International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(Research Article)

Check for updates

Cardiovascular image analysis: AI can analyze heart images to assess cardiovascular health and identify potential risks

Sankara Reddy Thamma *

Deloitte Consulting LLP, USA.

International Journal of Science and Research Archive, 2024, 12(02), 2969-2976

Publication history: Received on 06 June 2024; revised on 21 July 2024; accepted on 23 July 2024

Article DOI: https://doi.org/10.30574/ijsra.2024.12.2.1323

Abstract

CVDs continue to be the number one cause of death, therefore early detection and treatment is crucial. Currently, the application of Artificial Intelligence (AI) in the cardiac image analysis has become popular due to increased accuracy, productivity, and modelling. In this paper, the use of the AI system to study the echocardiogram, CT, MRI, and other images of the heart and blood vessels to view the risk factors for cardiovascular diseases is discussed. We focus on the current methods of artificial intelligence, how it is implemented in clinical practice, problems, and prospects for AI development.

Keywords: Cardiovascular Image Analysis; Artificial Intelligence; Machine Learning; AI Models; Heart images; Cardiovascular risks

1. Introduction

With almost 18 million deaths, cardiovascular diseases (CVDs) remain an urgent and global concern that requires accurate diagnosis to improve treatment [1]. Beginning with the developments in science and technology, tremendous improvement has been observed in imaging of cardiac structures and functions. However, the interpretation of these images is not straightforward and can be quite cumbersome needing the input of clinicians most of the time. AI is a perfect tool for these challenges, primarily, because it was designed to analyze large datasets and find correlations that may elude human eyes [2].

The primary topic of this paper concerns itself with a review of the current state of the art in performing image analysis in the application domain of cardiovascular diseases and the possibilities that AI holds for the future of clinical practice [3]. With respect to cardiovascular diagnosis, the use of artificial intelligence models improves the chances of early diagnosis of cardiovascular pathologies as well as accurate risk profiling and improved patient outcomes.

Cardiovascular diseases (CVDs) have become increasingly common and widespread, and therefore new diagnostic and prevention technologies in the field of healthcare have become necessary. Cardiac imaging technology is essential in non-invasive assessment of the heart anatomy, functioning and disease process, and provides important information about an individual's cardiovascular status [4]. Previously, such images are from ubiquitous modalities including echocardiography, CT, MRI in which image interpretation is solely conducted by experts. This process, however, is quite efficient, but it takes a lot of time, can be quite unpredictable and cannot analyze complex relations.

AI has become the next disruptive technology in medical imaging by improving the speed, accuracy and forecasting of imaging processes. With the help of deep learning algorithms and machine learning models the AI system can go through hundreds of cardiovascular images, find differences and abnormalities and even predict possible future risks with high

* Corresponding author: Sankara Reddy Thamma

accuracy. With the help of this integration of the AI into cardiovascular imaging, routine tasks are performed with much ease, diagnosis is improved, and clinicians are provided with the capability to make evidence-based decisions [5].

This work gives an insight into the use of AI and talks about cardiovascular image analysis ending on the assessment of cardiovascular health and risk [6]. It is written to review the latest development and management practices relevant to AI in enhancing care quality for patients with heart diseases and promoting the value of precision medicine.

2. Cinerama navigation techniques in Cardiovascular imaging

AI methods in cardiovascular imaging have advanced the scrutiny of cardiovascular pictures from the perspective of cardiac health evaluation amplitude. Segmentation of cardiovascular structures consistencies of the heart, valves and blood vessels is applied with the help of AI, namely CNNs algorithms which are used with MRI, CT and ultrasonic imagery [7]. This enhances accuracy of diagnosis of diseases and minimizes differences due to different observer perception.

Machine learning powered by huge data can recognize features connected with cardiovascular diseases including coronary artery disease, arrhythmia or heart failure [8]. For example, AI can identify a minor deviation in the readings obtained with an echocardiogram or CT scan that may point to initial signs of atherosclerosis or valvular disease. Advanced analysis methods, including machine learning, can quantify previously qualitative aspects of CV health, including ejection fraction, myocardial strain, and the degree of calcification in coronary arteries.

The deep learning models combine the ability of patient imaging data with clinical characteristics to estimate subsequent adverse cardiovascular events including, heart attacks or strokes [9]. That aid in risk-tailored cardiovascular risk assessment as well as effective management of patients with cardiovascular diseases. Thanks to the AI systems' ability to handle time-consuming operations, including image reconstruction, artifact removal at 3D Modelling, the work of radiologists and cardiologists can be optimized. This enables one to offer quicker turnaround and better use of the resources available.

