Breakthrough imaging for our most precious patients

Take a closer look at the world's first mini 3D TEE probe – 9VT-D. Designed for patients as small as 5 kg.

More than 1.5 million babies worldwide are born with a congenital heart defect each year.[1] The pressing health problem becomes even more daunting when you consider the smallest patients are often the most challenging.[1] Emerging technologies in echocardiography, including the 9VT-D mini 3D TEE probe, are providing clear advantages at Cleveland Clinic Children's. For their pediatric cardiologists and surgeons—like Justin Tretter, M.D.—everything is in the details.

Director of Advanced Imaging for the Pediatric and Adult Congenital Heart Center, Justin Tretter, M.D., has a unique background that includes training in advanced non-invasive imaging and cardiac morphology. He works alongside renowned surgeon, Hani Najm, M.D., and together they serve as Co-Directors of the Congenital Valve Procedural Planning Center. Their innovative techniques have helped Cleveland Clinic Children's earn its place as one of the top cardiology and heart surgery programs in the US.

Cleveland Clinic Children's features two leading-edge catheterization suites for both simple and complex interventional procedures, such as atrial septal defect closure or pulmonary valve implantation, avoiding the need for open-heart surgery. There is also a Hybrid Pediatric Catheterization Laboratory with advanced imaging technology that enables interventional cardiologists and surgeons to perform hybrid procedures without cardiopulmonary bypass.

Dr. Tretter and Dr. Najm rely on the latest 3D and 4D imaging techniques to get a detailed understanding of a patient's heart structure and function to personalize every interventional and surgical procedure. With advanced imaging, they can create a blueprint and plan before ever stepping into the operating room.

Their expanded toolbox now includes the world's first 3D TEE probe designed with children in mind.[2] The breakthrough innovation, powered by the Vivid™ E95 Ultra Edition, allows for real-time multiplane and 3D imaging in patients as small as 5 kg.[2]

We sat down with Dr. Tretter to find out more about how rapid advancements in imaging technology are impacting pediatric care at Cleveland Clinic Children's.

Can you tell us about your unique background and how it drives your daily practice?

Dr. Tretter: *I am trained as a pediatric cardiologist with additional training in advanced cardiac imaging, cardiac MRI, CT, and three-dimensional echo, but the foundation of my training is really as a cardiac anatomist. My passion is really understanding the basis of cardiac form, and how cardiac form dictates cardiac function and physiology—and ultimately patient outcomes. My approach starts with understanding very detailed cardiac development and cardiac anatomy, then figuring out what is clinically and surgically relevant, and then image that detail with standard 2D and more advanced 3D and 4D imaging to help personalize surgical and interventional procedures.*

> *"Now that good quality 4D echo imaging is easy and accessible, I think our patients deserve that detailed imaging evaluation before they go into the operating room or the cath lab.*

Why is 4D echo technology so important in pediatric cardiology and congenital heart disease?

Dr. Tretter: *The heart is a very complex structure with significant variability and when we deal with congenital heart disease that variability becomes even more significant. To try to understand that 3D complexity—and if we talk about the motion of the heart, 4D complexity—it becomes very challenging.*

Often, we can get by with 2D imaging when we're following patients, but now that good quality 4D echo imaging is easy and accessible, I think our patients deserve that detailed imaging evaluation before they go into the operating room or the cath lab. 3D and 4D imaging really help us to understand the specific patient and their specific lesion, whether they have congenital heart disease or acquired heart disease.

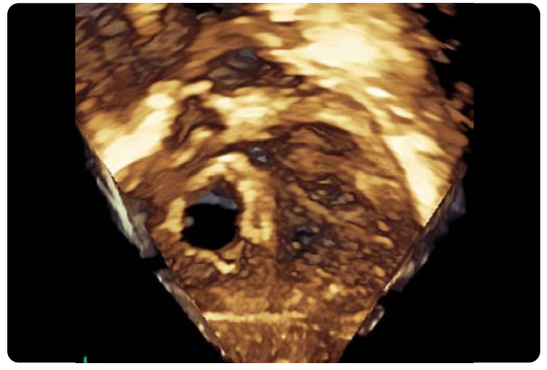

Image 1: 3D of newborn with DORV with subaortic VSD viewed in short axis of the ventricles with tricuspid valve seen in short axis, the VSD seen at the septal and anterior leaflet commissure, and the aortic valve seen near the VSD and above the tricuspid valve.

