THE EUROPEAN SOCIETY OF MEDICINE
Medical Research Archives, Volume 12 Issue 10

RESEARCH ARTICLE

Integration of Teleradiology and Artificial Intelligence: Opportunities and Challenges

Dr Arjun Kalyanpur[1]; Dr Neetika Mathur[2]

[1] Chief Radiologist and Founder, Teleradiology Solutions, Plot No. 7G, Opposite Graphite India, Whitefield, Bengaluru, 560048, India
[2] Training and Research Coordinator, Teleradiology Solutions, Plot No. 7G, Opposite Graphite India, Whitefield, Bengaluru, 560048 India

OPEN ACCESS

PUBLISHED
31 October 2024

CITATION
Kalyanpur, A., and Mathur, N., 2024. Integration of Teleradiology and Artificial Intelligence: Opportunities and Challenges. Medical Research Archives, [online] 12(10). https://doi.org/10.18103/mra.v12i10.5904

DOI
https://doi.org/10.18103/mra.v12i10.5904

ISSN
2375-1924

ABSTRACT

Over the past few decades, radiology has become an increasingly important part of diagnosis and healthcare delivery in general, and correspondingly the burden on radiologists continues to increase with greater imaging volumes and stringent reporting turnaround time expectations, resulting in radiology reporting delays and errors. To bridge the gap, teleradiology has played an important role over the past two decades, but given the mismatch between the dramatically increased utilization of radiologic imaging and the relatively constant number of trained radiologists entering practice, additional solutions are necessary. Teleradiology and Artificial Intelligence have exceptional synergies from the perspective of both being technology enabled healthcare delivery mechanisms that address the same fundamental issue of radiologist shortages. These synergies lead to a multiplier effect in terms of Teleradiology enabling Artificial Intelligence algorithms to be deployed at scale globally over a short time frame to rapidly achieve greater impact than either solution can individually. This article will review the opportunities whereby Artificial Intelligence can further enhance Teleradiology practice, as well as explore the challenges that exist at this time that may potentially delay this process of integration.

Keywords: Teleradiology, Artificial Intelligence, Medical Imaging, Emergency Radiology, Elective Radiology, Opportunities, Challenges

Introduction

Over the last two or three decades there has been a significant increase in imaging utilization in healthcare. The quantum of medical imaging that is performed has increased in proportion with a) advances in diagnostic imaging capabilities, with higher speed and higher resolution imaging b) an increase in clinical indications and applications that utilize medical imaging such as stroke, heart disease and cancer c) an increase in the overall population d) an increasing dependence by emergency staff on medical imaging in the acute setting as part of the triage process (this last in particular leads to significant increase in after-hours emergency imaging).

Unfortunately, the availability of trained radiologists has not increased in proportion to the above trends, resulting in a growing mismatch between the number of radiologic images needing to be interpreted and the number of radiologists available to interpret them. This in turn has set in motion a set of related trends namely a) delays in reporting, which may either delay urgent care in the emergency setting or stretch into weeks from the time the outpatient radiologic examination is performed b) diagnostic reporting errors which occur due to radiologist overwork, particular at the end of a long shift or due to the need to complete the report in a short time frame c) radiologist fatigue and burnout, which are increasingly being reported in the literature [1-4].

Since the beginning of the millennium, teleradiology has been providing a solution to global radiologist shortages. It is today an essential part of the telehealth armamentarium, and is arguably (one of) its most evolved avatars. It has established impact in many areas, notably in the emergency setting wherein it allows images to be transported to the location of the radiologist to ensure immediate interpretation. In this setting, the use of a global model ensures that the radiologist is well rested and working during his/her workday to support the hospital in the middle of its night [5-8]. In another version, teleradiology enables quality healthcare access to rural populations which are deprived of onsite radiologist services [9-12]. In the setting of complex and rare diseases requiring subspecialist analysis, teleradiology facilitates image transfer to the rare breed of subspecialist teleradiologists [13,14].

Today, coupled with Artificial Intelligence [15,16], teleradiology promises a long-term solution to the crippling radiologist shortages that diminish the impact of the dramatic technologic advances that imaging science has made, such as ultrafast and ultra-high-resolution Computed Tomography (CT) and Magnetic Resonance Imaging (MRI), Digital radiography, Doppler sonography and Positron Emission Tomography (PET) imaging.

