GE HealthCare

Vivid™ Magazine

EDITION 1

Dagfinn Saetre,
General Manager
Cardiovascular Ultrasound

Dear Reader,

We at GE HealthCare believe that, together, we can achieve a future where healthcare has no limits, and it is a privilege to collaborate with such dedicated and hard-working professionals like yourself.

We are honored to share the first release of the Vivid Magazine where we pay a special tribute to the dedicated professionals in the field - the sonographers, cardiologists, and cardiac imagers who conduct cardiac examinations day in and day out and are responsible for providing diagnoses for both simple and complex cases. This magazine serves as a repository of inspiring stories, remarkable achievements, challenging clinical cases, and publications that have been achieved with the help of our **Vivid** solutions.

In this first edition of Vivid Magazine, we highlight recent achievements in Structural Heart Interventions, where echo imagers provide expertise and support to increase access to minimally invasive therapies. 4D ultrasound visualization is critical in improving diagnostic confidence, understanding patients' heart morphology, and guiding interventions.

However, some patients cannot tolerate the adult 4D TEE probe, which limits their access to minimally invasive therapies. Additionally, general anesthesia requires more time and staff support, limiting the number of procedures that can be performed per day. Some patients are also too frail to undergo cardiac surgery or minimally invasive structural heart interventions that require general anesthesia.

Dr. Marta Sitges and Laura Sanchis from Hospital Clinic de Barcelona share their experience with the world's first miniaturized 4D TEE probe[1], which aids wider access to minimally invasive therapies to help improve diagnostic confidence. Dr. Carey Kimmelstiel and Dr. Praveen Mehrotra from Tufts Medical Center, Boston, Massachusetts, discuss the challenges in structural heart procedures and the future of structural heart imaging.

We hope that this magazine will inspire you to share your success stories with your peers and provide a platform to learn from one another. Feel free to contact us if you would like to share your own stories with your peers in the next edition.

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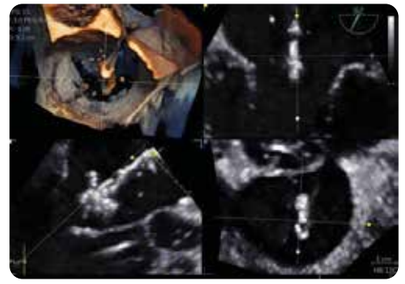
1. 9VT-D probe is exclusively available for Vivid E95 and Vivid E90 systems. Vivid Ultra Edition is released as of 25th August 2022 Ultra Edition is not a product name, it refers to the 2022 release of the Vivid portfolio.

Vivid Magazine



STRUCTURAL HEART INTERVENTIONS

First experience of left atrial appendage occlusion using a 3D mini transoesophageal echocardiographic probe with conscious sedation

Laura Sanchis, MD, PhD ; Ander Regueiro, MD, PhD ; Pedro Cepas-Guillen MD, PhD; Marta Sitges, MD, PhD ; Xavier Freixa, MD, PhD

Publication: EuroIntervention 2023 - Print January 2023

Patient History

Male, 77 years old, 55 kg LAAO with Amplatzer Amulet 20

- Duration of the intervention 40 min
- Fluoroscopy 10 min
- Duration of probe insertion 24 min

Percutaneous left atrial appendage (LAA) occlusion (LAAO) is an alternative to oral anticoagulation for those patients with atrial fibrillation and a contraindication to or high risk for anticoagulation1. LAAO procedures are typically performed with a 3D imaging technique (transoesophageal echocardiography [TOE] or computed tomography [CT]). For intraprocedural guidance, 3D-TOE is generally used, requiring general anaesthesia in most centres. Technological improvements such as the micro-TOE probe (10T-D; GE Healthcare)2, allow LAAO guidance using only minimal sedation and resulting in same-day patient hospital discharge. However, micro-TOE also has limitations (monoplane imaging, bad visualisation of the far field, need for specialised training…) which limit intraprocedural guidance in complex anatomies or inexperienced centres.

A novel mini TOE probe with 3D capabilities (9VT-D; GE HealthCare) has recently been released on the market for use in the paediatric population (Figure 1A) but with the potential to be used in adults as well. Theoretically, it will maintain the good tolerance of the micro-TOE probe while providing full 3D imaging capabilities. There are additional advantages, as compared to the micro-TOE probe, that include superior 2D imaging quality, bi-plane imaging for a safer transseptal puncture and better control during device implantation, and the possibility to perform 3D measure-ments for device selection during the intervention.

We present a series of the first 4 patients who underwent LAAO guided with a 3D mini TOE probe at our centre. All patients were consecutively treated on the same day. The tolerance of the probe was excellent for all of the patients, with local oropharyngeal anaesthesia with lidocaine and minimal sedation (0.025-0.05 mg of fentanyl and 1-2 mg of midazolam − the same regimen used with the micro-TOE probe at our centre). Imaging was good, allowing a safe transseptal puncture with bi-plane guidance and 3D measurement of the landing zone. Device sizing was based on the 3D measurements obtained during the intervention. All four procedures were success- ful with no residual leaks and no intraprocedural complications (mean duration of the intervention 52 min, fluoroscopy 12.5 min, radiation dose 58.1 microGy/m2, TOE probe insertion 25.2 min). Only one patient (#2) required angiographic contrast administration due to the extreme chicken wing morphology of the LAA. Figure 1B-Figure 1G and Moving image 1 show the interventional echocardiographic images during LAAO of patient #1. All patients were discharged on the same day with no complications after a 6-hr monitorisation and check-up echocardiogram for pericardial effusion evaluation. Supplementary Table 1 includes patient characteristics and procedural data for all patients; Supplementary Figure 1 includes images from the interventions in patients #2-4.

