Artificial Intelligence in Interventional Cardiology

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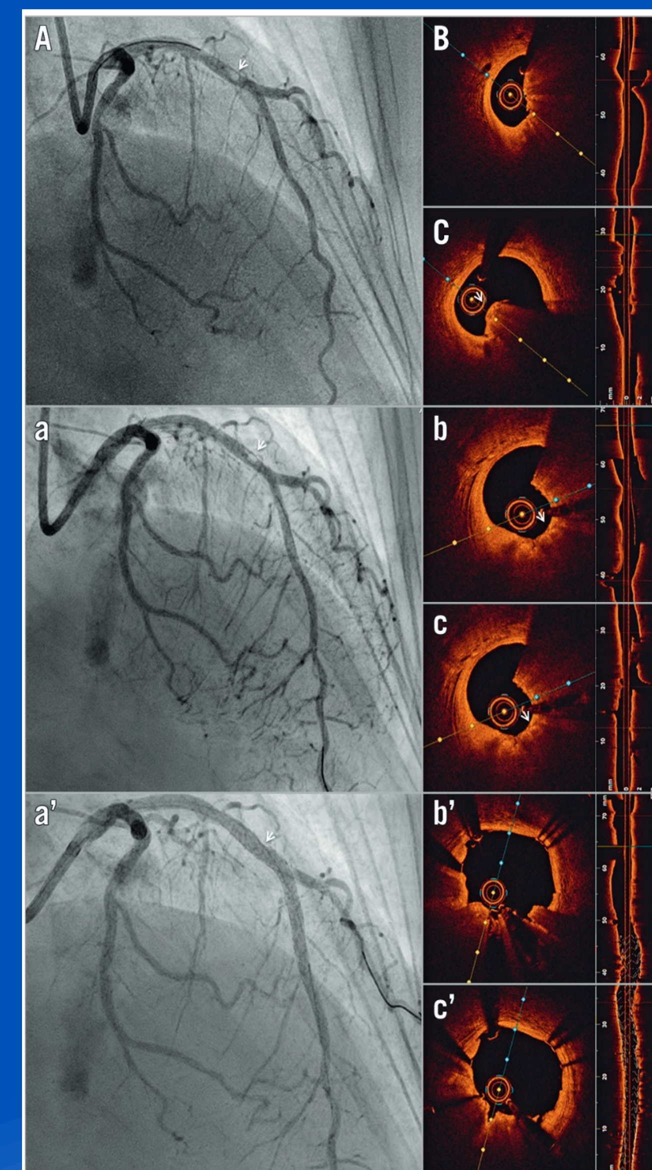
Introduction

- "Cardiac Catheterization is the insertion and passage of small plastic tubes (catheters) into arteries and veins to the heart to obtain x-ray images (angiography) of coronary arteries and cardiac chambers and to measure pressures in the heart (hemodynamics)" (Sorajja, Lim, & Kern, 2020, p. 1).
- Technological advancements in the field of cardiac cath have allowed the introduction of better imaging equipment such as intravascular ultrasound (IVUS) and optical coherence tomography (OCT) to be at the forefront of decision-making in interventional cardiology (IC) procedures such as percutaneous coronary interventions (PCI).
- The introduction of these particular pieces of imaging equipment has allowed for higher processing algorithmic functions when the use of artificial intelligence (AI) is deployed.

Artificial Intelligence (AI)

- The application of AI in IC can be divided into two main branches, virtual and physical.
- The virtual branch includes informatics from:
- Machine Learning (ML)- an automated system that learns to perform a task or make decisions automatically from an available data source
- Deep Learning (DL)- algorithms that are inspired by the workings of the human brain (Sardar et al., 2019, p. 1294)
- Natural Language Processing (NLP)- a confluence of AI and linguistics, focused upon developing a computer's ability to understand human language (Sardar et al., 2019, p. 1295)
    - Cognitive Computing- platforms integrate ML, reasoning, NLP, speech and object recognition, human-computer interaction, and dialog and narrative generation
    - Automated Clinical Decision Support Systems- under development with cognitive computing to include self-learning systems using ML, pattern recognition, and NLP to mimic human thought processes
- The combination of these main concepts allows AI to function as intended. AI is not just one type of software or algorithm, rather a multitude of different moving cogs coming together to form what is seen as the whole of "AI."
- The physical branch is best represented by robotic interventional procedures. While fascinating, the physical branch doesn't relate to the application of AI into these interventional procedures (Sardar et al., 2019, p. 1294).