The aim of this article is to review the current literature and discuss the opportunities whereby Artificial Intelligence can further enhance Teleradiology practice, as well as explore the challenges that exist at this time that may potentially delay this process of integration.

Methodology

This is a review article that draws on our own perspective and experience as a global teleradiology service provider with twenty years background in providing international teleradiology services, and now currently engaged in developing and integrating artificial intelligence within its workflow, combined with a review of the literature published on the subject, which includes publications based on our experience on the subject.

OPPORTUNITIES-

While Teleradiology has certainly made a significant impact on addressing radiologist shortages over the past two decades by increasing the reach of the radiologist, the continuing increase in imaging volumes currently exceeds the capacity of teleradiology to meet its demands. While teleradiology leverages time zone differences and reporting efficiencies in order to enhance radiologist productivity, ultimately its benefits are finite and limited and the workload is distributed among the same cohort of radiologists. In this scenario, Artificial Intelligence (AI) offers the potential of a paradigm shift in terms of leveraging technology to further increase and even multiply the productivity of radiologists [17].

There are multiple synergies between Teleradiology and AI related to a) both are information technology (IT) enabled and data driven b) both address the issue of radiologist manpower shortages c) both simultaneously enhance radiologist quality as well as productivity d) both diminish costs in the long term.

Given these synergies, it is evident that the combination of Teleradiology and AI can powerfully disrupt the existing framework of delivery of radiology reporting services, with positive impact on patient care outcomes.

Opportunities for integration of AI into Teleradiology workflow exist in multiple clinical scenarios:

Emergency Radiology: Artificial Intelligence algorithms today can be transformational in meeting the dual challenges of turnaround time and quality which are the cornerstone of emergency radiology [18].

The areas where AI can help improve Emergency Radiology workflow include

a) Triage/Prioritization – by highlighting positive examinations within a busy worklist, an AI algorithm can facilitate the timely interpretation of emergency radiology examinations [19-23].
b) Quality Enhancement – by identifying subtle anomalies which may be missed in the rapid pace of emergency radiology analysis and bringing them to the attention of the radiologist, error can be avoided [24].
c) Detection of complications, such as Midline shift in the setting of intracranial hemorrhage or right heart strain in the setting of pulmonary thromboembolism can ensure that such life-threatening complications are appropriately escalated within instants of the scan being performed.
d) Report Generation: multimodal large language models are today under investigation for their potential role in image analysis and report generation which can be of particular value in the emergency setting where radiologists are under time pressure and often become backlogged and where such assistance can be extremely valuable [25].

e) Communication Workflow enhancement – by identifying critical findings within the report text, Natural language processing (NLP) models and Large Language models (LLM) can ensure that these are communicated in a timely manner [26,27].

An array of AI models today addresses common emergency conditions, including neurologic conditions such as acute cerebrovascular events, intracranial hemorrhage, thoracic emergencies such as pneumothorax, pleural effusion, pulmonary thromboembolism, aortic dissection and congestive heart failure as well as abdominal emergencies such as bowel obstructions, abdominal visceral injuries, free intraperitoneal air and intra-abdominal fluid collections. Musculoskeletal emergencies such as fractures, dislocations and soft-tissue injury are another area where AI has a potential role in assisting radiologist detection and triage [28-36] (Figure 1-6).

These algorithms can be applied to any form of emergency digital imaging, including plain radiographs, CT scans and even ultrasound scans.

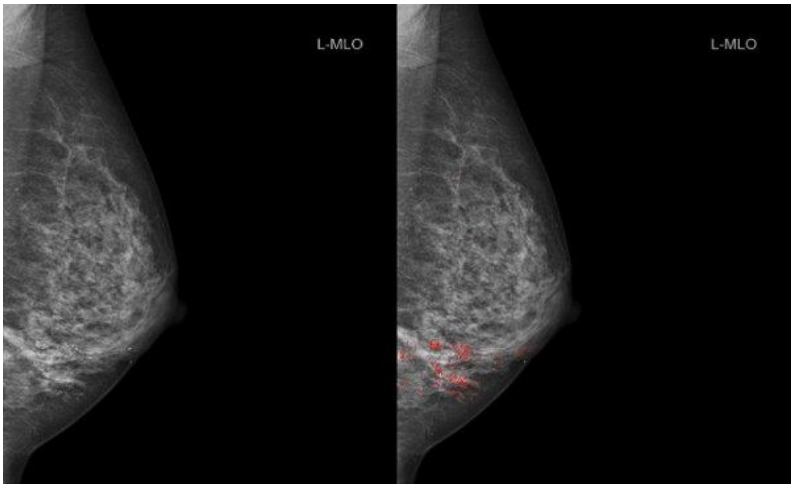

Figure 1. AI algorithm (MammoAssist, TeleradTech) demonstrating a focus of microcalcification, a feature of early breast cancer detected on Mammography.

