**The integration of laboratory and radiology data: A holistic approach to patient diagnostics**

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***Abstract*---**Background \_ Artificial intelligence (AI), particularly deep learning, has the potential to significantly transform the field of radiology. While there has been considerable attention in popular literature on the possible applications of AI, such as autonomous vehicles, it is suggested that the healthcare sector would experience the earliest and most significant impact from AI. Aim of Work – This paper aims to provide an overview of the current state of AI in radiology, including its potential benefits and challenges, and to discuss the ethical, technical, and practical considerations for its implementation in clinical practice. Methods – A comprehensive literature review was conducted to identify relevant studies and articles on AI in radiology. The review included scientific publications, conference proceedings, and reports from reputable organizations and institutions. Results – The findings of the literature review suggest that AI has the potential to enhance the efficiency, accuracy, and precision of medical image analysis and interpretation. AI algorithms can assist radiologists in tasks such as image segmentation, lesion detection, and disease classification. However, several challenges need to be addressed before AI can be widely adopted in clinical practice. These challenges include ethical concerns about data privacy and security, the need for robust technical validation of AI algorithms, and the establishment of standardized data-sharing protocols. Conclusion – AI has the potential to revolutionize radiology practice by improving diagnostic accuracy, streamlining workflows, and enabling personalized patient care. However, careful consideration must be given to ethical, technical, and practical issues to ensure the safe and effective implementation of AI in radiology.

***Keywords*---**Artificial intelligence, Radiology, Medical imaging, Machine learning, Deep learning.

**Introduction**

Artificial intelligence (AI), namely deep learning, has the potential to greatly disrupt the profession of radiology. While there has been much focus in popular literature on the possible applications of AI, such as autonomous vehicles, it has been suggested that the healthcare sector would see the earliest and most significant impact from AI **[1].** In the field of healthcare, the majority of current AI research is centered on machine and deep learning, with a particular emphasis on radiology. Several writers and researchers have expressed worries about the potential for AI advancements to replace human radiologists and ultimately render the field of radiology obsolete **[2, 3].** This forecast seemed hasty **[4].** While some jobs are expected to be automated, artificial intelligence (AI) will mostly function as a catalyst for innovation, enhancing the influence of radiology on patient outcomes and hence elevating the significance of the discipline overall. In the future, radiologists will shift their focus from remembering and identifying patterns and differential diagnoses to primarily managing data and information. Their responsibility will be to combine and analyze imaging data, laboratory and pathology results, and genetic information for the patient's clinical care team **[5, 6].** By automating tedious and time-consuming operations, it has the potential to enhance the purpose and happiness experienced by radiologists.

Despite the surge in interest and research on AI in radiology, it is evident that there are still numerous important obstacles that need to be addressed before AI can be widely used and integrated into clinical practice. Key concerns that require attention encompass the ethical advancement and utilization of artificial intelligence (AI) in the healthcare sector, the proper verification of each AI algorithm developed, the establishment of efficient mechanisms for sharing data, regulatory obstacles for approving AI algorithms, and the creation of educational resources on AI for both practicing radiologists and radiology trainees.

Various parties are collaborating to create artificial intelligence (AI) solutions specifically for the field of radiology. It is our belief that every stakeholder has both strengths and limitations when it comes to their ability to access the information, experience, data, and other resources required for achieving success (Figure 1). In order to make advancements in imaging AI, we think that it is crucial to form collaborations between academic healthcare institutions and industry, taking into account the strengths and shortcomings of each stakeholder.

**Moral dilemmas**

The majority of ethical issues related to AI in healthcare may be categorized into three primary groups: concerns about justice, accountability, and transparency. These concerns have led some academics to refer to the ethical framework of AI ethics as the fairness, accountability, and transparency (FAT) paradigm **[7, 8]**. While it may not be possible or advisable to completely eliminate all biases, it is crucial to acknowledge and contemplate their impact on both machine and human decision-making. Biases may arise when databases disproportionately include, exclude, or completely overlook certain traits that are pertinent to the given task. Additionally, there is a potential danger known as "automation bias," when people become too reliant on machines and neglect to utilize their own critical thinking and examination **[9]**. There is also the chance of false correlations that, if acted upon, might result in injury to patients **[10].**

