The Role of Advanced Imaging Technology in Structural Heart Interventions

Dr. Carey Kimmelstiel and Dr. Praveen Mehrotra about the challenges they face in structural heart procedures, how the equipment they use helps to address those challenges, and the future of structural heart imaging.

Carey Kimmelstiel, MD, FACC, FACP, MSCAI
Director of the Cardiac Catheterization Laboratories and Interventional Cardiology, Tufts Medical Center, Boston, Massachusetts.

Praveen Mehrotra, MD, FACC, FASE
Director of Echocardiography, Thomas Jefferson University Hospital, Philadelphia, Pennsylvania.

Cath Lab Digest

Can you tell us about the setup of your structural heart lab, the systems you work with, and the types of procedures you do?

Carey Kimmelstiel, MD: *Our lab does about 3000 procedures a year in three rooms. We have three GE HealthCare labs: one biplane, one single plane, and one hybrid.*

We do all manner of procedures, including coronary procedures, biopsies, and right heart catheterizations for our transplant program, all the way through to septal ablations for hypertrophic cardiomyopathy, transcatheter aortic valve replacement (TAVR), MitraClip™, Watchman™ for left atrial appendage occlusion, patent foramen ovale (PFO)/ atrial septal defect (ASD) closures, and paravalvular leaks. We do some different cases in our lab as well, such as percutaneous decommissioning of left ventricular assist devices, closing pulmonary arteriovenous malformations, and coarctation of the aorta. We have even delivered two babies in our cath lab for high-risk patients with primary pulmonary hypertension and at high risk for needing extracorporeal membrane oxygenation (ECMO). We do a high number of ECMO and Impella® procedures in a variety of patient populations to provide percutaneous myocardial circulatory support.

Praveen Mehrotra, MDl: *We have four cardiac catheterization labs (one GE HealthCare lab, three Philips labs) and we do approximately 4500 procedures per year. The echocardiography laboratory supports the cardiac catheterization laboratory for the performance of select structural heart procedures including TAVR, MitraClip, Watchman for left atrial appendage occlusion, patent foramen ovale (PFO)/atrial septal defect (ASD) closures, and paravalvular leak closure, among others. We utilize the GE HealthCare Vivid E95 Vivid Uultrasound system to support the guidance of structural heart procedures.*

What are some of the challenges you face during structural heart procedures?

Carey Kimmelstiel, MD: *Over time, as our cases have increased in complexity, the heart team continues to grow in size. Space is always an important limitation, even in the large hybrid room we have at Tufts, so it is key to be able to modify the footprint of your room in order to accommodate the specific procedure being performed. If we are doing myocardial support and need to have a surgeon involved for a cut down, for instance, it is very important to have the room accommodate you, as opposed to you accommodating the room. Or if we are doing an alternative access TAVR, perhaps a transcarotid or transsubclavian TAVR, for instance, there will be different people in different positions than in a usual femoral access approach. Our ability to change the actual footprint of the room with the use of a movable gantry is important. Our GE HealthCare system has a number of preprogrammed settings for different procedures where the gantry moves to a position accommodating the presence of a surgeon, anesthesiology team, or perfusion team, depending on the procedure.*

Praveen Mehrotra, MD: *At Jefferson, one of my roles is helping to guide transcatheter and structural heart procedures in the cardiac catheterization laboratory and hybrid OR with transesophageal echocardiography. One of the main challenges we face is the requirement for crystal clear two- and three-dimensional (2D and 3D) echocardiographic imaging during these procedures, particularly when there are catheters, wires, and other devices in the heart, which tend to create significant artifact. We need to then provide information rapidly, in real time, to the interventional cardiologist or surgeon. We also need to be aware about what is happening from a procedural standpoint under fluoroscopic imaging as well as on echocardiography, and integrate that information in order to provide the best possible feedback to the proceduralist.*

What technology and/or artificial intelligence (AI) is helping to solve clinical challenges in structural heart procedures and what would you like to see from your imaging provider in the future?

