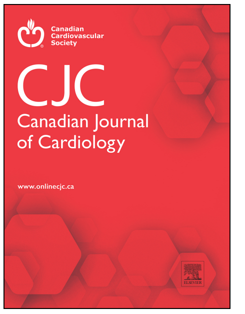

Exploring the Integration of Artificial Intelligence in Cardiovascular Medical Education: Unveiling Opportunities and Advancements

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Artificial intelligence (AI) is increasingly utilized in cardiovascular medicine. AI within education surged during COVID-19, as restrictions adversely affected the education of medical learners. AI emerged as a cost-effective solution to unmet educational needs, including assessment of trainee knowledge, clinical skills, and competence. Beyond mere knowledge assessment, AI has the capacity to train learners in various aspects such as image acquisition, interpretation, and the execution of interventional procedures. It has introduced versatile and innovative yet reliable methods for credentialing and facilitating continuous medical education. AI has the potential to educate, train and credential learners, thereby enhancing patient care.

AI in medical education: the nidus for discovery

Although the COVID-19 pandemic disrupted medical education globally, the medical community adopted new strategies to facilitate learning. Limitations were particularly in clinical interactions and hands on experience and performing examinations. Medical schools, societies, and scientific meetings transitioned to virtual, web-based platforms. The pandemic broadened our perspective, showing that professional interactions, educational activities, and learning can be conducted virtually. In many situations, these new platforms are likely cost-effective, time-efficient, and often had a greater reach by increasing attendance. Even with the resumption of in-person events, many have continued to offer a hybrid format. With the acceptance of virtual learning, teaching has expanded to include clinical instruction and exam delivery. Although didactic teaching and administration of examinations are often conducive to remote delivery, hands-on teaching and direct assessment of clinical skills is more challenging. This has opened doors for innovative solutions for continued learning in all facets of medical care delivery.[1]

AI for knowledge and clinical skills assessment

AI can be used to assess trainees' knowledge, clinical skills, and competence. It can score written answers and assess in-person components of a clinical skills assessment. AI programs utilize natural language processing to score students' answers in real-time and provide immediate feedback. For instance, at the University of Minnesota, AI is currently employed to teach clinical skills. They have developed a library of clinical cases covering more than 800 conditions. Students can engage with these cases and answer questions, with AI assessing their knowledge and offering immediate insights into their performance.[1]

AI scores student performance in both written and clinical skill assessments. Written assessments include multiple choice questions, free text questions, case-based scenarios and images created for analysis. For clinical assessment, students interact with standardized patients simulating medical symptoms. For instance, a full-day exam may consist of 12 stations for each of 257 students, totaling 12,336 cases to grade and score, which can take up to a month. The AI program scores students in real-time and provides immediate insights into their performance.[1] Preliminary work suggests that this process, if reliable, would remove evaluation bias by human assessors,[1] eliminating the need for human assessors or potentially serving as a "second observer" to ensure accuracy and impartiality. As a teaching tool, AI could offer real-time feedback akin to a teacher's input.

Additionally, AI is applied to video recordings of physician-patient interactions. Algorithms are being designed to analyze these encounters particularly focusing on non-verbal communication, empathy, and eye contact. Such assessments are time efficient, free of bias and helpful for training assessors who would otherwise grade these interactions.

AI will continue to evolve as it learns from observations and experiences, incorporating them into deep learning algorithms.[2] Learning experience from AI in cardiovascular medicine resembles AI-based simulators for airplane pilot training, which prepare pilots for realistic flight situations. This has significantly improved flight skills, reducing pilot errors and the number of flight accidents by more than 90%.[2] Similarly, like the airline industry, AI in healthcare could utilize advanced imaging such as virtual reality, augmented reality, mixed reality, extended reality, simulation, and holographic images to simulate scenarios.[2]

<u>**AI in cardiac imaging.**</u>

AI-guided interpretation of electrocardiograms (ECG) can be used to educate inexperienced users by detecting and identifying abnormalities. These abnormalities include arrhythmias, ST-segment changes, QTc prolongation, and others, which can be utilized to teach ECG criteria and diagnoses.[3,4.] AI algorithms can be trained on ECGs- and detect specific patterns and link them with certain outcomes as measurement or diagnosis. As an example, PMcardio's deep neural network (deep learning algorithm) model has been trained on a total of 931,344 standard 12-lead ECGs from 172,750 patients to detect 38 individual diagnoses.