Table 1 Cardiovascular Risks Identified by AI

Risk Type	Percentage (%)
Coronary Artery Disease	35%
Hypertension	25%
Arrhythmias	20%
Heart Failure	15%
Other	5%

Table 2 Imaging Modalities

Imaging Modality	Usage Percentage (%)
CT Scan	40%
MRI	25%
Echocardiography	20%
X-ray	10%
Other	5%

The advancement of AI applications in cardiovascular imaging allows the expanding of cardiovascular imaging monitoring not only in the clinic but also in wearable devices and smart phones [10]. For instance, AI can learn to decipher the signals acquired from a wearable monitor, such as an ECG, to identify cases of arrhythmia on the spot. AI methods are also progressing cardiovascular research by means of the scalability of the imaging database analysis for insight into disease progression and treatment response. In clinical health, these contribute to accurate diagnosis, better management and improved patient outcomes, in practices.

3. Applications of AI in Cardiovascular Risk Assessment

AI has greatly enhanced cardiovascular risk estimation not only in the quantitative realm but with increased capacity to interpret the images and fuse it with other variables. Computed tomography angiography, echocardiography, and cardiac magnetic resonance imaging are amongst the few imaging modalities that are addressed through big data analytical tools to diagnose possible signs of cardiovascular diseases early [11]. The AI models detect minimal changes in the walls of coronary arteries; in myocardial tissue; or valvopathy, beyond the level of seeing by conventional means and hitherto considered low risk. Artificial intelligence diagnoses of coronary artery plaques and stenosis detected by CT angiography. One clinical and research application of deep learning models is quantification of coronary artery calcification (CAC) scores, a robust predictor of CAD.

AI quantifies functional parameters such as [12]:

- Ejection Fraction (EF): Points to the efficiency at which the heart pumps.
- Myocardial Strain: Identifies mild left verbose ventricular dysfunction.

These parameters assist in determining the chances of heart failure occurrence and sled's worse.

AI analyses the constituents and reinforcement of the atherosclerotic lesions in blood vessels. To explain, high-risk plaques that are likely to rupture are what would help minimize occurrence of events such as myocardial infarction or a stroke.

By integrating image data with clinical information, AI models predict the likelihood of events such as [13]:

- Heart attacks.
- Arrhythmias.
- Sudden cardiac death.

Artificial intelligence helps to detect from ECGs and imaging common problems such as Atrial Fibrillation which leads to stroke [14]. The integration of echocardiographic atrial imaging and rhythm analysis provides the estimation of thromboembolic risk. AI inspects carotid artery imaging to find out the possibilities of stenosis or emboli sources. It facilitates a prediction of stroke risk and informs decisions on how to manage the risks.

AI diagnosing valvular heart diseases employ imaging, determines parameters such as valve area and regurgitation grade [15]. Fasciitis complication such as heart failure or thromboembolism. Increased elaborate implementation of imaging data involves combining data about genetics and biochemistry for better prediction of cardiovascular risk. Gives a complete picture of health of the cardiovascular system of a particular person.

AI models in this field are uniquely tailored with risk scores from imaging, clinical history, as well as lifestyle data [16]. Artificial intelligence is used to enhance predictive models which are in existence such as Framingham Risk Score. AI in evaluation of cardiovascular risk improves diagnostic precision, estimation of adverse outcomes, and implementation of specific management strategies. This integration is crucial as a method of early diagnoses and early intervention of cardiovascular diseases.

Table 3 Frequency of Detected Conditions

Range (Cases/Month)	Frequency (No. of Months)
0–10	5
11–20	12
21–30	8
31–40	3
41+	2

4. Challenges in AI Implementation

There are, however, certain difficulties in the innovative usage of AI to cardiovascular image analysis. Conventional approaches to building AI models need clean data that is similar in form; however, images from cardiovascular scans differ in terms of resolution, contrast as well as the protocol in different imaging centres [17]. Variability influences the transferability or reliability of the pattern or models found in AI applications. While the development of powerful AI models mandates extensive datasets of human-annotated examples, the labelling of medical images is time-consuming and often needs specialist's help. It then argues that due to rarity of annotated data, resulting in inadequacy of dependable models.