Carey Kimmelstiel, MD: *It all comes down to image quality and radiation dose. The imaging system should automatically be optimizing dose and image quality so the physician can remain focused on the patient and procedure. I don't want to be changing parameters in the middle of a procedure. In our Discovery hybrid*

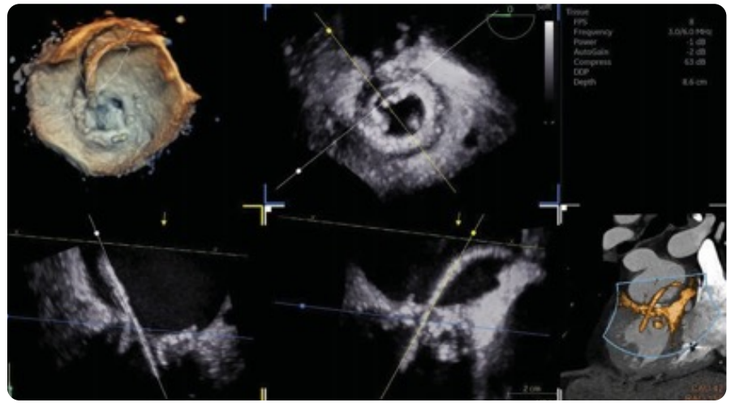

Figure 1. Live co-registered navigation in 4D ultrasound and CT data to better help understand the heart anatomy.

room, the AutoRight™ feature, which is AI-based, makes it possible to modify the parameters online, which will then reduce dose while maintaining image quality. AutoRight is able to tell how much kV (dose) is needed to get through the patient. This is quite an important feature, because you want the best image quality at the lowest radiation dose.

GE HealthCare's fusion system helps by al lowing us to fuse the live fluoroscopy to the pre-procedure CT scan. Most of the time, before walking into the room for a TAVR, for example, you already will have a fairly good understanding of how valve alignment is going to take place, because of the pre-procedure imaging. Fusion technology plus additional software that we use allows us to determine the angulation and directs how to position our detector so we have the best views for performing TAVR. The fusion software also allows us to further minimize the dose of radiation during the procedure, particularly in complex procedures using distal protection such as the Sentinel™ system to protect the cerebral circulation in patients who are undergoing TAVR.

Pre-procedure imaging is something that we rely on heavily. I expect to see further improvements in 3D reconstruction beyond what is currently available and is already excellent. We look forward to doing procedures such as left atrial appendage occlusion or even percutaneous mitral valve replacement not just with transesophageal echocardiogram, but potentially with enhanced imaging like intracardiac echocardiography (ICE), which we now routinely use for PFO closures. Further development of ICE capabilities is something that we want to see more of in the future from our imaging vendors. If we need to do a transseptal puncture, it is possible to get a good idea of the best places to puncture the septum with transesophageal echocardiogram (TEE); perhaps this is less true currently with ICE, but the technology is improving. You can even get a very good idea of where to puncture the interatrial septum with fusion imaging.

We are using the Medis system for online quantification of coronary stenosis. This is a quantitative flow ratio (QFR)-based system. Medis is not wire based, nor does it require administering any drugs or obtaining CT imaging. Tufts Medical Center is the first place to use Medis, and we have found the ability to assess physiologic coronary stenosis severity online in the cath lab without requiring a wire or giving adenosine to be an exciting advancement. You need two orthogonal views and it takes five minutes.

> *"There is a new technology called 4D Markers, which we can place on 2D and 3D echo images. The interventional cardiologist can view the 4D Markers onscreen and use them as a target, so he or she knows where we are asking them to direct a wire or catheter without having to verbalize it or struggle to communicate that information."*
> Praveen Mehrotra

In the future, I expect to see further advances, not just for TAVR. I think there will be more 3D imaging or holographic technology. Let's say you are doing a mitral or a tricuspid valve

case in a room that does not have biplane capability, yet allows you to image with one sweep of the detector and get better imaging of the structure that you are working on. It involves the speed of the movement of the x-ray detector at a reasonable radiation dose. This is a work in progress, I think, for most of the vendors, and they are doing interesting work around that ability right now. Some of this technology is already available, but it will certainly continue to be modified.