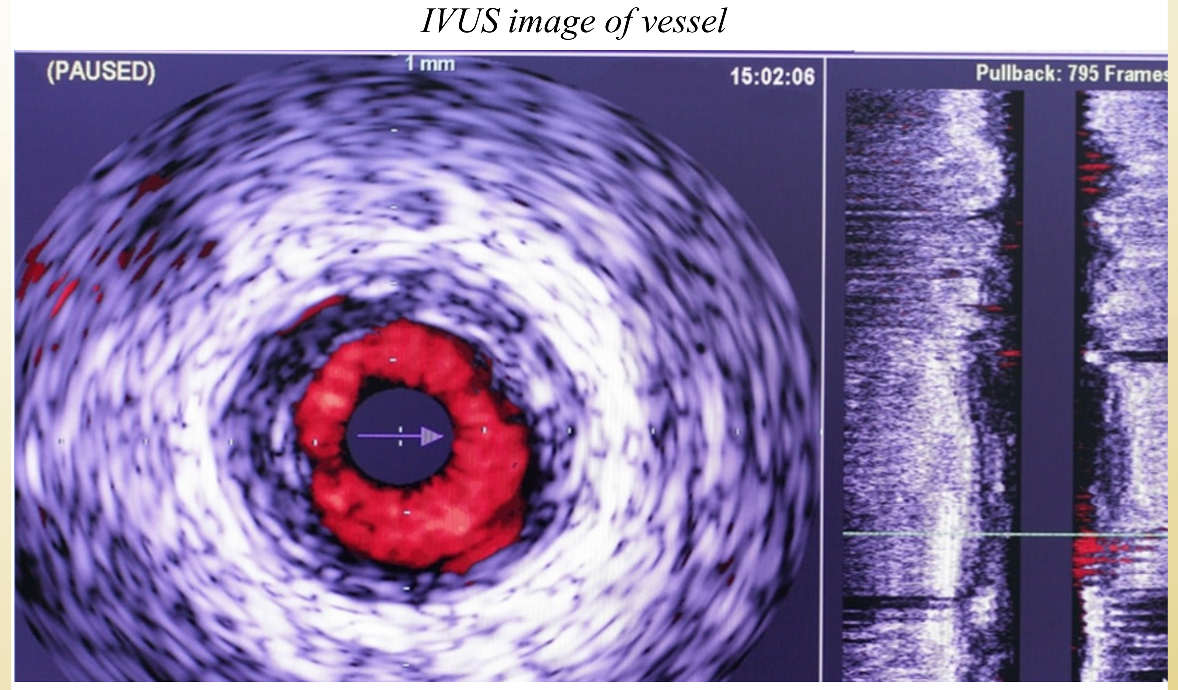
OCT-guided PCI on a calcified nodule

- These image demonstrate what OCT imaging looks like before and after rotational atherectomy and stent implantation.
- In image A, an arrow is showing a lesion in the mid LAD. Images B and C show the artery's small lumen and blockage.
- In image a, coronary angiography (CAG) shows what the artery looks like after rotational atherectomy. Images b and c demonstrate the artery's blockage after rotational atherectomy.
- Image a' uses CAG to demonstrate the vessel after stent implantation. Images b' and c' use OCT to show how stent implantation brought the lumen of this artery back to its normal size, as well as the length and width of the stent inside of the artery (Ali et al., 2021b, p. 115).

OCT and IVUS

- OCT utilizes near-infrared light directed at the vessel wall through a rotating single optical fiber coupled with an imaging lens within a short-monorail imaging sheath to obtain cross-sectional images of a vessel (Ali et al., 2021a, p. 106).
- IVUS uses high ultrasound frequencies of twenty to fifty MHz to provide qualitative and quantitative cross-sectional imaging of the lumen of a vessel (Lee & Hur, 2019, p. 773).
- When comparing these two devices together, IVUS penetrates farther into the vessel's morphology than OCT, but OCT has a tenfold higher imaging quality.