The initial experience with the new 3D mini TOE probe showed good tolerance (despite minimal sedation and the supine position of the patient) with excellent imaging quality of the LAA that allowed an effective and safe LAAO guidance. The use of mini/ micro TOE probes may improve the efficiency of the catheterisation laboratory by increasing the number of patients treated per workday and allowing a safe same-day hospital discharge.

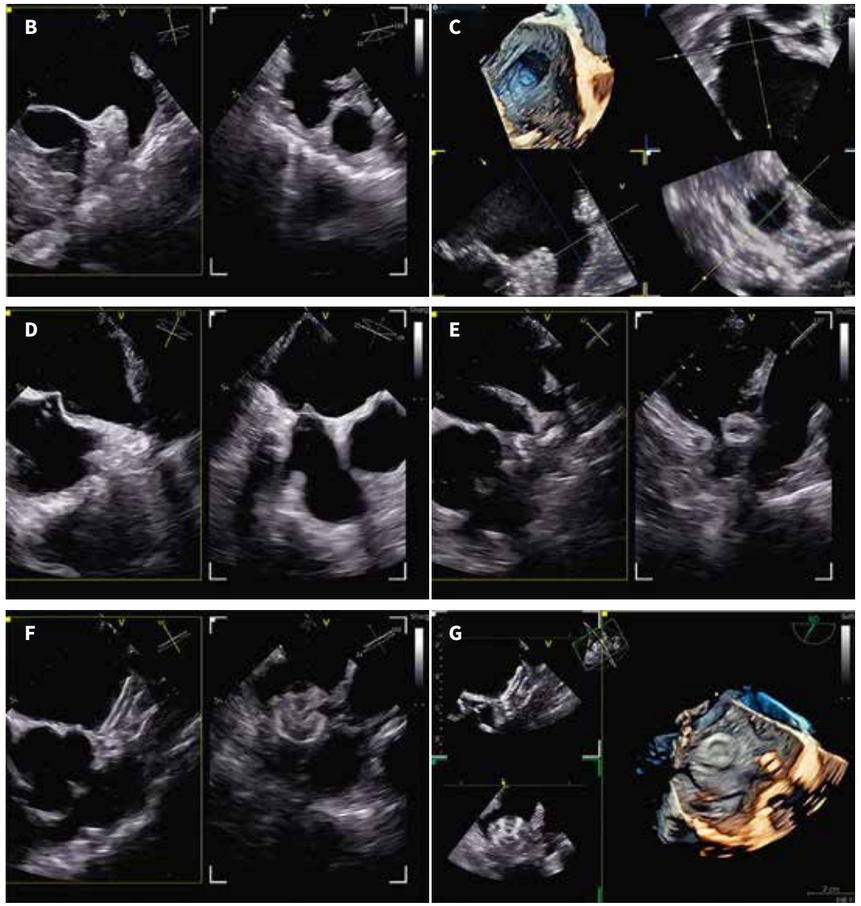


Figure 1. Interventional echocardiographic images during left atrial appendage oclusion of the first patient. A) A comparison of the mini 4D probe 9VT-D (centre, green circle) with the standard 4D probe 6VT-D (top) and the micro 2D probe 10T-D (bottom). TOE images of patient #1 during LAAO: B) LAA with bi-plane view, C) 3D LAA image with multiplanar reconstruction for landing zone measurement, D) bi-plane view for transseptal puncture with the needle inducing tenting in the septum, E) initial positioning of the device with bi-plane view, F) final position of the device with bi-plane and 3D imaging (G). 3D: three-dimensional; LAAO: left atrial appendage occlusion; TOE: transoesophageal echocardiography

Supplementary Table 1. Baseline patient characteristics and procedural data

	Patient #1	Patient #2	Patient #3	Patient #4
Sex	Male	Male	Male	Male
Age (years)	55	75	86	102
Weight (kg)	55	75	86	102
Midazolam dose (mg)	2	1.5	1	2
Fentanyl dose (mg)	0.025	0.05	0.025	0.025
Intervention duration (min)	40	61	46	60
Fluoroscopy	10	19	5	16
duration (min)				
Time with TEE inserted (min)	24	33	17	27
Contrast (ml)	0	60	0	0
Landing zone 3D measurement (mm)	16x15	14x13	22x21	22x18
Device	Amplatzer Amulet 20	Lambre 18/24	Amplatzer Amulet 25	Amplatzer Amulet 25

Patient #2 - 67 yo, 75kg,Lambre 18x24

Patient #3 - 78 yo, 86kg, Amplatzer Amulet 25

Patient #4 - 74 yo, 102kg, Amplatzer Amulet 25

Supplementary Figure 1. Echocardiographic images from the interventions in patients #2-4.
Bi-plane view of the LAA, 3D imaging from left atrium of the ostium of LAA, 3D measurement of the landing zone with multiplanar reconstruction and final visualization with the device after deployment are shown. For patient 3, it is also included the angiographic visualization of the LAA with contrast.

Conflict of interest statement
X. Freixa is a proctor for Abbott and LifeTech Science. M. Sitges is a consultant and speaker for General Electric, Medtronic, Edwards Lifesciences, and Abbott. L. Sanchis is a proctor for Abbott and a speaker for General Electric and Abbott. The other authors have no conflicts of interest to declare regarding the present paper.

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2. Jiménez Brítez G, Sanchis L, Regueiro A, Sabate M, Sitges M, Freixa X. Minimally- invasive Transesophageal Echocardiography for Left Atrial Appendage Occlusion With a Latest-generation Microprobe. Initial Experience. Rev Esp Cardiol. 2019;72: 511-2.