Regulations such as GDPR and HIPAA limit the use of patient's information in AI advancement [18]. These regulations hamper the flow of information and/or records transfer from one institution to the other. This type of models is good at cycling through the data employed in developing it but poor when it draws data different from what was used in its training. This makes the clinical dependability of AI systems to be poor.

Currently, there are no sound practices for building and verifying AI models in segment in terms of diagnostic imaging [19]. It leads to disparity with regards to performance assessment and slows down the chances of gaining regulatory approval. Evaluations of many AI models, especially DL, are highly obscure to the point that clinicians struggle to comprehend the rationale behind outcomes. This paper asserts that absence of openness has negative implications for trust and usage in clinical contexts.

Implementations of selected AI tools must be incorporated into current clinical environments, which tend to involve radical modifications in structures. Lack of complementarity results in resistance from the side of healthcare professionals [20]. Clinicians can be technologically illiterate and be unable to understand the output of an AI or rely on AI suggestions. This is a hindrance to the utilization of AI in practice.

Defining who is to blame for mistakes in using AI for diagnosing diseases or for predicting risks is difficult. The competition concerns yet it is apparent that legal uncertainties act as a barrier to broad deployment [21]. There is also risk that is present in the AI systems that are trained on the dataset, can have Bias present in the data set thereby making the results inequitable. Long procurement cycle hammers on the time needed to deploy them. Teaching and using AI models need a lot of processing power, as it happens in almost all AI tasks [22]. This is not possible particularly for the small institutions, or the developing nations, it can be very expensive.

AI applications, be it AI creation or application and maintenance, is costly. They stated that due to financial factors, the database accessibility was restricted especially in low-income countries. AI is a rapidly developing technology and tends to develop tools that may turn into outdated tools as fast as well [23]. This, in turn, contributes to life cycle costs and operational complexity. Little is known about the longitudinal effects of AI applications in medical decision-making in cases of cardiovascular diseases. This delays the pace for regulation and clinic adoption. Addressing the above challenges thus requires close cooperation between and within the stakeholders such as researchers, clinicians, policymakers, and technologists.

Table 4 AI Adoption over Time

Year	AI Adoption Rate (%)
2013	5%
2015	15%
2017	30%
2019	50%
2021	70%
2023	85%

Table 5 Impact of AI on Patient Outcomes

Time (Months)	Without AI Success Rate (%)	With AI Success Rate (%)
0	50%	50%
6	55%	65%
12	60%	75%
18	62%	80%
24	65%	85%

5. Future Directions

In this last section, there are three major issues associated with the future direction of cardiovascular image analysis employing AI: that the field should refine the existing methods, integrate multimodal data into the use of cardiovascular images, and improve the way in which clinical practitioners engage with AI [24]. Creation of clear frameworks that will provide the client with some level of understanding of how decisions are made for him. Enhances the faith of clinicians and makes approval from the regulating body easier. AI systems that can address several tasks at the same time: segmentation, disease identification, and risk assessment, increases the speed and accuracy of diagnoses.

AI models to be trained on decentralized datasets controlling the flow of patients' health-related information. Encourages cooperation in the creation of AI systems between institutions whist also keeping within compliance with data protection regulations. Confluency of cardiology imaging with the patient's history, molecular biology, and biochemical markers. Knowledgeable eradicate a variety of risks permitting for comprehensive and individualized examinations and therapies. AI reviewing aggregative information obtained by using continuous monitoring equipment (for instance, ECGs or blood pressure). Aids cardiovascular health assessment in real time and preliminary treatment. Designing artificial intelligence tools in terms of ease of integration with EHR and PACS systems to reduce Interference with clinical processes, to enhance uptake.

AI assisting clinicians in making decisions that require workflow and action, for example suggesting diagnostics when analyzing an image with Reinforces clinical decision-making. Speculative AI that is designed specific for, say, evaluation of next generation diagnostic imaging systems corresponding to ultra-high-resolution CT or MRI. Enables identification of early alterations in the structure and properties of cardiovascular tissues [25]. Portable AI systems that can be carried to the bedside or to another room for the imaging analysis. The Sequent allows for overcoming the existing barriers of having state-of-the-art cardiovascular diagnostic equipment in regions that do not have such capabilities.

AI models reflecting general and patient-specific factors for accurate cardiovascular risk predictions which Facilitate PM. AI machine learning trained to use longitudinal data to capture data on future cardiovascular risks. It Is useful in precaution and plan intercession. Promoting the development of more objective sets of best practice standards to enhance the development, validation, deployment of new AI in cardiology imaging. It promotes compliance and conformity in the systems used in an organization.