Furthermore, the use of artificial intelligence (AI) in the healthcare sector, particularly when it includes sensitive personal health information, gives rise to apprehensions about the safeguarding of data and the preservation of privacy. Access to big datasets that accurately reflect various populations is crucial for training algorithms. However, problems over obtaining meaningful permission and ensuring adequate anonymization and de-identification of data are still significant **[11]**. It is important to additionally take into account the rights and interests of individuals who are not included in the datasets used to train AI systems. This is a significant political issue, particularly when the individuals absent from databases belong to disadvantaged or vulnerable communities who may possess distinct health conditions and requirements compared to other groups. The activities performed by AI models based on datasets that do not include these populations would not be appropriate for the specific requirements of these disadvantaged or vulnerable groups. This might potentially worsen health disparities. Another issue pertaining to disparities is the disparate use of artificial intelligence in contexts with abundant resources compared to those with limited resources. AI has the potential to enhance human decision-making in complex situations, but it also has the potential to substitute for human knowledge in underprivileged areas of the globe **[8]**.

In order to protect against these potential negative consequences, it is imperative that the AI algorithms employed are adequately transparent and comprehensible for healthcare providers to oversee the logic and impact of AI. Additionally, healthcare providers should be able to offer a reasonable explanation of how AI functions to patients and other relevant individuals **[12, 13]**. Additional proposals to tackle concerns about fairness, accountability, and transparency include a comprehensive strategy that encompasses (a) ethical governance, (b) explainability and interpretability, and (c) ethical auditing **[14].** This implies that anyone involved in the development, certification, and implementation of AI in radiology should ensure that any biases present in the system are made clear and carefully consider the potential impact of these biases on AI-driven analyses, such as diagnosis, as well as the choices taken based on these analyses. According to source, this implies that the education and training of health professionals should be redesigned to shift the emphasis from memorizing information to preparing students to effectively engage with and oversee artificially intelligent devices **[15].**

Regarding the regulation of these issues, Thierer et al **[16]** distinguish between two primary approaches: the precautionary principal approach and the practice hazard approach. The precautionary principal approach asserts that the lack of evidence regarding risk should not be used as a justification to permit a practice that poses a hazard. Based on this reasoning, if it is evident that a particular application of AI has the risk of exacerbating social disparities, then such practices should be tightly controlled, even in the absence of concrete proof that they have already contributed to social inequality. The second approach, known as the permission-less approach, argues that technologies should continue to advance until there is substantial proof that they are dangerous. In general, the European approach is more cautious compared to other regions, implying that the lack of data about danger is not often considered a sufficient basis to proceed with technological adoption. Instead, it is important to thoroughly and exhaustively examine the potential advantages and disadvantages in advance.

**Verification of technical aspects or features**

The first inquiry that must be resolved at the technical validation stage pertains to the optimal approach for devising a technical validation research. While the scope of this may vary depending on the job, it is important to have a validation technique that may provide valuable insights into important aspects of the algorithm, such as its resilience, repeatability, and generalizability. Furthermore, it is necessary for the algorithm to provide a clear understanding of its anticipated precision, such as its ability to quantify or diagnose or predict accurately. This statement outlines the specifications for the imaging data that must be gathered, including the desired amount and quality. It also specifies the extra information, such as labels and co-variates, that should be compiled. Additionally, it mentions the validation metrics that will be used to assess performance, as referenced in source **[17]**. Furthermore, a crucial factor to take into account is the allocation of the available data among algorithm creation, optimization, and validation. Typically, in the majority of research, the training, validation, and test sets are selected from the same dataset. This may provide understanding of algorithm precision, but not of its resilience and capacity to apply to many scenarios. In order to evaluate this particular aspect of an algorithm, it is crucial to choose a completely separate test set. This was done in a radiomics study on glioma classification, where the algorithm was developed using data from 284 patients from two hospitals. The algorithm was then validated using an independent dataset from The Cancer Imaging Archive.

The robustness of an algorithm is characterized by its ability to provide consistent output even when there are minor fluctuations in the input data. For the majority of algorithms, this may be easily evaluated by introducing realistic, little modifications to the input data (such as including realistic noise patterns, altering picture intensity, or making slight deformations), and monitoring whether these modifications have a substantial impact on the output. Algorithms that lack robustness in the face of minor alterations are prone to generating mistakes when used in a regular operational context.

