporting: AI can ease the reporting workflow. "Common data elements" or CDEs define data dictionaries and aid in structured reporting and creating standard report annotations, leading to the development of patient-specific structured reports.[48,49]

Issues and Disadvantages

CAD of cancers has limited sensitivity and specificity. The medicolegal responsibility of such diagnosis is thus questionable. Large amount of data analysis is required to create trained algorithms, which is both time- and labor-intensive.[50]

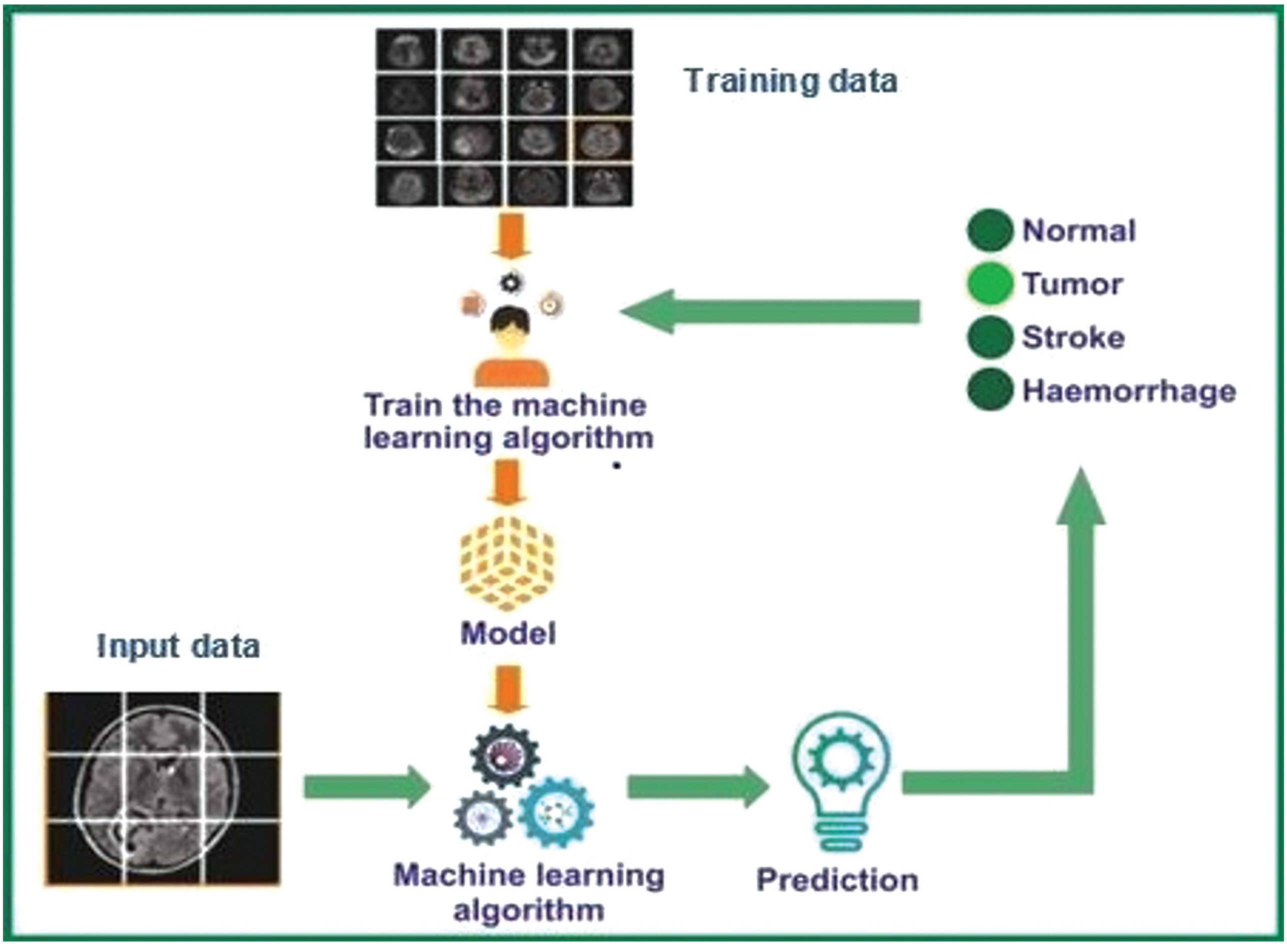

Fig. 4 Machine learning in radiology. Diagrammatic representation of the application of deep learning in radiology denoting "self-training" of the machine software with available data.