Praveen Mehrotra, MD: *There are several echocardiographic technologies, recently developed, that help to solve some of the imaging challenges during structural heart procedures. First and foremost is the need for outstanding 3D volumetric and multiplanar imaging with high spatial resolution and frame rates. We use live 3D imaging to help guide certain procedures and to obtain critical measure- ments prior to the start of the procedure, usually for device sizing. There is a new technology called 4D Markers (GE HealthCare), which we can place on 2D and 3D echo images. The interventional cardiologist can view the 4D Markers onscreen and use them as a target so he or she knows where we are asking them to direct a wire or catheter, without the echocardiologist having to verbalize it or struggle to communicate that information. The markers exist in 3D space, so we can see them in multiple views simultaneously. Another useful technology called View-X (GE HealthCare) places the fluoroscopic image adjacent to the TEE image on the echo machine. This technology allows me to visualize the procedure from the standpoint of the interventionalist, integrate fluoroscopic and echocardiographic data, and anticipate what information will be needed next by the interventional cardiologist or surgeon.*

In real life, catheters and cardiac structures don't exist in perfect 2D planes, but in 3D space, and so we frequently rely on 3D technology to guide structural heart procedures. We recently performed a transcatheter mitral valve intervention with MitraClip, and we were not able to guide device placement with routine 2D imaging because we couldn't visualize the MitraClip delivery system in conventional 2D imaging planes. However, we were able to utilize live multiplanar 3D imaging with FlexiSlice (GE HealthCare), which allowed us to manipulate the imaging planes such that the guide catheter, delivery system and MitraClip could be visualized in a single imaging plane. The technology allowed us to visualize and implant the device with ease, resulting in a good outcome for the patient.

We are also starting to use fusion technology. There are several different types of fusion imaging technology currently available on the market; one recently released fusion technology is CT-Echo Fusion (GE HealthCare) that fuses previously acquired CT data to the live 3D echo image. Echocardiography can suffer due to dropout from calcification or devices. This fusion technology allows us to integrate CT imaging that we already utilize for pre-procedural planning of structural heart procedures and integrate that with the echocardiographic images obtained on the day of the procedure. These fusion technologies are currently evolving and may prove to be very useful in complex structural heart procedures where echocardiography alone may not be sufficient.

Another new technology called FlexiLight imaging (GE HealthCare) is a new 3D rendering technique that provides photorealistic, light-sourced based illumination of heart structures that help the imager with depth perception when visualizing cardiac structures. This imaging technique can provide realistic detail of the contours of cardiac structures that we have not been able to appreciate previously. FlexiLight can also potentially better illustrate the interaction of devices with valve leaflets or when complications such as leaflet perforation may have occurred.

> *"We often want to perform structural heart procedures when patients are not fully intubated or anesthetized, so a miniature 3D TEE probe is potentially a very useful technology that may allow us to utilize TEE when the patient is only under moderate sedation.*
> Praveen Mehrotra, MD

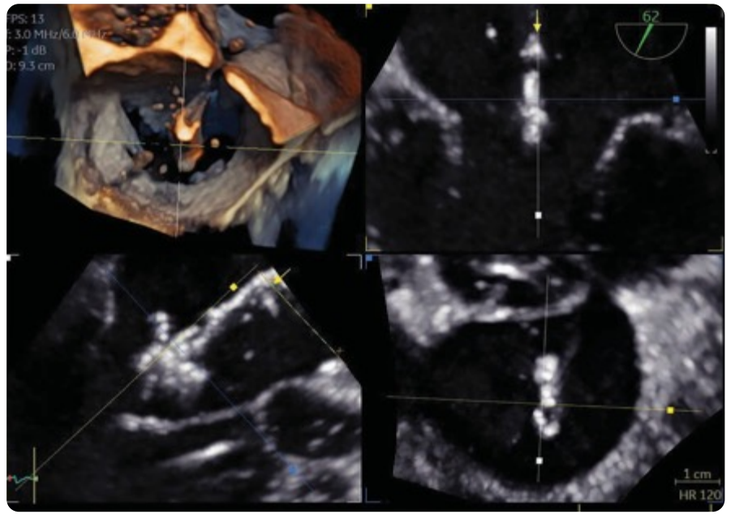

Figure 2. Multiplanar 3D imaging to guide transcatheter mitral valve repair with MitraClip.

Holographic imaging technology is another technology that is being developed and is used in some institutions. Interventional cardiologists and surgeons can work with these holographic displays and manipulate them in 3D space so they can plan their procedures with greater accuracy.