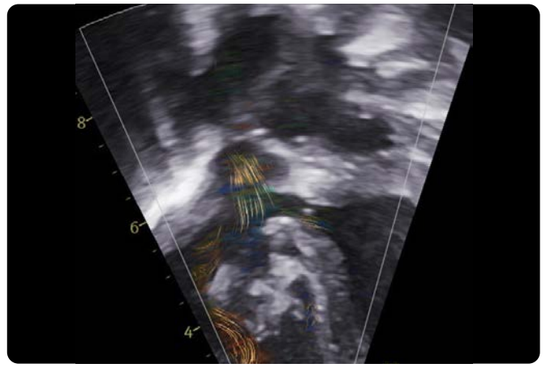

Image 2: Subcostal short axis view in a similar plane to Image 1, showing blood flow both from the LV to the aortic valve, and from the RV to aortic valve. Even though this patient had a subaortic VSD, and should have demonstrated normal oxygen saturations, the patient's anatomy resulted in streaming of blood with deoxygenated blood from the RV entering the aorta and causing lower oxygen saturations. This was not well appreciated with standard color Doppler imaging.

4D functionality is relatively new in the world of pediatric cardiology compared to adult echocardiography. How has the 9VT-D mini 3D TEE probe made a difference in your program?

Dr. Tretter: *The 4D technology has been around for a while with the 6Vc-D TTE probe, which has allowed us the ability to do 4D transthoracic echo in some of our pediatric patients and do it in the outpatient setting. But I think the honest truth is we're not as good as our adult acquired counterparts because many pediatric imagers are not trying to obtain 4D images on a daily basis.*

Now that we have the 9VT-D mini 3D TEE probe, I've seen a dramatic change. Our sonographers and cardiologists, who maybe weren't familiar or were intimidated to do 3D and 4D echo, are getting that daily exposure. They are getting comfortable and now a larger proportion of our providers can create these images. Surgeons and interventionists are seeing these imaging capabilities in our management conferences so now it's becoming, rightfully so, an expectation.

> *"The mini 3D TEE probe has enabled Dr. Najm to tailor his repair during surgery and it's also enhanced his ability to repair what was previously thought to be unrepairable. That includes many, many valves that would have gone for replacement.*

Has the 9VT-D mini 3D TEE probe changed the way surgeons and interventional cardiologists approach procedures?

Dr. Tretter: *Dr. Najm has told me it has exponentially increased the advanced imaging support of this program and that it really has made it an expectation for our patients. He says he's a better surgeon because it has improved his preoperative evaluation of looking at structures in their loaded condition. The mini 3D TEE probe has enabled Dr. Najm to tailor his repair during surgery and it's also enhanced his ability to repair what was previously thought to be unrepairable. That includes many, many valves that would have gone for replacement.*

Is there anything that surprised you about the 9VT-D mini 3D TEE probe?

Dr. Tretter: *Yes, the excellent image quality. You need good 2D image quality to create good 3D image quality. When we're using this probe, the 2D image quality is excellent, leading to good, useful, and additive 3D image quality. These programs I have trained and worked have all been multi-vendor programs, and having used different vendor systems I haven't seen this level of 2D imaging quality in a pediatric TEE probe. With 3D imaging, it's really garbage in, garbage out.*

Do you think the 9VT-D mini 3D TEE probe can possibly reduce some other testing that is ionizing or possibly reduce fluoroscopy time?

Dr. Tretter: *The short answer is yes, but as an expert in cardiac CT, I am a lover and promoter of the appropriate use of cardiac CT. I think there is a lot of benefit in certain scenarios and very often it may take a multi-modality imaging approach. But now, especially with increasing echo technology and with the new 9VT-D probe with our younger pediatric patients, often times echo is certainly enough.*

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We hopefully have a paper coming out soon that will show how when using 3D echo and meticulously interrogating the surface area of the parts of the leaflets that coapt together, we can pick up very subtle abnormalities that are surgically and clinically significant that we aren't picking up by our detailed CT assessment and standard echo imaging. I think echo is certainly the mainstay of imaging and in many patients with the 4D echo, it can be the sole modality for imaging.