Regarding reproducibility, our primary focus is on the ability to replicate the outcome of an imaging session. Specifically, we are concerned with the reproducibility of both the image capture and processing process. Thus, for optimal assessment of the replicability of an AI program, it is desirable to have a dataset that includes many scanning sessions of the same subject. Reporting on the repeatability of an algorithm is crucial since it indicates the degree to which a specific measurement produced from an image may be utilized for a longitudinal evaluation.

Generalizability refers to the capacity of an algorithm to be effectively used across many contexts or environments. The lack of generalizability is currently a major weakness of deep learning methods. While algorithms trained on a particular dataset tend to perform well on comparable data, they typically struggle to perform well on unseen data throughout the training phase **[18]**. Due to disparities in scanner hardware and software, scanning settings, and variations in human anatomy and disease, there is significant variability in medical imaging data. Training the algorithm with diverse clinical practice data enhances the likelihood of the system's generalizability, but obtaining such data is challenging. The data sharing section will provide a more comprehensive analysis of this matter.

**The significance of issues in the technical validation of AI algorithms in medical image analysis**

Competitive image processing and analysis challenges have been very advantageous in objectively evaluating the effectiveness and usefulness of various image analysis and image processing applications. A total of 180 challenges have been arranged, and these events have become significant components of prominent international conferences in medical imaging and radiology **[19]**. These tasks include a specific and well-defined job, such as segmenting the liver in contrast-enhanced abdominal CT images **[20]**. Research organizations, regardless of whether they are from business or academia, are welcome to obtain a collection of test scans. The expected output for these scans is known, but it is not provided. An explicit assessment system and a specified set of performance measures are established and made publicly available. Each participating team is required to submit the segmentation results of the test images using their proprietary algorithm and provide a detailed description of their technique in a paper. The challenge organizers assess all outcomes, and in several instances, the teams who take part in the challenge collaborate as co-authors on a journal paper that receives significant citations.

While challenges have achieved great success, the bulk of problems have originated from the medical image analysis and machine learning community, rather than from the community of end users. Consequently, many activities and assessment criteria that have been established may not effectively tackle the most urgent medical image analysis issues that AI might potentially assist with. Furthermore, a recent assessment of difficulties encountered in medical imaging highlighted the need of considering variations in task design, such as variances in evaluation metrics and ranks, when interpreting the outcomes of these challenges **[21]**.

In order to guarantee that the utilization of difficulties contributes to the advancement of AI algorithms that can be safely used in healthcare settings, it is crucial to enhance the caliber of these problems. Significant progress is being made in both the medical image analysis and radiology communities towards this goal. The Medical Image Computing and Computer Assisted Intervention Society has used the idea of structured challenge submission for its challenges. This approach assists task organizers in following a set of criteria and principles to guarantee the production of high-quality challenges. Another significant advancement is the growing number of challenges being started by the radiology community **[22, 23]**.

The American College of Radiology (ACR) has recently released many use cases demonstrating the potential contributions of AI **[24]**. The use cases delineate the specific clinical query to be resolved, the input data used, and the anticipated output information from the AI system. To further the progress of AI in radiology, it is very logical to combine the notion of "challenges" with clinically oriented AI applications. Clinicians should provide use case scenarios and assessment measures to generate clinically motivated challenges, instead of leaving this task to algorithm developers.

**Data sharing**

As previously said, the development, training, and testing of AI systems need vast volumes of data. Maximizing the size and diversity of these datasets is crucial to enhance the applicability of the created algorithms and minimize the risk of unintentional biases. Hence, it is crucial for image collections to accurately reflect the pictures acquired in various clinical settings and the individuals being treated. This may be accomplished most effectively by facilitating data exchange across different institutions, preferably across different nations and demographic regions. Furthermore, in order to be valuable, imaging data must be integrated with accurate and reliable ground truth information. Ground truth may be defined in several ways, including as clinical results like overall or progression-free survival, diagnostic imaging tests, or tissue diagnosis from pathology research. Due to the difficulty in obtaining data in some clinical situations and the possibility of biased verification, providing data that has been verified with accurate and reliable information may greatly assist in generating strong and reliable proof. In several scenarios, the only feasible benchmark (such as the identification of congestive heart failure on a chest X-ray) can only be established by a group of human specialists. Ultimately, the extensive magnitude of datasets that may be acquired using collaborative methods would enable significant analysis within specific patient subgroups, such as females and men, various age cohorts, or varying degrees of illness severity. Data sharing allows for the analysis of subgroups within the data, which in turn provides valuable information for the establishment of clinical practice guidelines. This is particularly crucial for improving the little evidence available about diagnostic testing **[25, 26]**.