Supplementary data
Supplementary Table 1. Baseline patient characteristics and pro- cedural data.
Supplementary Figure 1. Echocardiographic images from the interventions in patients #2-4.
Moving image 1. The interventional echocardiographic images during LAAO of patient #1.
The supplementary data are published online at: https://eurointervention.pcronline.com/ doi/10.4244/EIJ-D-22-00921

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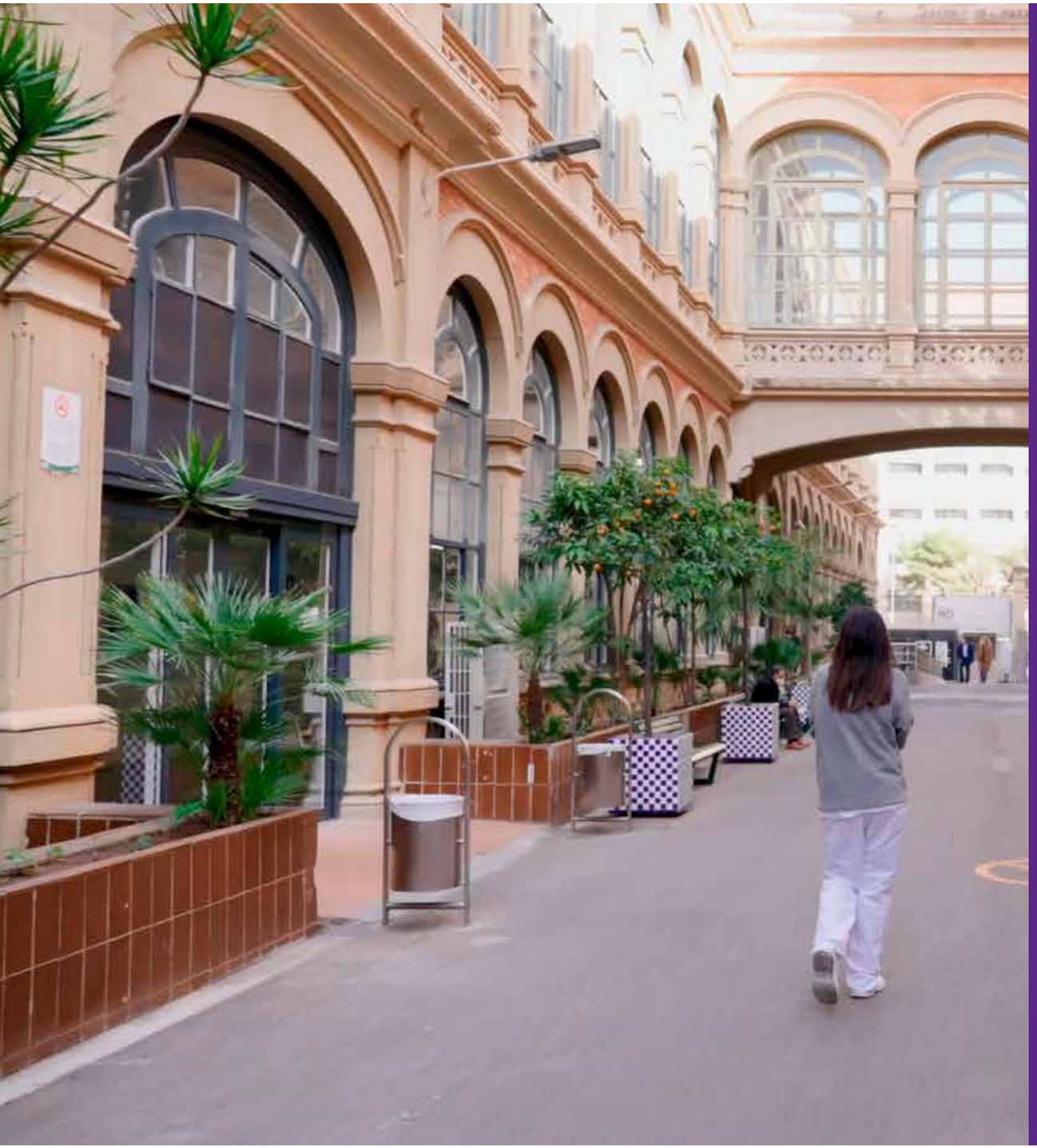
This paper also includes supplementary data published online at: https://eurointervention.pcronline.com/doi/10.4244/EIJ-D-22-00921



Introducing the world’s first mini 4D TEE probe: Early experiences in structural heart interventions

Research and innovation that advance patient care are driving forces behind the century-old Hospital Clinic de Barcelona in Spain. Recognized as a center of excellence around the world, the public university hospital continues to push for progress. Most recently, its state-of-the-art Cardiovascular Institute was one of the test sites for the new 9VT-D mini 4D TEE probe. Dr. Marta Sitges, MD, Ph.D., who is the director of the Cardiovascular Institute, and Dr. Laura Sanchis, MD, Ph.D. shared their initial experiences with the novel probe.

The Cardiovascular Institute is a referral center for all of Spain for heart transplantation, mitral valve repair, pulmonary hypertension, inherited heart disease and adult congenital heart disease. With specialists in cardiology, cardiac surgery and vascular surgery, the Cardiovascular Institute at the Hospital Clinic reported an estimated twenty-two thousand patient visits, fourteen thousand echocardiograms, and nine hundred cardiac surgeries during 2022. The staff includes more than 60 medical professionals, along with three hundred nursing and administrative support professionals.

The Institute's structural heart interventions program began in 2009 with TAVI and expanded to include edge-to-edge procedures in 2011, followed by tricuspid interventions in 2018. In 2021, the operatory area was completely redesigned to modernize all technologies, including the two existing angiography suites. A new hybrid interventional room was also created to support an ever-growing number of structural heart procedures. Today, the Cardiovascular Institute remains focused on exploring new ways to keep up with the growing demand for diagnosis and treatment.