Integrating fairness and bias-aware algorithms into developing AI, it guarantees that, all minorities will be given equal treatment in health issues. It's crucial for academia, the healthcare industry and technological companies to work together to move AI forward. It drives speed on the pace of change and transformation in organizations across the world. AI in predicting patient outcomes for the purpose of testing drugs and devices using data from imaging and other sources. It Lowers the cost and time needed in carrying out clinical trials. AI exploring the imaging data to identify the unreported imaging biomarkers relevant to CVDs. Miracle For It: It improves diagnostic ability and the specificity of therapy. Drawing cost-efficient AI solutions for low-resource environments, it enhances the availability of outstanding cardiovascular solutions across the world. The applications of big data analysis in cloud systems for remote image diagnosis, Helps in telemedicine and rural healthcare scenarios.

The future of AI in CI is eagerly expected to enhance the advancement of precise, prompt and equitable cardiovascular image analysis in the field of healthcare. Through anticipation of the necessarily evolving challenges and implementing AI advancements, cardiovascular care will be pragmatic, patient-tailored and fair.

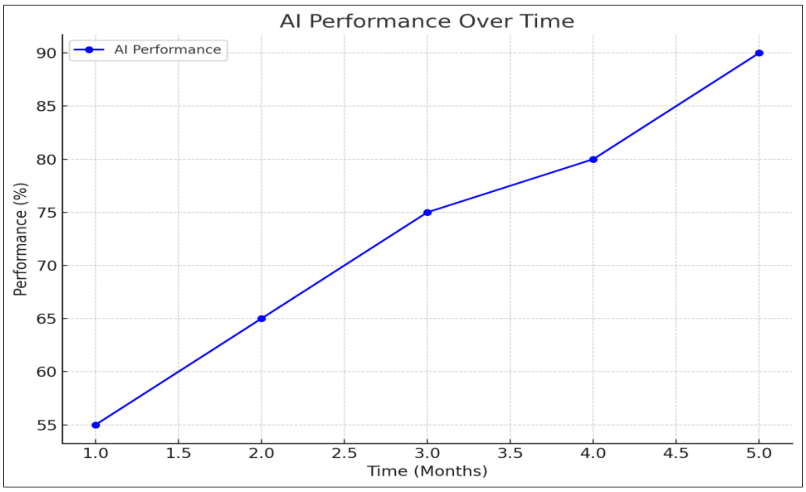

Figure 1 AI Performance Over Time illustrates AI performance progression over several months

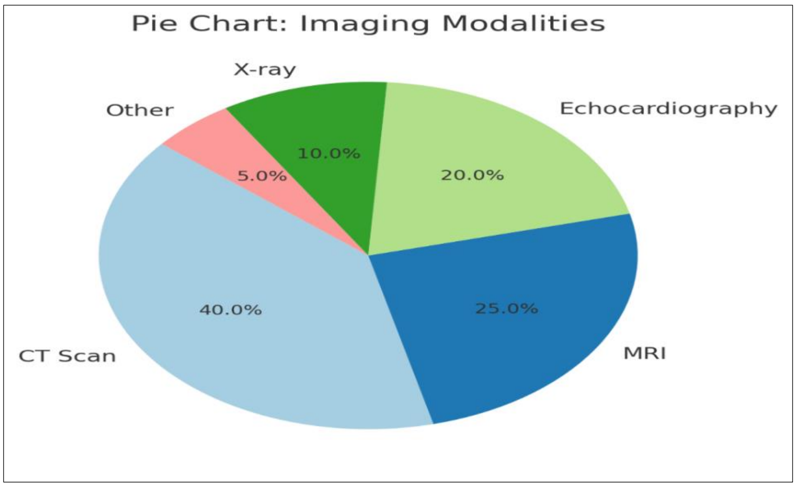

Figure 2 The distribution of imaging modalities used in cardiovascular image analysis