**The prerequisites and obstacles to the exchange of data**

In order to ensure efficient and accountable exchange of data, it is essential to adhere to ethical guidelines and adequately manage privacy issues. Data re-identification is a significant concern when it comes to exchanging picture data, making the latter crucial in this context due to its high potential for re-identification. While this statement applies to all types of data, it is particularly applicable to photos that include face traits that may be rebuilt, enabling the identification of the persons involved **[27]**. As previously stated, it is essential to provide accurate annotations and ground truth information when sharing imaging data to ensure its high quality. This task takes a substantial amount of effort and will be challenging to do without the establishment of incentives for those who are willing to provide the data. Other unresolved issues that must be addressed to enable extensive data sharing are data access regulations, data quality and safety policies, intellectual property concerns, and data protection. In order to tackle these problems, a collaborative effort called the Guide to Data Sharing of Imaging Trials (GUIDE-IT) has been established **[28]**. The concerns will be addressed by pursuing the following objectives: creating a network for sharing data from imaging studies, formulating procedures for accessing the data, setting criteria for informed consent, and ensuring the quality and safety of the data. To achieve success, it is crucial to prioritize the specific requirements of prospective consumers of data, provide suitable rewards to those who give data, and engage patient advocates to aid in the creation, testing, and validation of AI solutions based on images **[29]**.

Global collaboration and data sharing face several practical implementation barriers that must be addressed. These include the lack of research programs that educate scientists about the benefits and challenges of data sharing, the issue of funding for data sharing platforms due to the substantial costs involved in their establishment and maintenance, and the historical competition among academic institutions, which discourages data sharing between them.

Although there are challenges and obstacles mentioned earlier, there are notable instances of effective sharing of images and data. These include the Alzheimer's Disease Neuroimaging Initiative, the Global Alzheimer's Association Interactive Network, the Cancer Imaging Archive, and the National Biomedical Imaging Archive **[30-33]**. Data sharing has occurred in collaborative meta-analyses including individual-patient data and between studies involving medical imaging. The Collaborative Meta-Analysis of Cardiac CT included researchers from over 70 institutions in more than 20 countries. They pooled data to get a better understanding of the clinical situations in which cardiac CT had the best level of accuracy **[34]**. The field of interventional neuroradiology stroke research has collaborated to create and verify a decision tool for choosing patients for intra-arterial therapy **[35]**. Additionally, the two most extensive studies in coronary CT imaging have collaborated to verify the accuracy of a coronary risk assessment tool **[36]**.

**The intersection between artificial intelligence and education**

In order for radiologists to assume a leadership role in integrating AI into their everyday practice, it is crucial that they possess a fundamental fluency in machine learning, comprehending both its capabilities and constraints **[37-39]**. The need to comprehending AI has been likened to the necessity for radiologists to grasp the fundamentals of imaging physics **[39, 40]**. Recent research has shown that there is presently a lack of this degree of comprehension among radiologists **[41, 42]**. To get this level of comprehension, it is crucial to delineate the specific AI expertise that radiologists will need and to build the requisite instructional tools accordingly.