"*The number of patients is rising. We need to know how to do more patients in less time with less beds,*" says Dr. Laura Sanchis .

Easing workload challenges by improving efficiencies continues to be a driver for the entire healthcare community. Institutions are moving towards advanced technology that provides wider access to minimally invasive therapies that increase the number of patients treated per day and enable same day discharge. Procedures that negate the need for general anesthesia allow for faster interventions, fewer staff, and can reduce overall hospital costs (inpatient vs. outpatient).

"*An important challenge is the need for anesthesia, and that's a universal problem everywhere. It may increase the risk and the complexity of the intervention, so we are going towards less invasive procedures with the same safety. Without general anesthesia and without the need of a conventional probe, it makes everything go faster and quicker,*" says Dr. Marta Sitges.

A Small Solution

A recent innovation in probe technology, first released for pediatrics, could address these challenges, and provide opportunities to treat more patients. For certain indications, the 9VD-T mini 4D TEE could be a potential option for older and clinically fragile patients not suited for general anesthesia or those who can't tolerate 4D TEE adult probes.

Some of the latest research on the mini 4D TEE comes from the structural heart team at the Cardiovascular Institute at Hospital Clinic. Dr. Laura Sanchis and Dr. Marta Sitges explored the capabilities and potential benefits of the mini 4D TEE performing percutaneous left atrial appendage occlusion (LAAO) procedures on adult patients. Their paper, 'First Experience of left atrial appendage occlusion using 3D mini transesophageal echocardiographic probe with conscious sedation[1],was published in *EuroIntervention* in January 2023.

> *"An important challenge is the need for anesthesia. It may increase the risk and the complexity of the intervention, so we are going towards less invasive procedures with the same safety. Without general anesthesia and without the need of a conventional probe, it makes everything go faster and quicker". Dr. Marta Sitges*

Background

Percutaneous left atrial appendage occlusion procedures rely heavily on transesophageal echocardiography (TEE) or computed tomography (CT). 4D TEE is typically used for intraprocedural guidance and requires general anesthesia in most centers[1].

The Cardiovascular Institute utilizes the standard 4D TEE adult probe (6VT-D) with the Vivid E95 ultrasound system for most complex LAAO cases. For simpler procedures, the team trusts the 2D micro TEE probe (10T-D) in conjunction with the Vivid S70N ultrasound system.

For their research, Dr. Sanchis and Professor Sitges utilized the new mini 4D TEE with conscious sedation to help guide LAAO procedures on four patients treated consecutively on the same day. According to their paper, 'The initial experience showed good tolerance (despite minimal sedation and the supine position of the patient) with excellent image quality of the LAA that allowed an effective and safe LAAO guidance[1].

The experts shared more about their experience with the world's first mini 4D TEE probe, along with some insights about the potential for future interventions.

The Cardiovascular Institute was one of the test sites for the new mini 4D TEE probe. In your experience, what are some of the advantages of the mini 4D probe?

Dr. Sitges: *Compared to the micro TEE, I think we should highlight the 3D and good quality images. Probably for LAAO procedures, the image quality is as good as the conventional 3D TEE probe.*

Dr. Sanchis: *The 3D is very nice for me and is the same that we can get with the standard probe. When we were doing the left atrial appendage occlusion—closing it with the mini TEE was super easy and you are super relaxed because you have all the control.*

Dr. Sitges: *Laura and our team have extensive experience in this type of interventions, but for less experienced echocardiographers and interventionalists in the learning part or the initial experience, I think the 3D is really useful because you have this smaller probe with the same capabilities as the conventional one.*

Dr. Sanchis: *To do it without 3D is risky if you are not very skilled in left atrial appendage occlusion. It's always better to do it with biplane than monoplane because you have more control. So, it's another point for the mini 4D TEE probe.*

I also want to bring up that many people are not using the micro TEE because it's difficult to manipulate and you need to be very skilled. I think it's easier with the mini because it's a little thicker and it's easier to use.

How did the mini 4D TEE probe impact your workflow?

Dr. Sitges: *The advantage of the mini is that we can optimize the process by making it quicker. The mini TEE probe has 3D so the planning can be performed during the procedure. With the micro, it's only 2D so we need to do another 3D screening echo before the procedure day to do all the measurements for planification.*

Dr. Sanchis: *For me, the main benefit is for the left atrial appendage occlusion because with the mini TEE we may simplify the patient pathway because we can do all the measurements in the cath lab.*

Does the mini 4D TEE probe enable other opportunities to increase efficiencies when performing LAAO procedures?

Dr. Sitges: *With the mini TEE, you can avoid general anesthesia and you are reducing or avoiding hospital stays. So that's a big impact.*

Dr. Sanchis: *We tested the mini TEE and you can also make many patients in one morning and the tolerance was nice.*

Along with simple LAAO cases, do you think the mini 4D TEE probe could be beneficial in other structural heart interventions?

Dr. Sanchis: *The thing is that when we have a new technology, we start exploring how it can be used and try to apply it to different procedures.*

Dr. Sitges: *We have limited experience with the probe, but I am sure we will discover new indications. We didn't have time to test it, but maybe in some very simple, straightforward cases of functional MR, for example. These cases are usually very easy to treat with an edge-to-edge repair and it typically gets us less than an hour.*

Dr. Sanchis: *If we have this probe, we will of course use it for the left atrial appendage occlusion. I think that is the main value of this probe. PFO is simple and you can do it without 3D, but some cases are difficult, and I think it's great if you can use 3D and biplane. We could use it also for percutaneous valvuloplasty of the mitral valve. As Marta said, I think that for functional mitral regurgitation in patients where we think it will be easy, it could be also an option.*

Dr. Sitges: *Choosing the 4D mini probe will not depend on the tolerance of the probe. It will depend on the quality of the image that you need to do the procedure. If it's an easy procedure, we can do it. If it's a very complex and long procedure, probably not. Taking that into account, ASD and PFO are indeed a possibility in the experienced hands as Dr. Sanchis and our interventional team.*

In addition to the mini 4D probe, what other ultrasound features or applications are useful in your structural heart procedures?