The Canadian Journal of Cardiology published “Interpreting Wide-Complex Tachycardia using Artificial Intelligence”. Using 3330 wide complex tachycardia ECGs (including Supraventricular Tachycardia-SVT; and Ventricular Tachycardia-VT) a training/ validation and test algorithm was created to differentiate between SVT and VT. AI appeared to have superior accuracy than Cardiologists and like those of Electrophysiologists. Such AI models could assist with ECG interpretations and may result inl better patient care.

AI should be able to teach ‘fundamentals and basics’ where teaching more ‘nuanced and rare ECG’ may still require human expert teachers until further AI training is undertaken. One of the limitations is ‘common things’ are easy to find and train AI, but more rare conditions may requiretime to amass the data needed for training. AI has an interactive learning whereby it evaluates itself against other experts and learns from its mistakes.

Moreover, AI can also guide inexperienced operators in performing echocardiography. This guidance provides instructions on how to use ultrasound equipment and manipulate the probe to obtain standard views and optimize image quality in real-time. Once an acceptable view has been obtained, the clinician is instructed to proceed with the acquisition. This method offers teaching to less experienced users, enabling them to acquire diagnostic-quality images with real-time guidance and feedback.[2,4] Caption Guidance and Caption Health programs emulate the guidance of an expert sonographer by providing more than 90 types of real-time feedback and instructions. However, a human operator must approve these images.[2] This human "in-loop" approach ensures that AI results are sensible and prevent complete reliance on AI. The DiA LVivo is an AI-based automated ultrasonographic system for assessing Left Ventricular Ejection Fraction.[2] This approach is time-efficient, improves diagnostic accuracy, and is more reproducible and consistent. The EchoNet database contains more than 10,000 echocardiograms.[2] **(Figure 1).**

AI image analysis and interpretation are widely used in radiology to detect and classify abnormalities on plain radiographs, computed tomographic (CT) scans, and magnetic resonance imaging (MRI), leading to more accurate diagnoses and better treatment decisions.[3] Quantification algorithms perform segmentation and measurement of anatomical structures or abnormalities and can be used to detect clinically important findings such as lung masses, pneumothoraces, and pulmonary embolisms. AI is expanding into the cardiovascular space with algorithms being developed to assist and teach the interpretation of images in nuclear cardiology and cardiac CT.

If AI can accurately and safely be incorporated into clinical practice, it can then be used as an education tool for the trainees. It could be used to evaluate, supervise, and test trainees~~;~~ and provide feed-back.

AI integrated frameworks enable “precision medical education” E-learning modules can identify the learning styles of individuals and give instructions to the individual trainees based on their learning styles and needs. AI-augmented radiology can be used to interpret and provide diagnoses against which trainees can compare their own different diagnoses.

<u>Virtual procedural education.</u>

AI based deep learning algorithms can generate realistic 3D models of environments and even create dynamic scenarios based on user interaction. Virtual reality provides complete visual and tactile immersion that separates participants from the physical world. By using virtual reality devices like Oculus Rift or Google Cardboard, users experience virtual environments such as the cardiac catheterization laboratory, allowing them to interact within the simulated 3D environment. This system can be utilized for education, as the virtual reality headset enables viewers to visualize and virtually experience an interventional procedure, while instructors can guide learners in 3D space. The same platform could also be used for procedural planning.[2] Mixed reality combines both virtual and augmented reality, where real-world and digital objects interact, as seen in products like the Microsoft HoloLens for endovascular intervention. Extended reality combines various sense-enhancing technologies that provide information about the actual world or create completely simulated worlds to experience.