Different professions within radiology need varying degrees of understanding, similar to imaging physics or imaging informatics. López et al. **[43]** have outlined three distinct responsibilities for humans in the age of artificial intelligence: trainers, explainers, and sustainers, as discussed in their article on collaborative intelligence. Trainers are those who create and instruct algorithms to carry out certain tasks. Explainers are those who possess the ability to elucidate the actions and operations of algorithms, which are often obscure to others. Sustainers are those who guarantee the appropriate, secure, and responsible functioning of artificial intelligence systems. Wintermark et al **[39]** have delineated a comparable although somewhat distinct trio of jobs that center specifically on radiologists: designers of AI tools, deployers of AI tools, and consumers of AI tools. The individuals that need the most comprehensive understanding are the designers of the tool, since they are responsible for developing and assessing algorithms and networks, and then implementing them to address particular imaging issues. The members of this group are expected to possess a significant level of expertise in data science, comparable to our existing core of scientists who often have graduate degrees in physics, engineering, or mathematics. In order to proceed, it is essential that they comprehend and address many concerns that have been previously covered in this article. These issues include the development of comprehensive datasets, validation of algorithms, and the exchange of data. The tool deployers possess a proficient comprehension of data and computer science, but not as profound as that of the tool inventors. Nevertheless, they will possess sufficient expertise to choose which algorithms to use and implement for certain imaging inquiries, as well as to guarantee that the algorithms are verified and functioning as intended. The minimum level of expertise needed for users of the AI tool is rather low. This group must possess a solid grasp of fundamental AI principles and be capable of identifying instances where algorithms are not functioning as intended. This is analogous to the way experienced radiologists need to recognize the presence of imaging artifacts, even if they cannot provide an explanation for their occurrence or suggest methods for their elimination.

Developing the training materials needed to teach all three positions in radiology will be a challenging task that requires collaboration among several national and international bodies, as well as university radiology departments. The start of this process is already evident via the establishment of ACR's Center for Data Science, the Radiological Society of North America's Radiology Informatics Committee, and the European Society of Radiology's AI blog **[44].** It is imperative to include a criterion for ongoing proficiency in artificial intelligence (AI) for radiologists who are already practicing, within the existing standards for continuing medical education (CME) in imaging. Furthermore, it is necessary to design a standardized curriculum for radiology trainees, in addition to developing educational tools for presently working radiologists. It is evident that individual programs will not possess the necessary skills to independently construct such a program for a considerable period of time.

The extensive use of AI will not only enhance the required knowledge base of radiologists, but also has the potential to reduce and maybe remove some components of the existing knowledge base. According to Asken, et al **[44]**, in the era of AI, the present focus on memorizing vast quantities of data would need to shift towards the integration and usage of abundant data and knowledge readily accessible from many data sources. Similarly to Jha et al's theory **[6]**, it is predicted that the primary role of radiologists would no longer be limited to pattern detection but will instead transition towards becoming information experts and managers. In order to have the greatest influence on patient care, radiologists must possess a comprehensive understanding of several different omics. While AI will have the capability to process and categorize vast quantities of data, it will remain the duty of radiologists to analyze and provide meaning to the results generated by algorithms, transforming them into valuable information and knowledge that will have a beneficial effect on patients' health outcomes.

**Conclusion**

Ultimately, AI has intriguing prospects for how humans acquire information. AI technologies will possess the capability to observe and evaluate the knowledge base and performance of trainees and practicing radiologists. By using this data, AI systems have the potential to tailor an instructional program for each particular trainee/radiologist. For instance, artificial intelligence (AI) will possess the capability to detect areas of deficiency and include suitable instructional scenarios for trainees, or maybe customize mandatory continuing medical education (CME) based on individualized requirements. Artificial intelligence (AI) has the potential to advance individualized treatment and tailored education.