Dr. Sanchis: *If they are complex intervention, I really like Vivid's FlexiSlice, the Live MPR feature. I really like that, for example, for MitraClip, as you can guide it all will 3D and MPR at the same time. With the new Ultra Edition release, the quality of 3D and MPR is much better, so it is very nice.*

Dr. Sitges: *Dr. Sanchis explained very nicely the advantages of MPR, which I completely agree with. Then there is the CT-Echo fusion that is getting better and better, but still need to work on it to add it to more procedures.*

Looking ahead, what advances would you like to see in technology, and how do you envision the cath lab of the future?

Dr. Sitges: *For the cath lab of the future, we should have a robot that would allow remote manipulation of catheters, but also of the mini TEE probe with all the 3D capabilities. We would have tools that would help get rid of anesthesia, of course.*

Dr. Sanchis: *We will make more things than now. I think it's increasing exponentially.*

Dr. Marta Sitges, MD, PhD. is a senior consultant non-invasive cardiologist at the Cardiovascular Institute in Hospital Clinic at the University of Barcelona. Her main clinical practice is related to clinical and interventional echocardiography, sports cardiology, and heart valve disease. She has published more than 280 peer reviewed papers and presented more than three hundred lectures in national and international meetings. Professor Sitges has been Director of the Cardiovascular Department since 2015.

Dr. Laura Sanchis, MD, PhD. specializes in noninvasive cardiac imaging at the Cardiovascular Institute. She is part of the Valve Team and performs echocardiography and advanced echocardiography techniques, as well as echo-guidance of structural interventions in the catheterization lab. Her main research currently focuses on the application of cardiac imaging to understand the pathophysiology of heart valve disease, its clinical management, and the structural heart interventions planification. Dr. Sanchis is credited with more than one hundred research publications.

1 Sanchis L, Regueiro A, Cepas-Guillen P, Sitges M, Freixa X, First experience of left atrial appendage occlusion using a 3D mini transoesophageal echocardiographic probe with conscious sedation. EuroIntervention. 2023 Jan.; DOI: 10.4244/EIJ-D-22-00921

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Left Atrial Appendage Closure with 9VT-D, mini 4D TEE probe

Courtesy of Dr. Marta Sitges and Dr. Laura Sanchis, Hospital Clinic Barcelona, Spain

Patient History/ Pathology

68-year-old man was admitted due to heart failure after new-onset rapid atrial fibrillation (AF). Despite having a previous episode of paroxysmal AF, oral anticoagulation had been suspended after recurrent hematuria (chronic cystitis resulting from a previous radiotherapy treatment for prostate carcinoma). A transesophageal echocardiography (TEE) was performed to rule out thrombus before electric cardioversion. The patient was discharged with low-dose subcutaneous heparin and, after another episode of hematuria, percutaneous left atrial appendage (LAA) occlusion (LAAO) was proposed.

Challenges

Percutaneous LAAO needs planning with a 3D imaging technique (CT or TEE). Our patient had a previous TEE but without 3D measurements of the LAA and dedicated evaluation. Performing a new imaging test would have implied a delay in treatment as well as additional cost and risk (radiation, esophageal intubation). Alternatively, LAAO with general anesthesia and 3D TEE guiding had to be performed to evaluate the LAA and guide the procedure.

System, probe & device used

As we had available the 9VT-D mini TEE probe with 3D capabilities with the Vivid E95 (206 release) echocardiographic system, we decided to perform LAAO under conscious sedation and on an ambulatory basis with same day hospital discharge. The patient was admitted in the morning, LAAO was performed under conscious sedation and after 6 hours monitoring and a transthoracic echocardiography to rule out pericardial effusion and device embolization, the patient was discharged from the hospital.

Step-by-step procedure

The tolerance of the probe was excellent with only pharyngeal topic lidocaine and conscious sedation (fentanyl 0.05 mg and midazolam 2 mg). 3D measurements of the LAA (ostium 14x23 mm and landing zone 16x21 mm) were performed during LAAO with live MPR and an Amplatzer Amulet 25-mm device was chosen for closure. Transseptal puncture and device implantation were guided with biplane 3D imaging with a successful implantation.

Conclusion

The use of a mini TEE probe with 3D capabilities (9VT-D) allowed us to directly perform a safe and effective LAAO with conscious sedation and same day hospital discharge. Without this probe it would have been necessary to do a previous 3D imaging technique (TEE or CT) or to perform LAAO with general anesthesia and 3D TEE guiding with the standard probe.

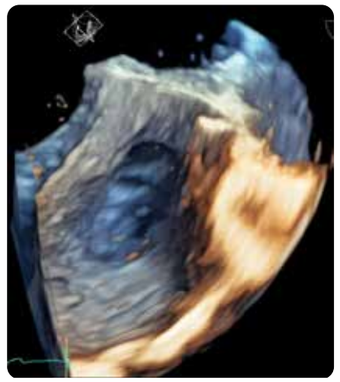
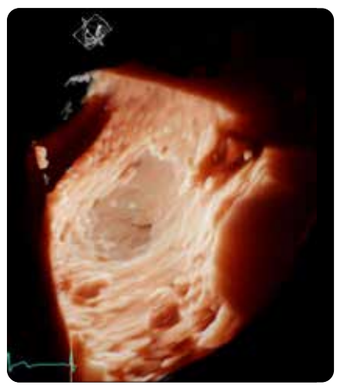


Figure 1. 3D visualization of the LAA ostium.