For example, in ASD device closures when there's potentially deficient rims. My experience has been that with the use of standard 2D echo imaging, there is often prolonged fluoroscopy time, failed attempts at putting in different size devices. That's where I think 4D echo could really reduce that fluoroscopy time.

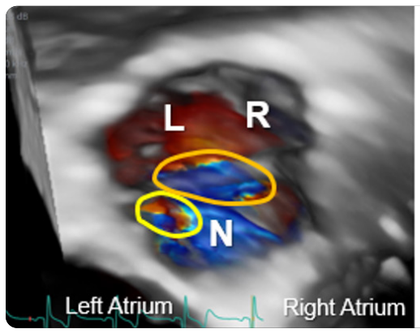


Image 1: Same patient showing these two jets (orange – central jet; yellow – jet near left/ non-coronary commissure).

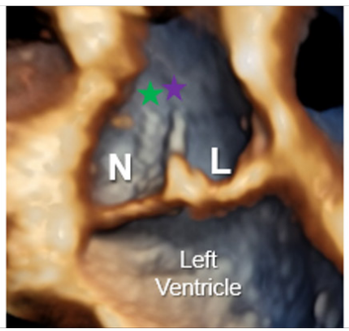


Image 2: Commissural long axis view in diastole demonstrating malalignment, or a separation between the left (purple star) and non-coronary leaflet (green star) at their commissure with coaptation deficiency.

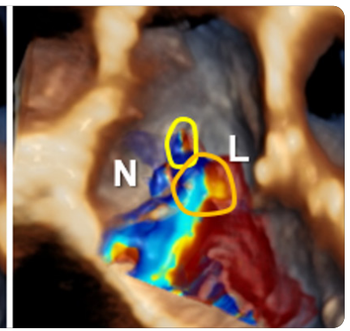


Image 3: Color comparison of the same colors as in Image 1.

What is the value of FlexiSlice, our multiplanar formatting tool, and how is it best utilized?

Dr. Tretter: *It's my favorite tool to use with 4D echo and I currently think it's underutilized. In my opinion, it should be the standard of care for any valve procedure, any procedure involving holes between chambers, such as Ventricular Septal Defect (VSDs), to obtain precise measurements in the short axis of the assessed structure utilizing FlexiSlice. Let's say in the setting of double outlet right ventricle where you're trying to baffle the left ventricle through interventricular communication to one or the other great arteries. Often, we will do very thorough preoperative planning, but that's where I think 4D echo and multiplanar formatting is necessary to quantitate the size of that communication and help to guide the surgeon creating the baffle.*

I've found that FlexiSlice is also helpful with any valve procedure. Besides the ability for accurate assessment of dimensions of the valve annulus, I teach our sonographers that FlexiSlice is the tool for very precise cropping. In addition to short axis views, it allows you to crop into orthogonal long axis planes so you can precisely get into the view you want.

Can you tell us a bit about blood speckle imaging. What information does BSI provide and how do you utilize it in your practice?

Dr. Tretter: *Many providers are familiar with 4D flow by MRI. In many ways, it's analogous. Blood speckle imaging shows you the vector flow lines of blood flow across a structure in two dimensions, whether you're looking across a VSD, ASD, or across a valve.*

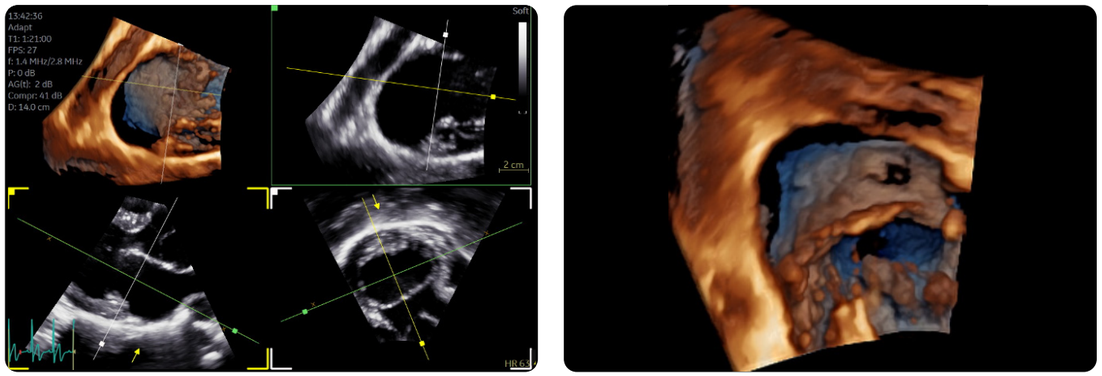
In our valve center, we have been creating computational models trying to understand how flow across a structure leads to stress and strain on adjacent structures, leaflets, walls and so on. In aortic valve cases, we try to use the patient's preoperative data to simulate surgeries to understand what options will lead to the most favorable hemodynamics. We are now working with blood speckle imaging, as it is more easily available than 4D flow MRI. The commercially available BSI is only a visualization tool currently, but we have had several scenarios where this is useful.