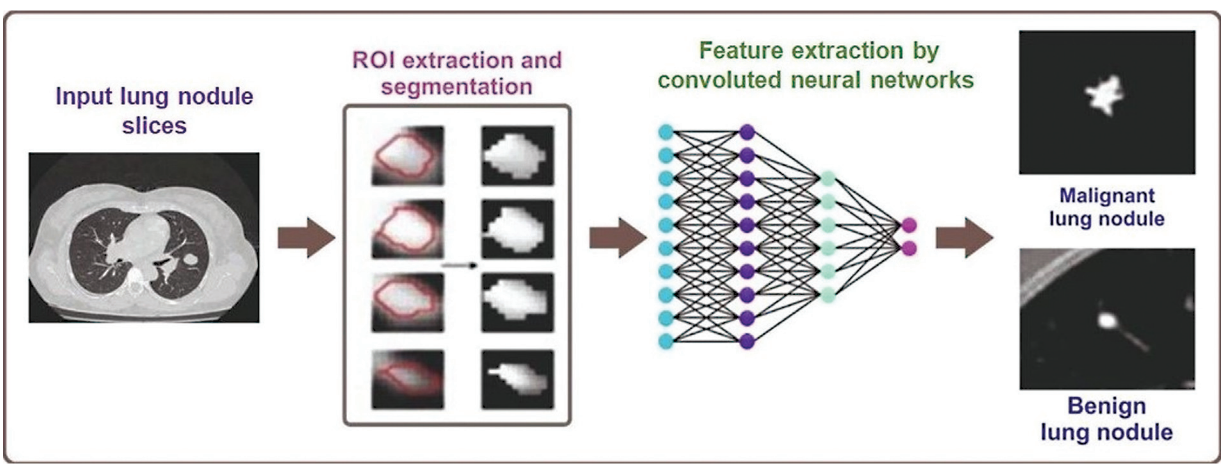

Fig. 5 Application of artificial Intelligence in imaging of pulmonary nodules. Diagrammatic illustration of the role of deep neural networks in distinguishing benign from malignant pulmonary nodules on imaging.

Future Perspectives

AI is still in its infancy and has a long way to go. It has created waves in medicine, particularly radiology, and has the potential to significantly transform the patient management algorithms. There is immense potential in the growth of this field as better research methodologies are coming up with passage of time. Radiologists' functioning is expected to become still smoother with the increasing number of AI tools being made available, which are reducing human effort and making workflow easier. AI is sure to create a massive positive impact on radiology. However, it must be reiterated that radiologists need to keep pace with the technology so that they can use it for optimum patient care and still remain in the thick of things in medical practice.[51,52]

Funding
None.

Conflict of Interest
None declared.

Acknowledgement
None.