3D measurement of LAA

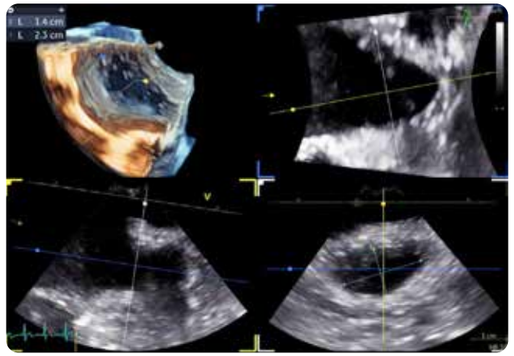


Figure 2. Ostium.

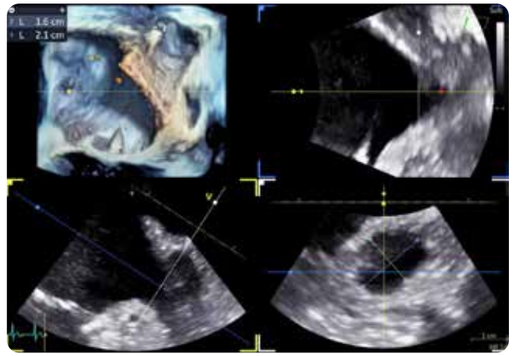


Figure 3. Landing zone.

Figure 4. Transseptal puncture.

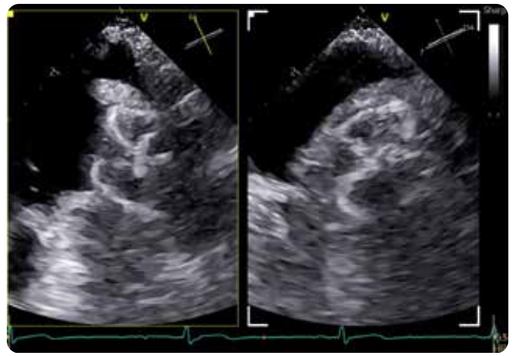


Figure 5. Lobe opening.

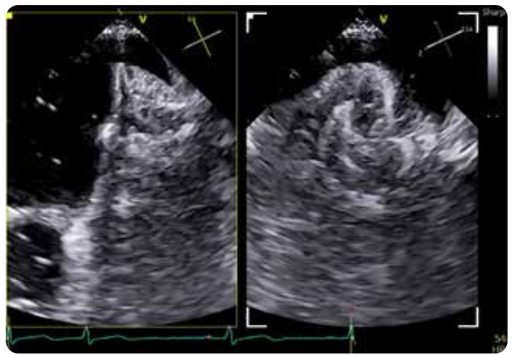


Figure 6. Disc opening.

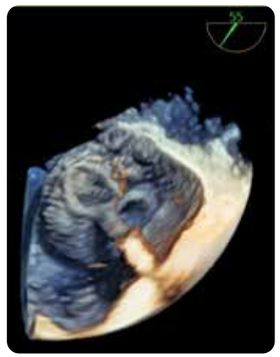


Figure 7. 3D evaluation of leaks before release.

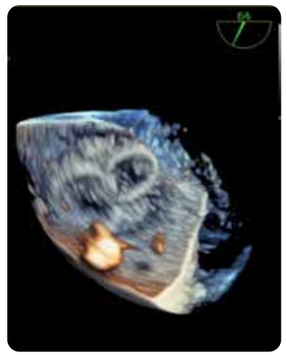


Figure 8. Final result.

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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*

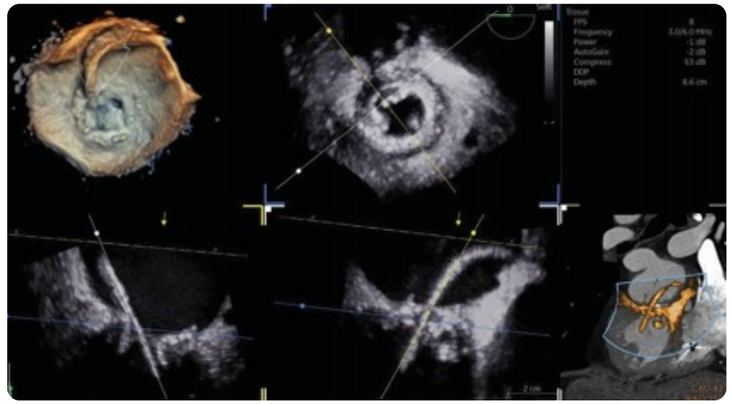

Figure 1. Live co-registered navigation in 4D ultrasound and CT data to better help understand the heart anatomy.

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

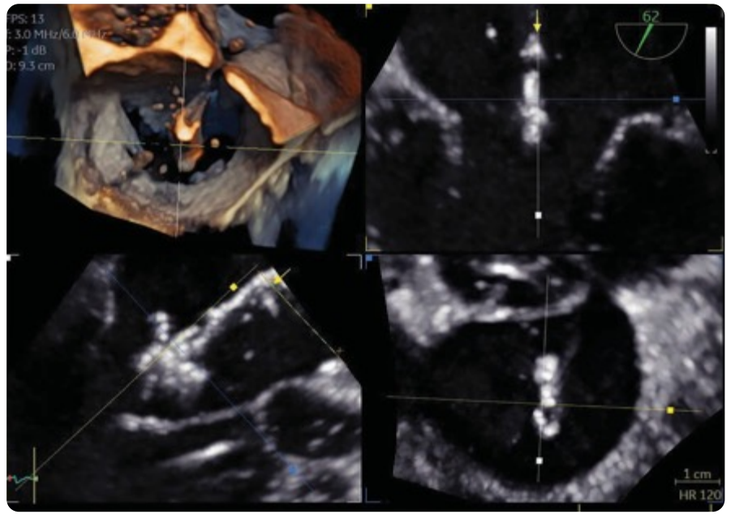

Figure 2. Multiplanar 3D imaging to guide transcatheter mitral valve repair with MitraClip.