Holography is the process of creating 3D images, known as "holograms," using laser beams. With the use of computer modelling software and AI based algorithms, medical imaging dataset like echocardiography, computer tomography or angiography can be converted to digital holograms. These can be used to create visual images used to teach anatomy, allowing access to different layers from different angles in an attractive and intuitive way. Holograms can also store and retrieve imaging data as a 3D volumetric density, requiring 1000-fold smaller physical storage space than a DVD or optical disk making them very suitable for AI-driven applications.[2]

Holography can be used effectively for educational and proctoring purposes in Cardiovascular medicine. It offers trainees and proctored students an opportunity to visualize all the procedure components from various angles. Such techniques allow imaging details that may not be visible from viewer's position. Its use in endovascular procedures gives easy access to control, images and equipment and makes complex procedures efficient and safer.[2]

Although AI would not eliminate teachers or educators, it would provide trainees with additional training opportunities when teachers are not readily available or could be used in remote settings where there is a paucity of teachers.

Role of AI in continuing medical education

Web-based AI applications can address unmet needs for properly structured and up-to-date educational resources for physicians in training. This provides on-demand and user-friendly proctoring, credentialing, and recredentialing in various aspects of cardiovascular education, imaging, and procedures.[5]

There is a desire by examination boards for AI to create and mark examination questions. AI would review existing literature, guidelines, and create questions that could be used for both certification and maintenance of certification.[5]

High-definition zoom cameras are used in procedural telemedicine and creates opportunities for remote proctoring. Remote users can control multiple displays simultaneously. It provides an easier way to collaborate with peers and experts.[5]

Cardiology training programs need critical review to inculcate AI related training and some institutions have begun to provide AI education. The Mayo Clinic provides a course “Artificial intelligence in Cardiology- current applications and future of artificial intelligence in Cardiology”.

AI and language models can help in medical education and training in cardiology by providing access to educational resources. A language model can analyse textbooks, research papers, and other resources to provide up to date information.

AI can be used to develop virtual training tools that mimic a patient with a cardiac condition and allow the trainees to practise diagnosing and treating the condition in a realistic setting. Simulate real-world clinical scenarios that can help medical professionals more accurate diagnosis and treatment conditions.

Language models like ChatGPT-4 can create simulated cases and questions for different level of training, like medical student, resident, and cardiology fellow.

AI technologies will hopefully have a positive impact on clinical training. It will be most beneficial if AI related topics are formalized in curricula and If trainees are provided sufficient and formal AI training. In doing so AI would ideally be an interactive platform not only to train, but also need to get feedback from seasoned clinicians and follow up from outcomes and erroneous interpretations, for example, incorrect diagnosis. Such feedback can improve algorithms, and would translate into changes in education and knowledge transfer. **(Figure 2).**

Future challenges

AI will face challenges related to changes in disease prevalence, advances in medical technology, and changes in clinical practice. There will be a need for continuous monitoring of model performance, anticipation, and addressing of dataset shifts over time, updating training data, training, and retraining the AI models. Similarly, checks and balances will be needed to ensure accuracy and identify AI misdiagnoses.

In addition, AI and language models will need to be current with latest research. AI tools will be expensive and lead to increased healthcare cost. There will be concerns of limited hands-on experience, loss of human empathy, touch, and consideration of cultural factors. With time there will be limited exposure to real-world scenarios compared to teaching models. As medicine evolves, there will be a need for feedback from clinicians who can guide AI in areas requiring improvement and practicality.[2,4,5]

Conclusion

The role of AI in education, learning, and professional development in healthcare continues to expand. With AI's expansion into the clinical realm, some of the knowledge can be transferred to educational forums. Future growth in medical education AI requires collaboration between computer scientists, healthcare professionals, teachers, and researchers. AI has the potential to improve education by expanding learner knowledge, facilitating experiential learning, and testing to ensure competency.