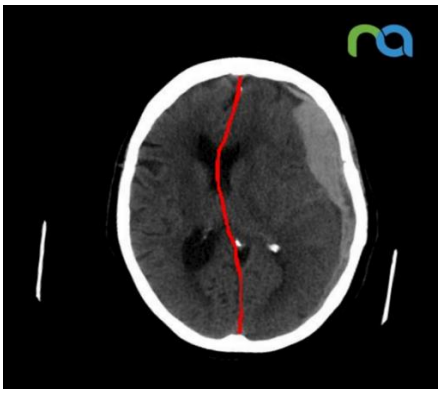

Figure 2. AI algorithm (NeuralAssist, TeleradTech) demonstrating midline shift an indication of poor outcome on a noncontrast CT of the brain CT in a patient with subdural hematoma.

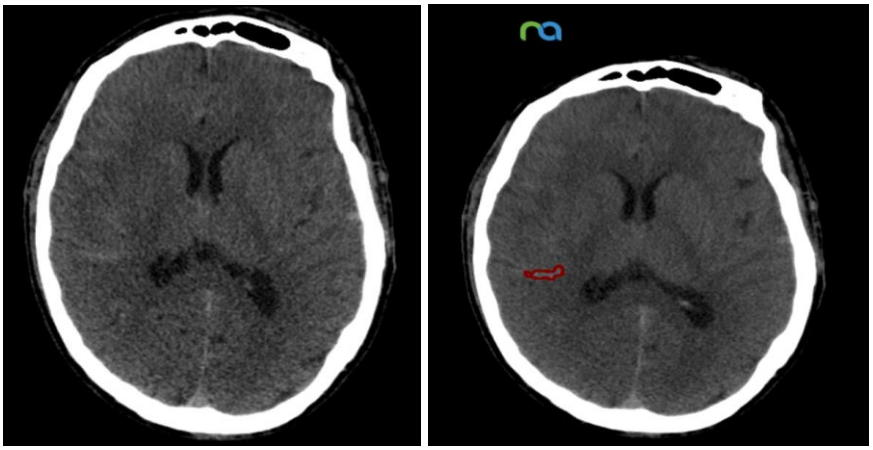

Figure 3. AI algorithm (NeuralAssist, TeleradTech) demonstrating a small right convexity sulcus subarachnoid hemorrhage on a noncontrast CT scan of the brain performed in the setting of trauma.

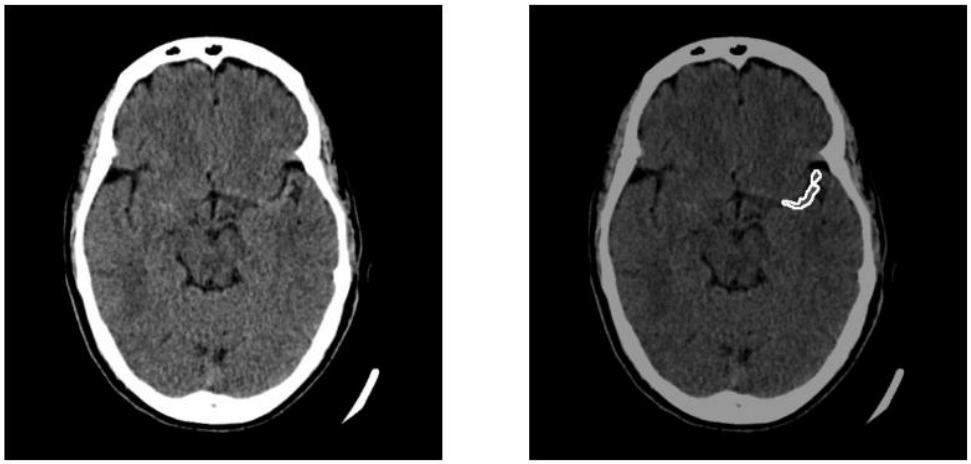

Figure 4. AI algorithm (NeuralAssist, TeleradTech) demonstration of hyperdense middle cerebral artery sign on a noncontrast CT scan of the brain performed in the setting of acute stroke.