I also want to note the recent development of the new mini 3D TEE probe (GE HealthCare), which will be very useful in certain patient populations such as pediatric patients, smaller adult patients, or those in whom general anesthesia may not be able to be utilized. This type of technology has not been available in the past. We often want to perform structural heart procedures when patients are not fully intubated or anesthetized, so a miniature 3D TEE probe is a potentially a very useful technology that may allow us to utilize TEE when the patient is only under moderate sedation. In cases of smaller-statured patients, we have had difficulty in certain instances in placing the larger, full-sized TEE probe. We have utilized pediatric probes in the past, but they previously were limited to 2D imaging. Having a new pediatric-sized probe with 3D multiplanar imaging is definitely a game changer.

Dr. Mehrotra, can you talk more about the use of transesophageal versus transthoracic echo?

Praveen Mehrotra, MD: *Transthoracic echo is now used predominantly for TAVR, particularly with transfemoral access, since it still provides basic information very well and allows the patient to avoid being fully anesthetized and intubated. We also use transthoracic imaging to guide procedures such as pericardiocentesis and myocardial biopsy. However, if you need exquisite tissue detail, 3D imaging, and more quantitative information, TEE is necessary and remains the gold standard. There is potential for the use of 3D intracardiac echo (ICE) and several companies have developed or are developing 3D ICE catheters. In the past, 3D ICE catheters have suffered from small volumetric acquisitions, meaning that the size of the 3D volume was small, but newer catheters have the ability to provide larger volumetric acquisitions.*

For echocardiologists, one common challenge is navigating the devices and communicating with the interventional cardiologist during the procedure. Dr. Mehrotra, how do you address this challenge?

Praveen Mehrotra, MD: *First and foremost, you have to communicate clearly. The interventional cardiologist also has to understand and appreciate what is happening on the echocardiographic images, and I have to know what is happening on fluoroscopy. We both have to utilize the same common spatial language so we understand each other during device deployment or catheter positioning. The echocardiographer also has to have a keen understanding of the procedure being performed, the device being implanted, and potential complications. Even though we are not performing the procedure itself, we still have to understand the procedure inside and out. Ultimately, when the*

quality of both the echocardiographic and fluoroscopic imaging is outstanding, communication between the two specialists becomes easier.

What impact do advancements in echo have in structural heart procedures and for overall patient care?

Praveen Mehrotra, MD: *Fluoroscopy suffers from not being able to visualize soft tissue, and as a lot of these interventional procedures become less invasive, echo is emerging as an important tool to provide critical information for sizing of devices, guidance of the actual procedure, and for postprocedural follow-up, including immediately after implant and evaluating for complications. For valve implantation or transcatheter mitral valve repair, we measure the gradients immedi- ately post device placement. We make sure that the valves are well expanded, and devices like the MitraClip are properly deployed, and not causing stenosis or leaving behind residual regurgitation. Assessing gradients and assessing residual regurgitation after device implantation is a critical part of the procedure. This type of evaluation is not the same as assessing native valve regurgitation or stenosis. It is much more complex because we have to understand the interaction of the device with cardiac tissue. In order to achieve an accurate assessment, we must have all the right tools in our toolbox. Echo is critical in all these areas and in order to provide the best clinical care for our patients, we have to utilize and provide these technologies to our patients so that we can achieve the best possible clinical outcome.*