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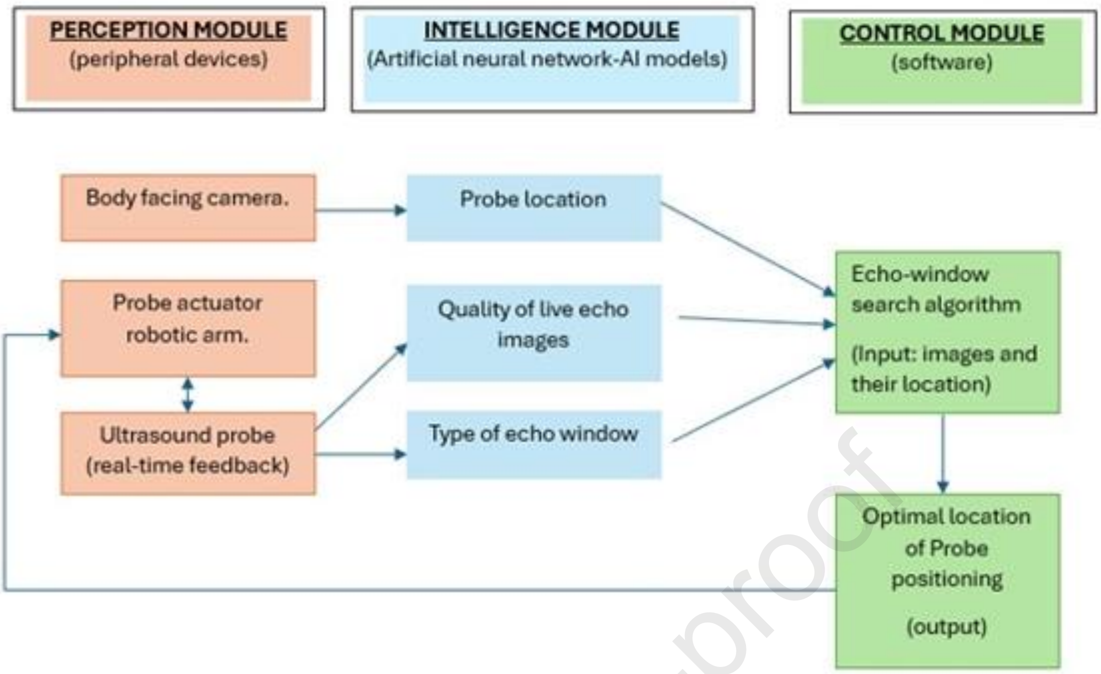

Figure 1. Diagram demonstrating how Artificial Intelligence Echocardiography programs work and provide feedback. Adapted and modifed from Soemantoro, R; Kardos,A; Tang, G; Zhao, Y. An AI-Powered navigation framework to achieve an automated acquisition or cardiac ultrasound images. Scientific reports, volume 13, Article number: 15008 (2023).

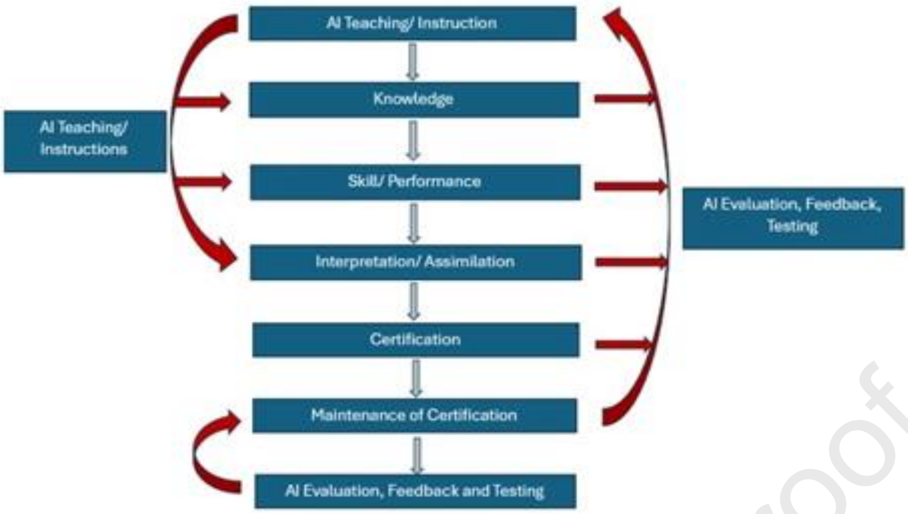

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Figure 2. Diagram showing steps involved in integrating Artificial Intelligence into Cardiovascular Medicine education to improve patient care.