References

1 Mintz Y, Brodie R. Introduction to artificial intelligence in medicine. Minim Invasive Ther Allied Technol 2019;28(02):73–81
2 McCarthy J, Minsky ML, Rochester N, Shannon CE. Proposal for the Dartmouth summer research project on artificial intelligence. Tech rep, Dartmouth College; 1955. Accessed October 13, 2018, at: http://www-formal.stanford.edu/jmc/history/dartmouth/dartmouth.html
3 cbinsights.com [Internet]. Healthcare remains the hottest AI category for deals; 2017. Accessed April 12, 2016, at: https://www.cbinsights.com/research/artificial-intelligence-healthcare-startups-investors/
4 Hamet P, Tremblay J. Artificial intelligence in medicine. Metabolism 2017;69S:S36–S40
5 Hosny A, Parmar C, Quackenbush J, Schwartz LH, Aerts HJWL. Artificial intelligence in radiology. Nat Rev Cancer 2018;18(08):500–510
6 European Society of Radiology (ESR) What the radiologist should know about artificial intelligence - an ESR white paper. Insights Imaging 2019;10(01):44
7 ubs.com[Internet]. Accessed September 29, 2016, at: https://www.ubs.com/microsites/artificial-intelligence/en/new-dawn.html;c2016
8 McCarthy J, Minsky ML, Rochester N, Shannon CE. Proposal for the Dartmouth summer research project on artificial intelligence. AI Mag 2006;27:4
9 Brink JA, Arenson RL, Grist TM, Lewin JS, Enzmann D. Bits and bytes: the future of radiology lies in informatics and information technology. Eur Radiol 2017;27(09):3647–3651
10 Russel S Norvig P Artificial Intelligence. A Modern Approach. New Jersey: Pearson Education, Inc.; 2010
11 Samuel AL. Some studies in machine learning using the game of checkers. IBM J 1959;3:211–229
12 Langlais ÉL, Thériault-Lauzier P, Marquis-Gravel G, et al. Novel artificial intelligence applications in cardiology: current landscape, limitations, and the road to real-world applications. J Cardiovasc Transl Res 2022. Doi: 10.1007/s12265-022-10260-x
13 Theofilatos K, Pavlopoulou N, Papasavvas C, et al. Predicting protein complexes from weighted protein-protein interaction graphs with a novel unsupervised methodology: evolutionary enhanced Markov clustering. Artif Intell Med 2015;63(03):181–189
14 Castellino RA. Computer aided detection (CAD): an overview. Cancer Imaging 2005;5:17–19
15 LeCun Y, Bengio Y, Hinton G. Deep learning. Nature 2015;521(7553):436–444
16 Miotto R, Wang F, Wang S, Jiang X, Dudley JT. Deep learning for healthcare: review, opportunities and challenges. Brief Bioinform 2018;19(06):1236–1246
17 Kevin Zhou S, Greenspan H, Shen D. Deep Learning for Medical Image Analysis. 1st ed. Amsterdam: Elsevier; 2017 (Academic Press, 2017)
18 Shen D, Wu G, Suk HI. Deep Learning in Medical Image Analysis. Annu Rev Biomed Eng 2017;19:221–248
19 Veeraraghavan H. MO-A-207B–01: radiomics: segmentation & feature extraction techniques. Med Phys 2016;43:3694–3694
20 Litjens G, Kooi T, Bejnordi BE, et al. A survey on deep learning in medical image analysis. Med Image Anal 2017;42:60–88
21 Cinteza M. Medicine with intelligence. be it an artificial one. Maedica (Buchar) 2022;17(02):251–252
22 Burley SK, Arap W, Pasqualini R. Predicting proteome-scale protein structure with artificial intelligence. N Engl J Med 2021;385(23):2191–2194
23 Stokes JM, Yang K, Swanson K, et al. A deep learning approach to antibiotic discovery. Cell 2020;180(04):688–702.e13
24 Maegerlein C, Fischer J, Mönch S, et al. Automated calculation of the Alberta Stroke Program Early CT Score: feasibility and reliability. Radiology 2019;291(01):141–148
25 Amukotuwa SA, Straka M, Smith H, et al. Automated detection of intracranial large vessel occlusions on computed tomography angiography: a single center experience. Stroke 2019;50(10):2790–2798
26 Jo T, Nho K, Saykin AJ. Deep learning in Alzheimer's disease: diagnostic classification and prognostic prediction using neuroimaging data. Front Aging Neurosci 2019;11:220
27 Alhasan AS. Clinical applications of artificial intelligence, machine learning, and deep learning in the imaging of gliomas: a systematic review. Cureus 2021;13(11):e19580
28 Adeoye J, Akinshipo A, Thomson P, Su YX. Artificial intelligence-based prediction for cancer-related outcomes in Africa: status and potential refinements. J Glob Health 2022;12:03017
29 Regge D, Halligan S. CAD: how it works, how to use it, performance. Eur J Radiol 2013;82(08):1171–1176
30 Al Mohammad B, Brennan PC, Mello-Thoms C. A review of lung cancer screening and the role of computer-aided detection. Clin Radiol 2017;72(06):433–442
31 Katzen J, Dodelzon K. A review of computer aided detection in mammography. Clin Imaging 2018;52:305–309
32 Huang X, Shan J, Vaidya V. Lung nodule detection in CT using 3D convolutional neural networks. IEEE 14th International Symposium on Biomedical Imaging (ISBI 2017); 2017:379–383
33 Tsehay YK, Lay NS, Roth HR, Wang X, Kwak JT, Turkbey BI, et al. Convolutional neural network based deep-learning architecture for prostate cancer detection on multiparametric magnetic resonance images. In: Medical Imaging 2017: Computer-Aided Diagnosis. Washington, USA: SPIE publications; 2017:1013405
34 Fartaria MJ, Bonnier G, Roche A, et al. Automated detection of white matter and cortical lesions in early stages of multiple sclerosis. J Magn Reson Imaging 2016;43(06):1445–1454
35 Zhang X, Yan LF, Hu YC, et al. Optimizing a machine learning based glioma grading system using multi-parametric MRI histogram and texture features. Oncotarget 2017;8(29):47816–47830
36 Avendi MR, Kheradvar A, Jafarkhani H. A combined deep-learning and deformable-model approach to fully automatic segmentation of the left ventricle in cardiac MRI. Med Image Anal 2016;30:108–119
37 Cheng R, Roth HR, Lay N, et al. Automatic magnetic resonance prostate segmentation by deep learning with holistically nested networks. J Med Imaging (Bellingham) 2017;4(04):041302
38 Roth HR, Lu L, Lay N, et al. Spatial aggregation of holistically-nested convolutional neural networks for automated pancreas localization and segmentation. Med Image Anal 2018;45:94–107
39 Wang S, Summers RM. Machine learning and radiology. Med Image Anal 2012;16(05):933–951