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.*

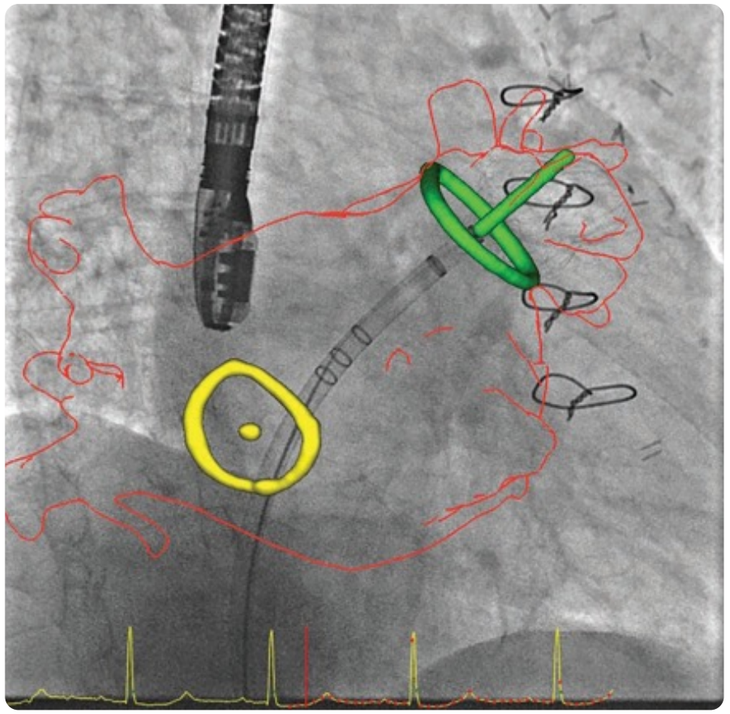

Figure 3. Left atrial appendage closure using GE HealthCare's Valve ASSIST 2 fusion imaging.

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.

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The Heart of Progress and Possibility

Vivid Celebrates 25th Anniversary

It’s been a history of firsts for GE HealthCare’s Cardiovascular Ultrasound and the groundbreaking Vivid™ brand. For a quarter century, its creative teams have turned big ideas into bold innovations and real healthcare solutions. The only thing more exciting than the pioneering past is GE HealthCare’s promising future.

By plane, by train, by car. The head of GE HealthCare's Cardiovascular Ultrasound hits the road regularly, making stops in hospitals and clinics around the globe to visit customers.

"*This time I'm in Missouri,*" says General Manager Dagfinn Saetre, before beginning a several hour road trip in the United States. Saetre embraces any travel that leads to new insights and better problem-solving.

"*It's so important to get first-hand information from physicians. Not only get their words, but also see how they are using our equipment and understand what can be developed to provide even better service. They're really driving us forward.*"

Working alongside physicians and researchers has always been a hallmark of GE HealthCare's revolutionary Vivid brand, which is celebrating its 25th Anniversary. The business began in 1998 when GE Medical Systems acquired Diasonics Vingmed in Horten, Norway. Now after a quarter century of medical milestones, GE HealthCare is considered a global leader in cardiovascular ultrasound. Saetre has had a front row seat for all of it.

The Early Days

Before finding its home at GE HealthCare, Diasonics Vingmed was revered for its groundbreaking Doppler devices and highly respected in the ultrasound space. Yet, insiders say Vingmed struggled with operations and distribution. Despite some initial growing pains, GE HealthCare is credited with vastly improving the quality of products by implementing new processes and procedures, resulting in a significant jump in U.S. market share.

Saetre, who was a young engineer at the time, led the development of one of the first products, the Vivid 7. "*It turned out to be even bigger than we thought because we generated a new platform for almost everything ultrasound. In terms of ergonomics, the look, how you interacted with it, the software functionality, it was a big step forward and went beyond anything on the market*," he recalls.

Soon after, engineers created miniaturized portable versions, the Vivid i and Vivid q, which was the first miniaturized cardiovascular ultrasound. These PC-based systems paved the way for further progress and led to more pioneering developments in image processing, beamforming, and image display.

The Power of cSound

In 2015, GE HealthCare made an unprecedented leap with the introduction of cSound and a new generation of scanners. The software-based beamformer platform enabled another level of versatility, flexibility, and processing power in image acquisition, reconstruction, and visualization. The Vivid E95 Ultra Edition and Vivid S70N Ultra Edition[1] ultrasound systems were the first machines to be built around the revolutionary architecture. The latest version, cSound ADAPT[2], powers even more solutions today.

"*This has given us a fantastic innovation platform for image quality. If you want to change algorithms, it's a matter of changing a piece of software instead of implementing a new electronic board. We keep coming up with new ways of processing the images, new ways of doing beamforming, and that gives us new possibilities*," Saetre explains.

Accelerating Structural Heart Innovation

GE HealthCare has also been an important player in the rapidly evolving world of structural heart interventions. For the last decade, it's been expanding Vivid's cutting-edge tools to meet the growing demand for minimally invasive procedures.

"*TAVR was the first and then came transesophageal imaging—with 4D imaging increasing big time. Heart teams are relying on our equipment for superb visualization of anatomy and flow dynamics to confidently plan, guide, and assess complex procedures*," Saetre says.

The ability to treat more patients, who aren't suited for general anesthesia is also a driver, along with uncovering new ways to boost productivity and reduce the overall cost of care.

The latest breakthrough is small in size but could make a big impact in patient care and daily efficiency. The Vivid brand recently launched the world's first mini 4D TEE probe (9VD-T)[3], and it's already stirring a lot of interest in the field. The compact probe is suitable for a broad range of pediatric and interventional cardiology procedures, potentially eliminating the need for general anesthesia in adult patients.