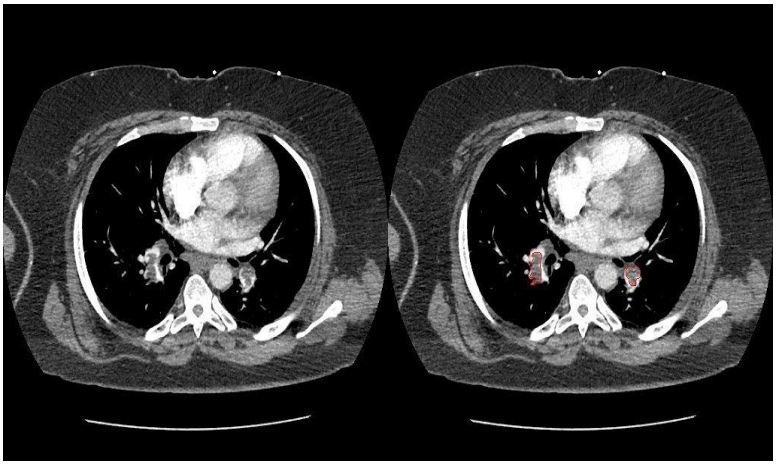

Figure 5. AI algorithm (PEAssist, TeleradTech) demonstrating bilateral pulmonary thromboembolism on a CT Angiogram of the chest performed in a patient with difficulty breathing.

Figure 6. AI algorithm (TeleradTech) demonstrating Type B Aortic Dissection on a CT Angiogram of the chest performed in a patient with acute onset of chest pain.

In elective or outpatient radiology, artificial intelligence algorithms can contribute significantly to improved workflow, throughput and productivity. This is particularly vital in two settings, namely

a) Screening, which involves mass interpretation of large volumes of radiologic examinations such as chest radiographs for detection of asymptomatic pulmonary tuberculosis or mammograms for early detection of breast cancer. Such screening programs typically result in a significant percentage of normal studies and artificial intelligence algorithms can greatly assist in the binary decision making of abnormal versus normal examinations, with the former being escalated for additional radiologist review [37-41].
b) High volume diagnostic imaging modalities such as MRI spine for degenerative diseases of the spine, or chest CT for early lung cancer detection. In oncologic examinations, artificial intelligence algorithms help to estimate quantitative parameters which assist in confirming disease progression or response to therapy [42-49].

CURRENT STATUS-

While in the elective environment, the integration of an artificial intelligence algorithms into the reporting workflow has already made impact in terms of increasing radiologist productivity, in the emergency setting, where the timelines are extremely stringent, artificial intelligence is yet to make significant impact in terms of increasing radiologist productivity. Where AI does add value currently in the emergency setting is in quality enhancement and positive study triage.

Some of the challenges which we currently face in the integration and deployment of artificial algorithms in the teleradiology environment include

1. From a practical workflow standpoint, the display of the AI output in the viewer of the teleradiologist constitutes the main challenge. Although there is potential for this to progress rapidly in coming years, at this time, the integration between various AI vendors and Teleradiology reporting workflows are still a work in progress. The integration of AI into Teleradiology workflow typically requires an aggregator platform to allow for seamless reporting workflow. Given the profusion of available AI algorithms for many clinical indications, the next stage of AI will essentially be related to consolidation of these technologies within a narrower range of aggregator platforms and workflows [50].
2. Infrastructure – Unlike routine Picture archiving and communication system (PACS) which functions in a Central Processing Unit (CPU) environment, AI to be effective requires a Graphics Processing Unit (GPU) type infrastructure which comes at a significantly higher cost [51].
3. Data integrity and Security – As AI solutions are often cloud based, it is necessary to explore the security of the data in the process of establishing connectivity with the AI cloud and the Teleradiology workflow [52].
4. Regulatory challenges – Ensuring that AI algorithms are certified by regulatory agencies such as the FDA and others is a prerequisite. Currently the majority of AI algorithms are in a state of 'clearance' as opposed to formal approval [53,54].
5. Billing and reimbursement – The billing practices and reimbursement for radiology AI are still in evolution. While in unregulated markets, these may vary based on market economics, in the highly regulated regions of the world, the reimbursements need to be incorporated within currently existing complex billing structures [55,56].