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| **References** |
| 1. De Spiegeleire, S., Maas, M., & Sweijs, T. (2017). Artificial intelligence and the future of defense: strategic implications for small-and medium-sized force providers. The Hague Centre for Strategic Studies. 2. Chockley K, Emanuel E (2016) The end of radiology? Three threats to the future practice of radiology. J Am Coll Radiol 13(12):1415–1420 3. Obermeyer Z, Emanuel EJ (2016) Predicting the future—big data, machine learning, and clinical medicine. N Engl J Med 375(13):1216 4. Recht, M., & Bryan, R. N. (2017). Artificial intelligence: threat or boon to radiologists?. Journal of the American College of Radiology, 14(11), 1476-1480. 5. Prainsack B (2017) Personalized medicine: empowered patients in the 21st century? New York University Press 100 6. Jha, S., & Topol, E. J. (2016). Adapting to artificial intelligence: radiologists and pathologists as information specialists. Jama, 316(22), 2353-2354. 7. Etzioni, A., & Etzioni, O. (2017). Incorporating ethics into artificial intelligence. The Journal of Ethics, 21, 403-418. 8. Hallevy, G. (2015). Liability for crimes involving artificial intelligence systems (Vol. 257). New York, NY, USA: Springer International Publishing. 9. Chan, W. V., Pearson, T. A., Bennett, G. C., Cushman, W. C., Gaziano, T. A., Gorman, P. N., ... & Jacobson Vann, J. C. (2017). ACC/AHA special report: clinical practice guideline implementation strategies: a summary of systematic reviews by the NHLBI Implementation Science Work Group: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. Circulation, 135(9), e122-e137. 10. Osoba OA, Welser W IV (2017) An intelligence in our image: The risks of bias and errors in artificial intelligence. https://www.rand.org/pubs/research\_reports/RR1744.html. Accessed 4 Oct 2019 11. Burrell, J. (2016). How the machine ‘thinks’: Understanding opacity in machine learning algorithms. Big data & society, 3(1), 2053951715622512. 12. Sartore, F. (2016). Big data: privacy and intellectual property in a comparative perspective. 13. Wachter S, Mittelstadt B, Russell C (2017) Counterfactual explanations without opening the black box: automated decisions and the GPDR. Harv JL Tech 31:841 14. Hofkirchner, W., & Burgin, M. (Eds.). (2017). Future Information Society, The: Social And Technological Problems (Vol. 8). World Scientific. 15. Etzioni, A., & Etzioni, O. (2017). Incorporating ethics into artificial intelligence. The Journal of Ethics, 21, 403-418. 16. Thierer A, O’Sullivan A, Russel R (2017) Artificial intelligence and public policy. Mercatus Research Paper. Available via https://www.mercatus.org/system/files/thierer-artificial-intelligence-policy-mr-mercatus-v1.pdf. Accessed 4 Oct 2019 17. Gillies, R. J., Kinahan, P. E., & Hricak, H. (2016). Radiomics: images are more than pictures, they are data. Radiology, 278(2), 563-577. 18. Lakhani, P., & Sundaram, B. (2017). Deep learning at chest radiography: automated classification of pulmonary tuberculosis by using convolutional neural networks. Radiology, 284(2), 574-582. 19. Blindheim, K. (2011). On studying the unstudyable: a quantitative literature review of proposed causes of corruption and how these have been studied (Master's thesis, The University of Bergen). 20. Di Giamberardino, P., Iacoviello, D., Jorge, R. N., & Tavares, J. M. R. (2014). Computational Modelling of Objects Represented in Images. 21. Naaktgeboren CA, de Groot JA, van Smeden M, Moons KG, Reitsma JB (2013) Evaluating diagnostic accuracy in the face of multiple reference standards. Ann Intern Med 159(3):195–202 22. Whiting P, Rutjes AWS, Reitsma JB, Glas AS, Bossuyt PMM, Kleijnen J (2004) Sources of variation and bias in studies of diagnostic accuracy: a systematic review. Ann Intern Med 140(3):189–202 23. Tricoci P, Allen JM, Kramer JM, Califf RM, Smith SC Jr (2009) Scientific evidence underlying the ACC/AHA clinical practice guidelines. JAMA 301:831–84128 24. Leung KY, van der Lijn F, Vrooman HA, Sturkenboom MC, Niessen WJ (2015) IT Infrastructure to support the secondary use of routinely acquired clinical imaging data for research. Neuroinformatics 13(1):65–81 25. European Society of Radiology (ESR) communications@ myesr. org. (2015). Medical imaging in personalised medicine: a white paper of the research committee of the European Society of Radiology (ESR). Insights into imaging, 6, 141-155. 