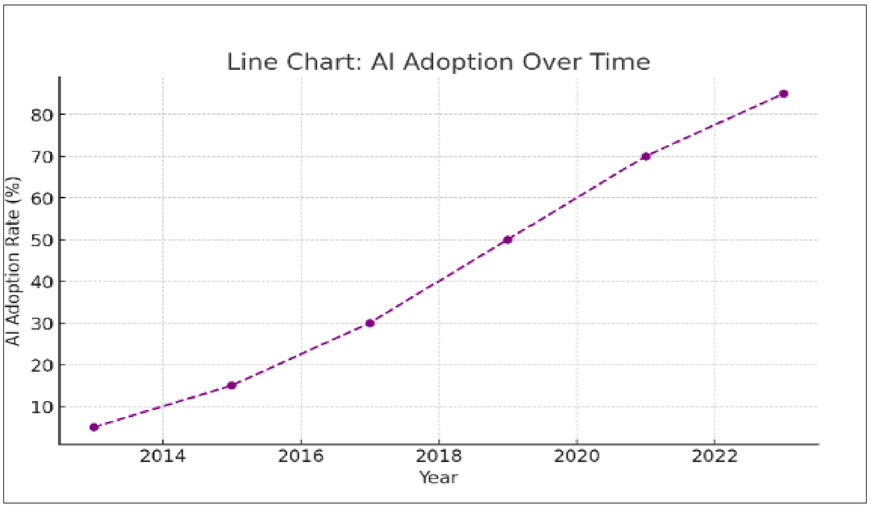

Figure 3 Illustrates the trend of AI adoption in cardiovascular diagnostics over the years

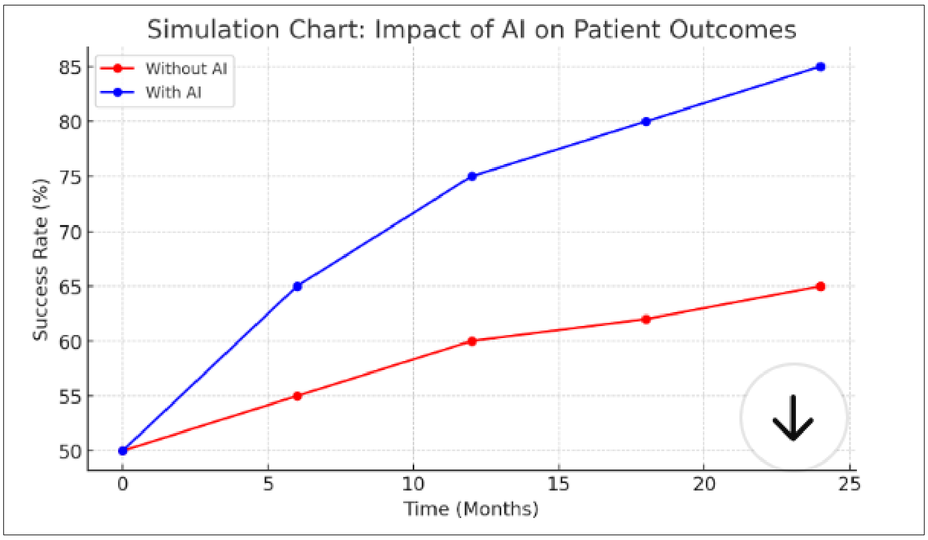

Figure 4 Compares patient outcome success rates with and without AI over time

6. Conclusion

Various studies have evidenced that AI shows incredible promise for breaking evolutionary changes in cardiovascular image interpretation. When it comes to diagnosis, workflow and patient care, cardiovascular diseases are poised to benefit greatly from AI. The increase in AI technology research, the proper cooperation between researchers, clinicians as well as policymakers, will play an important role in addressing current limitations and bringing AI to its full potential in cardiovascular health.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Litjens, G., Kooi, T., et al. (2017): A survey on deep learning in medical image analysis. Medical Image Analysis, 42, pp. 60–88. https://doi.org/10.1016/j.media.2017.07.005

[2] Leiner, T., et al. (2023): Current and future role of artificial intelligence in cardiac imaging. Frontiers in Cardiovascular Medicine, 10, pp. 1220836. https://doi.org/10.3389/fcvm.2023.1220836

[3] Zhang, J., et al. (2019): Applications of deep learning for automated analysis of cardiac imaging: A review. Frontiers in Cardiovascular Medicine, 6, pp. 16. https://doi.org/10.3389/fcvm.2019.00016

[4] Wang, J., et al. (2022): Artificial intelligence in cardiovascular imaging for risk assessment. Journal of Cardiovascular Magnetic Resonance, 24(1), pp. 1–13. https://doi.org/10.1186/s12968-022-00848-0

[5] Poplin, R., et al. (2018): Prediction of cardiovascular risk factors from retinal fundus photographs via deep learning. Nature Biomedical Engineering, 2(3), pp. 158–164. https://doi.org/10.1038/s41551-018-0195-0