Conclusion

- Successful integration of artificial intelligence into teleradiology requires capture of clinical data within the workflow to enable effective AI training and validation to enhance the performance of AI algorithms.
- It is essential that radiologists collaborate closely with AI developers as this will lead to the development of more clinically relevant algorithms as well as the rapid and seamless integration of AI into teleradiology practice.
- Another important requirement is to ensure a process for continuous AI model training through radiologist feedback. The process for providing feedback should be efficient and should not slow down the reporting process.

The integration of Artificial Intelligence with Teleradiology represents an idea whose time has come. This presents a scenario in which AI algorithms can be deployed at the largest possible scale, by making them available to radiologists at a global level, where they can have maximum impact. Teleradiology being data-rich can in parallel enable the rapid training of AI algorithms while eliminating the issues of regional population bias. While challenges exist, these are temporary and once the obstacles are overcome, the practice of radiology and healthcare in general will be forever transformed.

Conflicts of Interest Statement: The authors have no conflicts of interest to declare.

References

1. Shanafelt TD, Hasan O, Dyrbye LN, et al. Changes in Burnout and Satisfaction with Work-Life Balance in Physicians and the General US Working Population Between 2011 and 2014. *Mayo Clinic Proceedings*. 2015; 90(12): 1600-1613. doi: 10.1016/j.mayocp.2015.08.023
2. Kalyanpur A, Mathur N. Offshore reporting of radiologic examinations supplementing healthcare delivery worthy of Medicare reimbursement. *Imaging Radiat Res*. 2024 Jun 19;6(1):6404. https://systems.enpress-publisher.com/index.php/IRR/article/view/6404
3. https://arjunkalyanpur.in/radiologist-burnout-and-related-issues/
4. Chetlen AL, Chan TL, Ballard DH, et al. Addressing Burnout in Radiologists. *Academic Radiology*. 2019; 26(4): 526-533. doi: 10.1016/j.acra.2018.07.001
5. Kalyanpur A. The Role of Teleradiology in Emergency Radiology Provision. *Health management*. 2014; 14(1).
6. Kalyanpur A, Weinberg J, Neklesa V, Brink JA, Forman HP. Emergency radiology coverage: technical and clinical feasibility of an international teleradiology model. *Emergency Radiology*. 2003 Dec 1;10(3):115–8.
7. Kalyanpur A and Mathur N. The Role of Teleradiology in Interpretation of Ultrasounds Performed in the Emergency Setting. *Digital diagnostics*, Jan 2024. https://doi.org/10.17816/DD624586
8. Agrawal A, Sharma M, Sriram S, Blanco A, Nicola R, Kalyanpur A. Imaging of acute scrotal infections, complications and mimics. *Emerg Radiol* [Internet]. 2024 Jul 11 [cited 2024 Aug 16]; Available from: https://link.springer.com/10.1007/s10140-024-02263-9
9. Kalyanpur, A., Sudhindra, R. R., & Rao, P. (2022). The Role of Mobile Van Mammography Supported by Teleradiology in the Early Diagnosis of Breast Cancer: An Innovative Approach to a Growing Public Health Problem. *International Journal of Health Technology and Innovation*, 1(03), 2–8. Retrieved from https://ijht.org.in/index.php/ijhti/article/view/30 https://doi.org/10.60142/ijhti.v1i03.30
10. Kalyanpur A., Meka S., Joshi K., TS H., Mathur N. Teleradiology in Tripura: Effectiveness of a Telehealth Model for the Rural Health Sector. *International Journal of Health Technology and Innovation*. 2022;1(2):7-12. https://ijht.org.in/index.php/ijhti/article/view/36 https://doi.org/10.60142/ijhti.v1i02.36
11. Rudisill KE, Mathur N, Kalyanpur A. A teleradiology network for the improvement of healthcare and patient management in the developing countries of the African continent. *Clinical Imaging*. 2024 Jul;111:110188. https://doi.org/10.1016/j.clinimag.2024.110188.