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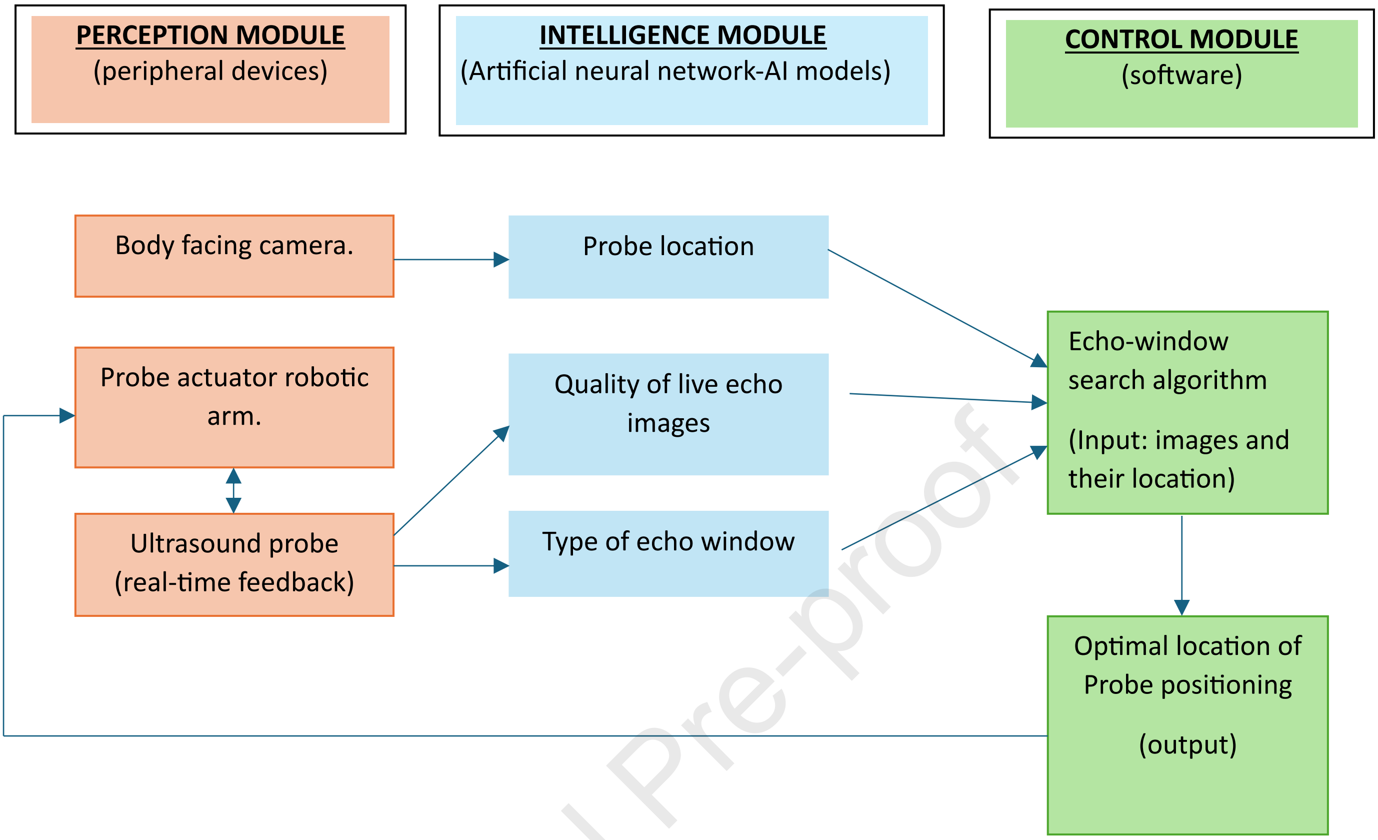
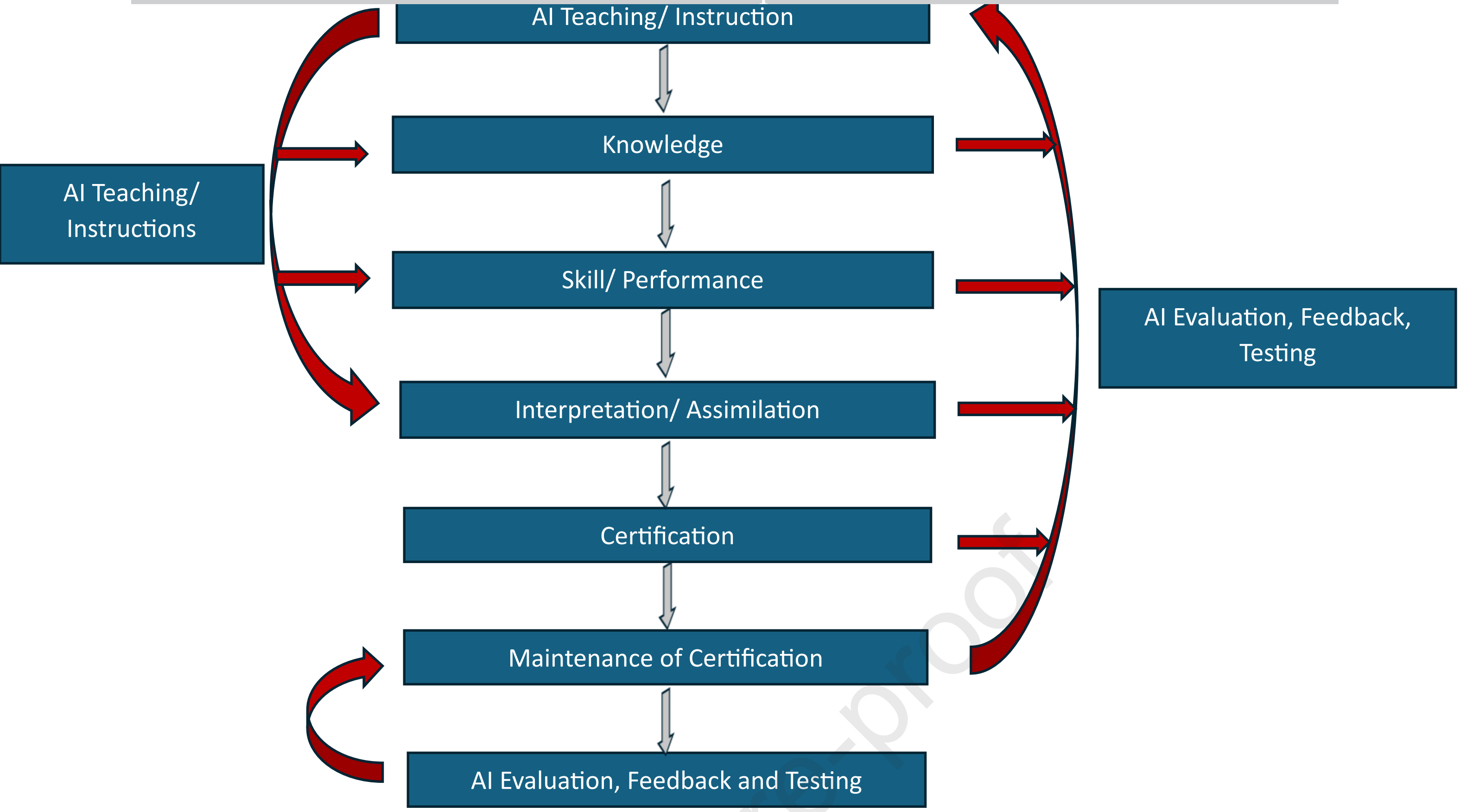

PERCEPTION MODULE
(peripheral devices)
INTELLIGENCE MODULE
(Artificial neural network-AI models)
CONTROL MODULE
(software)
Body facing camera.
Probe location
Probe actuator robotic arm.
Quality of live echo images
Echo-window search algorithm
(Input: images and their location)
Ultrasound probe (real-time feedback)
Type of echo window
Optimal location of Probe positioning
(output)


AI Teaching/ Instruction
Knowledge
Skill/ Performance
Interpretation/ Assimilation
Certification
Maintenance of Certification
AI Evaluation, Feedback and Testing
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