An Intelligent Future

GE HealthCare's vision for the future also encompasses more advances in automation, artificial intelligence, and machine/deep learning. Under Saetre's leadership, creative engineers continue to add progressive tools that not only enhance image quality, but also reduce tedious tasks and inter-operator variability. Areas of focus include intelligent image optimization and computer-assisted image acquisition, image interpretation and computer assisted diagnostic support, and measurement simplification.

As Vivid celebrates 25 years of inspired innovations and impact, Saetre has no intention of taking his foot off the gas. No matter where he travels—the direction is always forward. "*Hospitals in every corner of the world have a Vivid. We've been part of a big change in enabling a better diagnosis and in recent years, help enabling new treatments for countless cardiac patients,*" Saetre reflects. "*That's quite something, but there's so much more to come.*"

> *"We keep coming up with new ways of processing the images, new ways of doing beamforming, and that gives us new possibilities".*
> Dagfinn Saetre

PROFILES OF PROGRESS

The people and experiences that make Vivid™ shine

GE HealthCare is known for its revolutionary inventions in cardiovascular ultrasound, but it's really the people that make Vivid so vibrant. For the last 25 years, dreamers and doers have been putting in the work, day after day, to advance cardiac care. Here are some of their stories.

Eva Nilssen - R&D Program Manager

After 40 years in med tech, including 25 with GE Healthcare, Eva still marvels at the life-changing innovations that are dreamed up and developed in her small community off the southern coast of Norway. "*Our headquarters is in Horten. You would think it would be a huge cosmopolitan center, but it's just a tiny town. It's incredible to think that all this technology comes out of here.*"

It's also become a melting pot of sorts. The R&D Program Manager says as the Vivid brand has evolved over the years, it's added some of the best and brightest minds from around the globe.
She also appreciates that the team is multigenerational and includes some of her original Vingmed colleagues, which allows for different and dynamic perspectives.

Naturally curious, Eva says she thrives in a field that is based on problem solving. "*Sometimes you will be working on something, and you can't get anywhere. Then you work with engineers and suddenly solve it, and that joy is really inspiring.*"

Eva also understands the power in every discovery and decades of progress. "*We can do so much more, see so much more, and we can aid so much better care. Every improvement we make from the factory is making an impact. All that inspires me—the product, the people, and learning something new all the time.*"

Gunnar Hansen - Global Clinical Research Manager

"*I have been working very closely with researchers for more than two decades, and during that time we have built an extensive research program, both technical and clinical. This has given us a unique opportunity to learn and prioritize the best utilization of our technology for the maximum clinical benefit,*" he says.

Gunnar believes those relationships have propelled GE Healthcare Cardiovascular Ultrasound from a highly technical driven team to a global leader in echocardiography. He points to a few of the pioneering achievements that paved the way for major advances in cardiac care. "*Some of the main BTs were a result of an intensive investment in miniaturization of hardware, which was the enabler for 3D imaging and 3D probes, and the later development of the Vscan hand-held scanner.*"

And the best part of his job? "Seeing your work used in the clinic," Gunnar says. "*Knowing that more than 300,000 patients get their health checked or a procedure done with our equipment every day.*"

Claudia Lacerda - Global Clinical Leader

Claudia was never suited for a 9 to 5 desk job. It's just not her nature. *"I've always needed to be at the heart of everything that's happening in the hospital and working with physicians.*"

As Global Clinical Leader, she's the link between customers and engineers—gathering valuable feedback from the field and providing extensive training. Claudia says she's always eager to get reactions to new features, but the comments she values most might surprise you. "*I'm happy to hear what physicians like about our systems, but it's even better to learn what they don't like, so we can keep improving.*"

Claudia says today's technology needs to solve many challenges, including unprecedented workloads, staffing shortages, and training limitations. "*We are continuing to push the boundaries in image quality and are working on innovations to improve workflow, utilizing AI for automation and reproducibility in tasks.*"With a growing demand for minimally invasive procedures that don't require general anesthesia, Claudia is especially excited about GE Healthcare's latest advancements in structural heart. She sees great potential in the new mini 4D TEE probe and 4D ICE NUVISION™ Ultrasound catheter[4]. "*What I like about my job is that I get the opportunity to be creative and think outside the box. We are constanlty looking ahead to what's next and what would be the next Ultrasound revolution.*"

1. Ultra Edition is not a product name, it refers to the 2022 release of the Vivid portfolio. All features or products mays not be available in all markets, please contact your sales representative for more information.
2. cSound ADAPT is exclusively available for Vivid E95 Ultra Edition and Vivid E90 Ultra Edition
3. The content herein refers to 2022 release of Vivid portfolio. 9VT-D probe is exclusively available for E95 and E90. Vivid. Ultra Edition is released as of 25th August 2022
4. 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
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GE HealthCare

About GE HealthCare

GE HealthCare is a leading global medical technology, pharmaceutical diagnostics, and digital solutions innovator, dedicated to providing integrated solutions, services, and data analytics to make hospitals more efficient, clinicians more effective, therapies more precise, and patients healthier and happier. Serving patients and providers for more than 100 years, GE HealthCare is advancing personalized, connected, and compassionate care, while simplifying the patient's journey across the care pathway. Together our Imaging, Ultrasound, Patient Care Solutions, and Pharmaceutical Diagnostics businesses help improve patient care from prevention and screening, to diagnosis, treatment, therapy, and monitoring. We are an $18 billion business with 51,000 employees working to create a world where healthcare has no limits.

Follow us on Facebook, LinkedIn, Twitter, Instagram and Insights for the latest news, or visit our website gehealthcare.com for more information.

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