12. Kalyanpur A, Rao P, Mathur N. Utilization of Teleradiology by Intensive Care Units: A Cohort Study. *Indian Journal of Critical Care Medicine*. 2023 Dec 31;28(1):20–5. https://www.ijccm.org/abstractArticleContentBrowse/IJCCM/64/28/1/34854/abstractArticle/Article
13. Hanna TN, Steenburg SD, Rosenkrantz AB, Pyatt RS, Duszak R, Friedberg EB. Emerging Challenges and Opportunities in the Evolution of Teleradiology. *American Journal of Roentgenology*. 2020 Dec;215(6):1411–6.
14. Kalyanpur A and Mathur N. A Teleradiology System for Early Ischemic and Hemorrhagic Stroke Evaluation and Management. *Journal of Clinical Interventional Radiology*, 25 July, 2023. ISSN 2457-0214. DOI: 10.1055/s-0043-1771379 https://www.thieme-connect.com/products/ejournals/html/10.1055/s-0043-1771379
15. Najjar, R. (2023). Redefining Radiology: A Review of Artificial Intelligence Integration in Medical Imaging. *Diagnostics*, 13(17), 2760. https://doi.org/10.3390/diagnostics13172760
16. Khalifa, M., & Albadawy, M. (2024). AI in diagnostic imaging: Revolutionising accuracy and efficiency. *Computer Methods and Programs in Biomedicine Update*, *5*, 100146. https://doi.org/10.1016/j.cmpbup.2024.100146
17. Shoshan, Y., Bakalo, R., Gilboa-Solomon, F., Ratner, V., Barkan, E., Ozery-Flato, M., Amit, M., Khapun, D., Ambinder, E. B., Oluyemi, E. T., Panigrahi, B., DiCarlo, P. A., Rosen-Zvi, M., & Mullen, L. A. (2022). Artificial Intelligence for Reducing Workload in Breast Cancer Screening with Digital Breast Tomosynthesis. *Radiology*, 303(1), 69–77. https://doi.org/10.1148/radiol.211105
18. Katzman, B. D., Van Der Pol, C. B., Soyer, P., & Patlas, M. N. (2023). Artificial intelligence in emergency radiology: A review of applications and possibilities. *Diagnostic and Interventional Imaging*, 104(1), 6–10. https://doi.org/10.1016/j.diii.2022.07.005
19. Kolossváry, M., Raghu, V. K., Nagurney, J. T., Hoffmann, U., & Lu, M. T. (2023). Deep Learning Analysis of Chest Radiographs to Triage Patients with Acute Chest Pain Syndrome. *Radiology*, *306*(2), e221926. https://doi.org/10.1148/radiol.221926
20. Weisberg, E. M., Chu, L. C., & Fishman, E. K. (2020). The first use of artificial intelligence (AI) in the ER: Triage not diagnosis. *Emergency Radiology*, *27*(4), 361–366. https://doi.org/10.1007/s10140-020-01773-6
21. Goo, J. M. (2023). Triaging: Another Vital Application of the Deep Learning Technique on Chest Radiographs at the Emergency Department. *Radiology*, 306(2), e223112. https://doi.org/10.1148/radiol.223112
22. Murphy, D. J., & Tee, S. R. (2023). Expectation Meets Reality: AI-powered CT Pulmonary Angiogram Triage in the Real World. *Radiology*, 309(1), e232389. https://doi.org/10.1148/radiol.232389
23. Topff, L., Ranschaert, E. R., Bartels-Rutten, A., Negoita, A., Menezes, R., Beets-Tan, R. G. H., & Visser, J. J. (2023). Artificial Intelligence Tool for Detection and Worklist Prioritization Reduces Time to Diagnosis of Incidental Pulmonary Embolism at CT. *Radiology: Cardiothoracic Imaging*, *5*(2), e220163. https://doi.org/10.1148/ryct.220163
24. Makeeva, V., Gichoya, J., Hawkins, C. M., Towbin, A. J., Heilbrun, M., & Prater, A. (2019). The Application of Machine Learning to Quality Improvement Through the Lens of the Radiology Value Network. *Journal of the American College of Radiology*, 16(9), 1254–1258. https://doi.org/10.1016/j.jacr.2019.05.039
25. Jorg, T., Halfmann, M. C., Stoehr, F., Arnhold, G., Theobald, A., Mildenberger, P., & Müller, L. (2024). A

novel reporting workflow for automated integration of artificial intelligence results into structured radiology reports. *Insights into Imaging*, 15(1), 80. https://doi.org/10.1186/s13244-024-01660-5