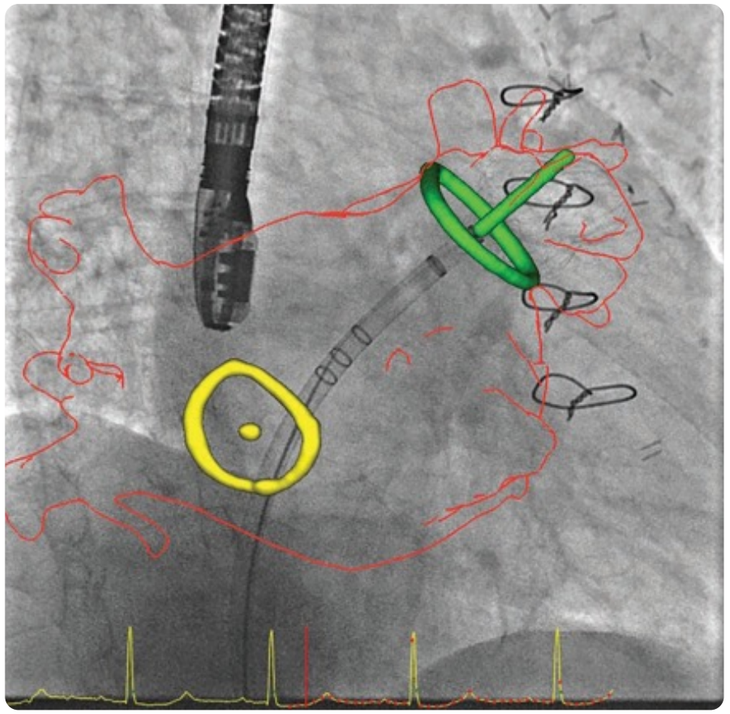

Figure 3. Left atrial appendage closure using GE HealthCare's Valve ASSIST 2 fusion imaging.

Dr. Kimmelstiel, with the indications for the treatment of aortic stenosis expanding for the TAVR population and the number of procedures expected to grow, how will your heart team accommodate that growth?

Carey Kimmelstiel, MD: *My partner, Dr. Charles Resor, has done a phenomenal job in accommodat ing the increased growth in TAVR procedures. He has streamlined the process of evaluation so that the surgeon and the interventional cardiologist, along with our advanced practice providers, see the patient on one visit. Patients are able to make one trip to see all of their providers and have all the requisite imaging done on the same day. It is a busy day, but they will get CT scans, meet with the physicians, and have all their questions answered. By streamlining the administrative side and the imaging side clinically, we are able to accommodate increased numbers into what is essentially a referral population that may not be living locally.*

There are current conversations regarding TAVR procedures moving into an outpatient, same-day discharge procedure. What do you think about this possibility?

Carey Kimmelstiel, MD: *It is amazing. I do a high volume of PFO and ASD closures, and Tufts probably offers the biggest program in Boston for these procedures. During COVID, one thing we learned is what is possible to be done as an outpatient. We switched over our PFO/ASD program to be almost all outpatient. On the TAVR side, I also believe that same-day discharge will ultimately happen. There are certain constraints. The valves and equipment will likely have to shrink somewhat. The outpatient population, of course, will initially be the younger, healthier patients, the so-called low risk or intermediate risk patients. The elderly, very high risk patients, are not likely to be safe for outpatient procedures and will continue stay overnight, just because they are older, sicker and takes them somewhat longer to get mobilized after an interventional procedure, even when you don't use general anesthesia.*

What factors do you take into consideration when balancing radiation dose to obtain the necessary image quality to achieve your procedural goals? How does your imaging system support your needs?

Carey Kimmelstiel, MD: *Maintaining a balance between image quality and radiation dosing is something that tends to be glossed over by many clinicians and interventionalists. You need to maintain a strong relationship with the vendor of your system. You want them to continuously remind you of the best algorithms for reducing dose while maintaining or improving image quality. It goes beyond the standard rubrics of keeping the detector as close to the patient as possible, and collimating judiciously. Most interventionalists know these things. However, there are nuances to every system, and it requires at least a basic understanding of the software in order to obtain the best image quality at the lowest dose. I strongly believe that these type of discussions with your vendor are underutilized by most interventionalists, so stay in touch with your vendor. I know GE HealthCare is very willing to send in their clinical specialists to help. It behooves you to take advantage of that experience and regularly seek to understand newer products and software packages, so that you can institute their use and maintain image quality. We bring in imaging specialists from GE HealthCare a few times per year to review our imaging quality, advise how we can improve, and evaluate whether there has been any degradation as the system ages. We have been very pleased with our partnership.*

Thank you to Drs. Kimmelstiel and Mehrotra for sharing their insights on the impact of technology advancements for structural heart procedures and their views on the future of structural heart imaging. ■

4D ICE NUVISION catheter is only available in the USA. The combination of Vivid E95 with 4D ICE NUVISION is not CE-marked. 4D ICE NUVISION is distributed by Biosense Webster.

9VT-D probe is exclusively available for Vivid E95 and Vivid E90 systems. Vivid Ultra Edition is released as of 25th August 2022 Ultra Edition is not a product name, it refers to the 2022 release of the Vivid portfolio.

JB01436XU