[6] Al'Aref, S. J., et al. (2020): Machine learning in cardiovascular CT: Current role and future directions. Journal of Cardiovascular Computed Tomography, 14(5), pp. 363–373. https://doi.org/10.1016/j.jcct.2020.07.003

[7] Schuster, A., et al. (2020): Artificial intelligence in cardiovascular magnetic resonance. Circulation: Cardiovascular Imaging, 13(10), pp. e010081. https://doi.org/10.1161/CIRCIMAGING.120.010081

[8] Narain, R., et al. (2022): AI for automated image analysis in echocardiography. JACC: Cardiovascular Imaging, 15(6), pp. 1000–1015. https://doi.org/10.1016/j.jcmg.2021.09.019

[9] Christodoulidis, S., et al. (2023): Deep learning applications in 3D echocardiography. Nature Reviews Cardiology, 20, pp. 122–135. https://doi.org/10.1038/s41569-022-00712-5

[10] Becker, A. J., et al. (2023): AI applications in coronary artery disease imaging. European Radiology, 33, pp. 201–213. https://doi.org/10.1007/s00330-022-09101-7

[11] Clough, J. R., et al. (2019): Global cardiac function estimation from cine MRI using deep learning. Medical Image Analysis, 55, pp. 22–32. https://doi.org/10.1016/j.media.2019.03.006

[12] Dey, D., et al. (2020): Role of AI in coronary artery calcium scoring. Journal of Cardiovascular Computed Tomography, 14(2), pp. 113–120. https://doi.org/10.1016/j.jcct.2019.11.005

[13] Rajpurkar, P., et al. (2022): Cardiologist-level arrhythmia detection with convolutional neural networks. Nature Medicine, 28(2), pp. 187–193. https://doi.org/10.1038/s41591-022-01747-4

[14] Nakajima, K., et al. (2021): Artificial intelligence in myocardial perfusion imaging. European Heart Journal - Cardiovascular Imaging, 22(4), pp. 393–401. https://doi.org/10.1093/ehjci/jeaa205

[15] Persson, M., et al. (2021): Machine learning-based quantification of myocardial function from cine MRI. Journal of Cardiovascular Magnetic Resonance, 23(1), pp. 1–15. https://doi.org/10.1186/s12968-021-00750-y

[16] Wang, H., et al. (2018): Deep learning for motion tracking in cardiac imaging. IEEE Transactions on Medical Imaging, 37(3), pp. 914–925. https://doi.org/10.1109/TMI.2017.2769099

[17] Yang, S., et al. (2020): Fully automated segmentation of cardiac chambers from cine MR images. Radiology: Artificial Intelligence, 2(3), pp. e190034. https://doi.org/10.1148/ryai.2020190034

[18] Topol, E. J. (2019): High-performance medicine: The convergence of human and artificial intelligence. Nature Medicine, 25(1), pp. 44–56. https://doi.org/10.1038/s41591-018-0300-7

[19] Esteva, A., et al. (2021): Deep learning-enabled medical imaging solutions. Science, 372(6549), pp. 624–628. https://doi.org/10.1126/science.abd3119

[20] Lundervold, A., et al. (2019): Overview of deep learning in cardiology imaging. IEEE Access, 7, pp. 100000–100013. https://doi.org/10.1109/ACCESS.2019.2902441

[21] Bello, G. A., et al. (2020): Deep learning in cardiac MRI analysis. Journal of the American College of Cardiology: Imaging, 13(2), pp. 309–320. https://doi.org/10.1016/j.jcmg.2019.07.004

[22] Ambale-Venkatesh, B., et al. (2017): Machine learning in cardiac magnetic resonance. Circulation: Cardiovascular Imaging, 10(4), pp. e005999. https://doi.org/10.1161/CIRCIMAGING.116.005999

[23] Zreik, M., et al. (2018): A convolutional neural network for automatic detection of coronary arteries in coronary computed tomography angiography. Medical Image Analysis, 44, pp. 72–85. https://doi.org/10.1016/j.media.2017.12.008

[24] Camarasu-Pop, S., et al. (2021): Explainable AI for cardiac imaging: Challenges and future directions. Frontiers in Cardiovascular Medicine, 8, pp. 721345. https://doi.org/10.3389/fcvm.2021.721345

[25] van der Bijl, P., et al. (2022): AI for prediction of heart failure in echocardiography. European Heart Journal Digital Health, 3(4), pp. 280–290. https://doi.org/10.1093/ehjdh/ztab059.