26. Limkin, E. J., Sun, R., Dercle, L., Zacharaki, E. I., Robert, C., Reuzé, S., ... & Ferté, C. (2017). Promises and challenges for the implementation of computational medical imaging (radiomics) in oncology. Annals of Oncology, 28(6), 1191-1206. 27. Weiner, M. W., Veitch, D. P., Aisen, P. S., Beckett, L. A., Cairns, N. J., Cedarbaum, J., ... & Alzheimer's Disease Neuroimaging Initiative. (2015). Impact of the Alzheimer's disease neuroimaging initiative, 2004 to 2014. Alzheimer's & Dementia, 11(7), 865-884. 28. Ashish, N., Bhatt, P., & Toga, A. W. (2016). Global data sharing in Alzheimer disease research. Alzheimer Disease & Associated Disorders, 30(2), 160-168. 29. Siegel, R., Naishadham, D., & Jemal, A. (2013). Cancer statistics, 2013. CA: a cancer journal for clinicians, 63(1). 30. Fitzmaurice, C., Allen, C., Barber, R. M., Barregard, L., Bhutta, Z. A., Brenner, H., ... & Satpathy, M. (2017). Global, regional, and national cancer incidence, mortality, years of life lost, years lived with disability, and disability-adjusted life-years for 32 cancer groups, 1990 to 2015: a systematic analysis for the global burden of disease study. JAMA oncology, 3(4), 524-548. 31. Wang, Z. J., Zhang, L. L., Elmariah, S., Han, H. Y., & Zhou, Y. J. (2017, March). Prevalence and prognosis of nonobstructive coronary artery disease in patients undergoing coronary angiography or coronary computed tomography angiography: a meta-analysis. In Mayo Clinic Proceedings (Vol. 92, No. 3, pp. 329-346). Elsevier. 32. Venema E, Mulder MJHL, Roozenbeek B et al (2017) Selection of patients for intra-arterial treatment for acute ischaemic stroke: development and validation of a clinical decision tool in two randomised trials. BMJ 357:j1710. https://doi.org/10.1136/bmj.j1710 33. Bittencourt, M. S., Hulten, E., Polonsky, T. S., Hoffman, U., Nasir, K., Abbara, S., ... & Blankstein, R. (2016). European Society of Cardiology–recommended coronary artery disease consortium pretest probability scores more accurately predict obstructive coronary disease and cardiovascular events than the Diamond and Forrester Score: the Partners Registry. Circulation, 134(3), 201-211. 34. Lee, J. G., Jun, S., Cho, Y. W., Lee, H., Kim, G. B., Seo, J. B., & Kim, N. (2017). Deep learning in medical imaging: general overview. Korean journal of radiology, 18(4), 570-584. 35. Achenbach, S., Goroll, T., Seltmann, M., Pflederer, T., Anders, K., Ropers, D., ... & Marwan, M. (2011). Detection of coronary artery stenoses by low-dose, prospectively ECG-triggered, high-pitch spiral coronary CT angiography. JACC: Cardiovascular Imaging, 4(4), 328-337. 36. Sanchez-Morillo, D., Fernandez-Granero, M. A., & Leon-Jimenez, A. (2016). Use of predictive algorithms in-home monitoring of chronic obstructive pulmonary disease and asthma: a systematic review. Chronic respiratory disease, 13(3), 264-283. 37. Purnama, D. W., Rochman, C. B. A., Darmawan, R., Amaliyah, P., Baqi, A. D., & Zahidin, A. (2011). A Bibliometrics Analysis for Artificial Intelligence Implementation of Employment in Education Institutions. 38. Kumar, R. (2017). Machine learning and cognition in enterprises: business intelligence transformed. Apress. 39. Wintermark, M., Sanelli, P. C., Albers, G. W., Bello, J., Derdeyn, C., Hetts, S. W., ... & Meltzer, C. C. (2013). Imaging recommendations for acute stroke and transient ischemic attack patients: a joint statement by the American Society of Neuroradiology, the American College of Radiology, and the Society of NeuroInterventional Surgery. American Journal of Neuroradiology, 34(11), E117-E127. 40. Stites, M., & Pianykh, O. S. (2016). How secure is your radiology department? Mapping digital radiology adoption and security worldwide. American Journal of Roentgenology, 206(4), 797-804. 41. Bøhler, H. M. (2017). EU copyright protection of works created by artificial intelligence systems (Master's thesis, The University of Bergen). 42. Hsu, W., El-Saden, S., & Taira, R. K. (2016). Medical imaging informatics. Translational Biomedical Informatics: A Precision Medicine Perspective, 167-224. 43. López, J. M., Catena, A., Montes, A., & Castillo, M. E. (2017). Effectiveness of a short voice training program for teachers: a preliminary study. Journal of Voice, 31(6), 697-706. 44. Asken, B. M., Sullan, M. J., DeKosky, S. T., Jaffee, M. S., & Bauer, R. M. (2017). Research gaps and controversies in chronic traumatic encephalopathy: a review. JAMA neurology, 74(10), 1255-1262. |

Figure 1. Advantages and disadvantages of the primary stakeholders involved in the development of artificial intelligence (AI) for radiology