26. Sacoransky, E., Kwan, B. Y. M., & Soboleski, D. (2024). ChatGPT and assistive AI in structured radiology reporting: A systematic review. *Current Problems in Diagnostic Radiology*, S0363018824001130. https://doi.org/10.1067/j.cpradiol.2024.07.007
27. Bhayana, R. (2024). Chatbots and Large Language Models in Radiology: A Practical Primer for Clinical and Research Applications. *Radiology*, 310(1), e232756. https://doi.org/10.1148/radiol.232756
28. Agrawal D, Joshi S, Poonamallee L. Automated Midline Shift Detection and Quantification in Traumatic Brain Injury: A Comprehensive Review. Indian Journal of Neurotrauma. 2024;21(01):006-012. doi:10.1055/s-0043-1777676
29. Seyam M, Weikert T, Sauter A, Brehm A, Psychogios MN, Blackham KA. Utilization of Artificial Intelligence–based Intracranial Hemorrhage Detection on Emergent Noncontrast CT Images in Clinical Workflow. Radiology: Artificial Intelligence. 2022;4(2):e210168. doi:10.1148/ryai.210168
30. Shinohara Y, Takahashi N, Lee Y, Ohmura T, Kinoshita T. Development of a deep learning model to identify hyperdense MCA sign in patients with acute ischemic stroke. Jpn J Radiol. 2020;38(2):112-117. doi:10.1007/s11604-019-00894-4
31. Sugibayashi T, Walston SL, Matsumoto T, Mitsuyama Y, Miki Y, Ueda D. Deep learning for pneumothorax diagnosis: a systematic review and meta-analysis. Eur Respir Rev. 2023;32(168):220259. doi:10.1183/16000617.0259-2022
32. Allena N, Khanal S. The Algorithmic Lung Detective: Artificial Intelligence in the Diagnosis of Pulmonary Embolism. Cureus. 2023;15(12):e51006. doi:10.7759/cureus.51006
33. Mastrodicasa D, Codari M, Bäumler K, et al. Artificial Intelligence Applications in Aortic Dissection Imaging. Seminars in Roentgenology. 2022;57(4):357-363. doi:10.1053/j.ro.2022.07.001
34. Stewart, J., Lu, J., Goudie, A., Bennamoun, M., Sprivulis, P., Sanfillipo, F., & Dwivedi, G. (2021). Applications of machine learning to undifferentiated chest pain in the emergency department: A systematic review. *PLOS ONE*, 16(8), e0252612. https://doi.org/10.1371/journal.pone.0252612
35. Shen X, Zhou Y, Shi X, Zhang S, Ding S, Ni L, et al. The application of deep learning in abdominal trauma diagnosis by CT imaging. *World J Emerg Surg*. 2024 May 6;19(1):17.
36. Yao J, Chu LC, Patlas M. Applications of Artificial Intelligence in Acute Abdominal Imaging. *Can Assoc Radiol J*. 2024 May 7;08465371241250197.
37. Shoshan, Y., Bakalo, R., Gilboa-Solomon, F., Ratner, V., Barkan, E., Ozery-Flato, M., Amit, M., Khapun, D., Ambinder, E. B., Oluyemi, E. T., Panigrahi, B., DiCarlo, P. A., Rosen-Zvi, M., & Mullen, L. A. (2022). Artificial Intelligence for Reducing Workload in Breast Cancer Screening with Digital Breast Tomosynthesis. *Radiology*, 303(1), 69–77. https://doi.org/10.1148/radiol.211105
38. Lehman, C. D., Yala, A., Schuster, T., Dontchos, B., Bahl, M., Swanson, K., & Barzilay, R. (2019). Mammographic Breast Density Assessment Using Deep Learning: Clinical Implementation. *Radiology*, 290(1), 52–58. https://doi.org/10.1148/radiol.2018180694
39. Ghorbian, M., & Ghorbian, S. (2023). Usefulness of machine learning and deep learning approaches in screening and early detection of breast cancer. *Heliyon*, 9(12), e22427. https://doi.org/10.1016/j.heliyon.2023.e22427
40. Alelyani, T., Alshammari, M. M., Almuhanna, A., & Asan, O. (2024). Explainable Artificial Intelligence in Quantifying Breast Cancer Factors: Saudi Arabia Context. *Healthcare*, 12(10), 1025. https://doi.org/10.3390/healthcare12101025
41. Youk, J. H., Gweon, H. M., Son, E. J., & Kim, J.-A. (2016). Automated Volumetric Breast Density Measurements in the Era of the BI-RADS Fifth Edition: A Comparison With Visual Assessment. *American Journal of Roentgenology*, 206(5), 1056–1062. https://doi.org/10.2214/AJR.15.15472
42. Huber, F. A., & Guggenberger, R. (2022). AI MSK clinical applications: Spine imaging. *Skeletal Radiology*, 51(2), 279–291. https://doi.org/10.1007/s00256-021-03862-0
43. Martín-Noguerol, T., Oñate Miranda, M., Amrhein, T. J., Paulano-Godino, F., Xiberta, P., Vilanova, J. C., & Luna, A. (2023). The role of Artificial intelligence in the assessment of the spine and spinal cord. *European Journal of Radiology*, 161, 110726. https://doi.org/10.1016/j.ejrad.2023.110726
44. Cui, Y., Zhu, J., Duan, Z., Liao, Z., Wang, S., & Liu, W. (2022). Artificial Intelligence in Spinal Imaging: Current Status and Future Directions. *International Journal of Environmental Research and Public Health*, 19(18), 11708. https://doi.org/10.3390/ijerph191811708
45. Tang, J. S. N., Lai, J. K. C., Bui, J., Wang, W., Simkin, P., Gai, D., Chan, J., Pascoe, D. M., Heinze, S. B., Gaillard, F., & Lui, E. (2023). Impact of Different Artificial Intelligence User Interfaces on Lung Nodule and Mass Detection on Chest Radiographs. *Radiology: Artificial Intelligence*, 5(3), e220079. https://doi.org/10.1148/ryai.220079
46. Nam, J. G., Hwang, E. J., Kim, J., Park, N., Lee, E. H., Kim, H. J., Nam, M., Lee, J. H., Park, C. M., & Goo, J. M. (2023). AI Improves Nodule Detection on Chest Radiographs in a Health Screening Population: A Randomized Controlled Trial. *Radiology*, 307(2), e221894. https://doi.org/10.1148/radiol.221894
47. Kim, R. Y., Oke, J. L., Pickup, L. C., Munden, R. F., Dotson, T. L., Bellinger, C. R., Cohen, A., Simoff, M. J., Massion, P. P., Filippini, C., Gleeson, F. V., & Vachani, A. (2022). Artificial Intelligence Tool for Assessment of Indeterminate Pulmonary Nodules Detected with CT. *Radiology*, 304(3), 683–691. https://doi.org/10.1148/radiol.212182
48. Yanagawa, M. (2022). Artificial Intelligence Improves Radiologist Performance for Predicting Malignancy at Chest CT. *Radiology*, 304(3), 692–693. https://doi.org/10.1148/radiol.220571
49. Annarumma, M., Withey, S. J., Bakewell, R. J., Pesce, E., Goh, V., & Montana, G. (2019). Automated Triaging of Adult Chest Radiographs with Deep Artificial Neural Networks. *Radiology*, 291(1), 196–202. https://doi.org/10.1148/radiol.2018180921
50. Ranschaert, E., Topff, L., & Pianykh, O. (2021). Optimization of Radiology Workflow with Artificial