IVUS image of vessel

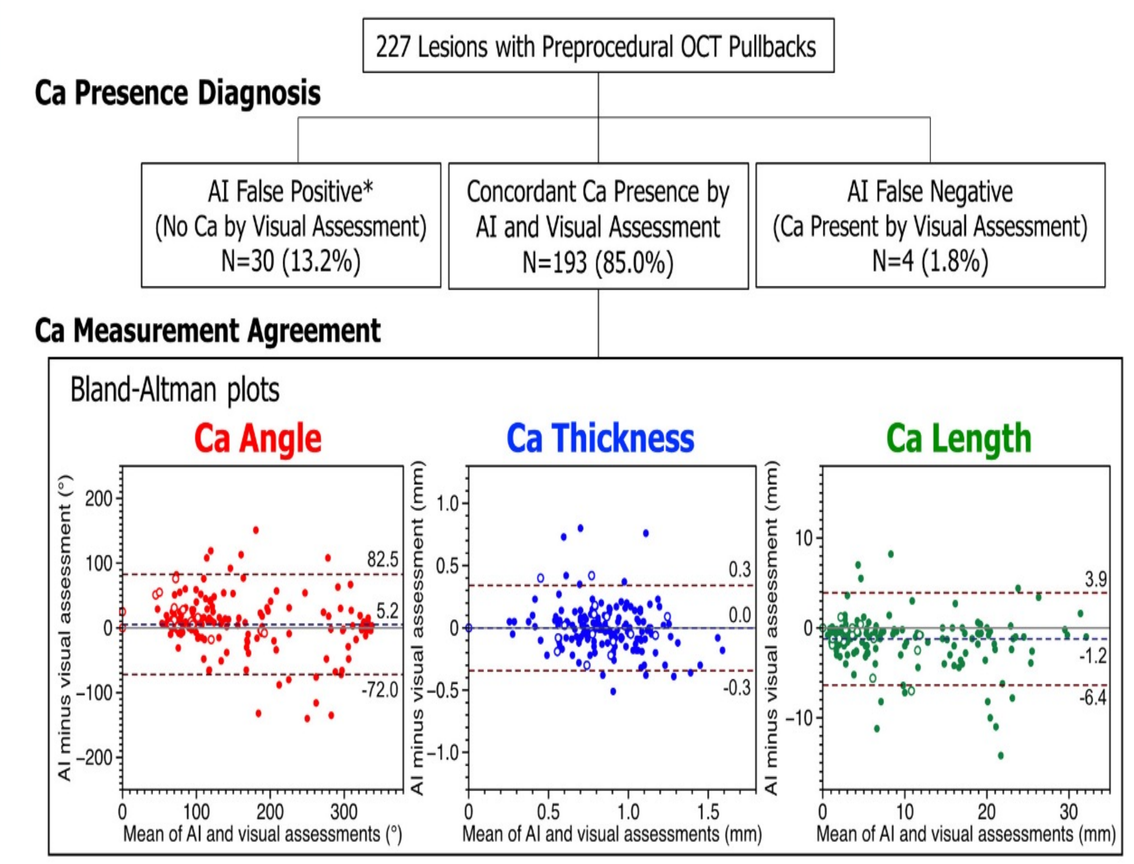


(Left Image) The inside of a vessel using IVUS. The red ring of the image represents the lumen and the white portion represents the outer edges of the vessel. The center circle represent the physical IVUS catheter.
(Right Image) The top of the image represents the distal end of the vessel being measured. Upon pullback of the IVUS catheter, the vessel will show its dimensions and any blockage or stent present inside (O'Sullivan, n.d.).

AI in IC

- The goal of AI is to make the job of a physician significantly easier so that procedural steps may be performed faster and more effectively.
- Based upon the aid of an AI, the outcomes of procedures should equate to a shorter stay post-procedure and a quicker recovery time.
- AI should be used in a way that allows physicians to make their own educated decisions while still being able have help from an outside source.

Comparison between AI and visual assessments of calcified plaque using OCT



This image show the comparisons between AI and visual assessments of a physician on the angle, thickness, and length of calcium (Ca) in vessels. Mean bias and 95% limits of agreement are shown by the dashed lines. White circles indicate acute coronary syndrome (ACS) lesions (Katagiri et al., 2022b, p. 2).

Limitations/Misconceptions

- Research done on an OCT AI system has shown that the current AI system overestimates the amount of calcification in ACS lesions with lipid components (Katagiri et al., 2022a, p. 2).
- Two-dimensional OCT imaging has limitations for bifurcation lesions during PCI's for evaluating stent deformations and fractures (Lee & Hur, 2019, p. 787).
- As with any novel technology, AI and its subspecialities are subjected to unrealistic expectations, which may lead to disappointment and disillusionment in the future (Sardar et al., 2019, p. 1300).
- "As more control is ceded to algorithms, it is important to note that these new algorithmic decision-making tools come with no guarantee of fairness, equitability, or even veracity" (Sardar et al., 2019, p. 1301).

Future Applications

- The future of AI relies heavily on more research. To further advance the understanding around AI, randomized, multicenter studies need to be completed to prove the superiority of OCT-guided PCI procedures.
- Ongoing developments have focused on engineering new OCT systems to increase the speed of OCT acquisition (e.g., within a single cardiac cycle with full sampling both cross-sectionally and longitudinally) and penetration depth (Ali et al., 2021a, p. 117).
- Promising progress has been made in developing algorithms for automated tissue classification using texture, attenuation, or other tissue characteristics on OCT that may aid in automated OCT image seg-mentation and interpretation (Ali et al., 2021a, p. 119).
- Since IC starts as soon as a person's heart is treated in any capacity, the addition of AI into emergency departments (ED) will become inevitable soon as well. A pilot study showed 94% accuracy of ML algorithms when detecting myocardial infarctions (MI) in patient's presenting with chest pain in ED's. (Sardar et al., 2019, p. 1299).
- "The ILUMIEN I trial reported that pre-PCI OCT contributed to a change in that treatment strategy in 57% of cases and post-PCI OCT drove further stent optimization in 27% of cases, suggesting that OCT already has a position as a user-friendly decision-making tool during stent implantations" (Lee & Hur, 2019, p. 788).

Conclusion

- The future of AI in IC will remain a heavily researched topic in the coming years.
- The advancements of AI in the healthcare field are still early on, and it is hard to tell when the introduction of AI into departments will be a more common occurrence.
- IVUS will remain the leading instrument in guiding PCI procedures for the foreseeable future because of the large amount of data that support its results.
- While America does not heavily use OCT, the number of studies being conducted in Asia and Europe are allowing the cardiology profession an insight into what the future of PCIs will look like.
- Robust evidence from the ongoing randomized trials on the impact of OCT guidance in improving clinical outcomes could increase the adoption of this imaging modality in clinical practice (Ali et al., 2021a, p. 119).

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