40 Mirsadraee S, Oswal D, Alizadeh Y, Caulo A, van Beek E Jr. The 7th lung cancer TNM classification and staging system: review of the changes and implications. World J Radiol 2012;4(04):128–134
41 Sohn K, Shang W, Lee H. Advances in Neural Information Processing Systems 27 (NIPS 2014). Red Hook, NY: Curran Assoc; 2014: 2141–2149
42 Lecointre L, Dana J, Lodi M, Akladios C, Gallix B. Artificial intelligence-based radiomics models in endometrial cancer: a systematic review. Eur J Surg Oncol 2021;47(11):2734–2741
43 Kohli M, Prevedello LM, Filice RW, Geis JR. Implementing machine learning in radiology practice and research. AJR Am J Roentgenol 2017;208(04):754–760
44 Ronneberger O, Fischer P, Brox TU. Convolutional networks for biomedical image segmentation. 2015 Accessed May 18, 2015, at: https://arxiv.org/abs/1505.04597
45 Moeskops P, Wolterink JM, Van der Velden BH, et al. International Conference on Medical Image Computing and Computer-Assisted Intervention. 2016:478–486
46 Neri E, Regge D. Imaging biobanks in oncology: European perspective. Future Oncol 2017;13(05):433–441
47 European Society of Radiology (ESR) ESR Position Paper on Imaging Biobanks. Insights Imaging 2015;6(04):403–410
48 Champaign JL, Cederbom GJ. Advances in breast cancer detection with screening mammography. Ochsner J 2000;2(01):33–35
49 Shiraishi J, Li Q, Appelbaum D, Doi K. Computer-aided diagnosis and artificial intelligence in clinical imaging. Semin Nucl Med 2011;41(06):449–462
50 Choy G, Khalilzadeh O, Michalski M, et al. Current applications and future impact of machine learning in radiology. Radiology 2018;288(02):318–328
51 Hricak H. 2016 New Horizons Lecture: beyond imaging-radiology of tomorrow. Radiology 2018;286(03):764–775
52 Pesapane F, Codari M, Sardanelli F. Artificial intelligence in medical imaging: threat or opportunity? Radiologists again at the forefront of innovation in medicine. Eur Radiol Exp 2018;2 (01):35