Intelligence. *Radiologic Clinics of North America*, *59*(6), 955–966. https://doi.org/10.1016/j.rcl.2021.06.006

51. Kapoor, N., Lacson, R., & Khorasani, R. (2020). Workflow Applications of Artificial Intelligence in Radiology and an Overview of Available Tools. *Journal of the American College of Radiology*, 17(11), 1363–1370. https://doi.org/10.1016/j.jacr.2020.08.016
52. Ritenour, E. R. (2023). Hacking and Artificial Intelligence in Radiology: Basic Principles of Data Integrity and Security. *Contemporary Diagnostic Radiology*, 46(5), 1–7. https://doi.org/10.1097/01.CDR.0000920216.83604.ce
53. Giansanti D. The Regulation of Artificial Intelligence in Digital Radiology in the Scientific Literature: A Narrative Review of Reviews. *Healthcare*. 2022;10(10):1824. doi:10.3390/healthcare10101824
54. Zhang K, Khosravi B, Vahdati S, Erickson BJ. FDA Review of Radiologic AI Algorithms: Process and Challenges. *Radiology*. 2024;310(1):e230242. doi:10.1148/radiol.230242
55. Rowell C, Sebro R. Who Will Get Paid for Artificial Intelligence in Medicine? *Radiology: Artificial Intelligence*. 2022;4(5):e220054. doi:10.1148/ryai.220054
56. Chen MM, Golding LP, Nicola GN. Who Will Pay for AI? *Radiology: Artificial Intelligence*. 2021;3(3):e210030. doi:10.1148/ryai.2021210030