One example is valve surgery in the CV operating room. We can display BSI both pre-op showing very turbulent flow and post-op, we can understand immediately if we restored laminar flow, which will lead to more favorable hemodynamics long term. We may see a post operative result that we did not restore good laminar flow and that might lead us, depending on other findings on that postoperative study, to go back to modify that surgical repair.

> *These programs I have trained and worked have all been multi-vendor programs, and having used different vendor systems I haven't seen this level of 2D imaging quality in a pediatric TEE probe. With 3D imaging, it's really garbage in, garbage out.*

Another example occurred in the cardiac ICU. We had a patient with double outlet right ventricle with a subaortic VSD. So the patient should have had normal oxygen saturation for a patient based on this general anatomy. However, the patient was desaturating, and we used BSI to better understand the hemodynamics within the right ventricle related to subtle variations in the anatomy, and the related outflows that lead to the desaturation.

No two patients are the same, even with the same congenital heart disease. The subtle variations can lead to significantly different hemodynamics and physiology. BSI is better than standard color flow, enabling quick and easy assessment of the patient's hemodynamics and physiology.



TTE FlexiSlice is used to view the anterior leaflet of the mitral valve in long axis 3D during systole with moderate prolapse, demonstrating mild leaflet thickening with mildly elongated chordae.

Are there any other tools or features that you find especially helpful?

Dr. Tretter: *The other thing that I love with the GE HealthCare platform is HD color. It makes the low velocity flows more translucent so we can focus on the high velocity flows. That really helps with color imaging of Ventricular Septal Defects, or the vena contracta of a regurgitant jet, and to really be able to visualize the anatomy along with the color flow of interest.*

I would also mention the 4D marker. As an anatomist, I spend my waking hours looking at nitty gritty anatomy, but I can still get disoriented when we crop into narrower fields of view with 4D echo. And as you rotate things, you can easily lose your orientation, especially if you're trying to narrow your field of view to improve resolution.

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As your toolbox of innovations keeps expanding, what is the biggest impact on your program and your pediatric cardiology care?

Dr. Tretter: *I would go back to what I mentioned about my surgical colleague, Dr. Najm. He has a reputation as a phenomenal surgeon and his outcomes speak to that. As we've brought this imaging support to the next level, Dr. Najm has said over and over again that it's made him a better surgeon. To hear somebody who is already leading the pack, say he's become even better because of the imaging support, I think that speaks volumes towards the advantage.* ■

Justin Tretter, M.D., is Director of Advanced Cardiac Imaging and Co-Director of the Congenital Valve Procedural Planning Center at Cleveland Clinics Children's in Cleveland, Ohio. He is Professor of Pediatrics at Cleveland Clinics at Cleveland Clinic Lerner College of Medicine at Case Western Reserve University. Dr. Tretter is a pediatric cardiologist with expertise in 3D echocardiography, cardiac magnetic resonance imaging, cardiac computed tomographic imaging, 3D and 4D reconstructions and other advanced imaging techniques used for personalization of interventional and surgical planning. Dr. Tretter also has unique additional training as a cardiac morphologist under the training of cardiac morphologist, Professor Robert Anderson. He has published over 140 peer reviewed articles with interests in translational (cardiac anatomical, developmental, computational modeling) and clinical (cardiac imaging and surgery) research. Dr. Tretter is also the founder and former editor-in-chief of Heart University, a popular educational platform for congenital heart disease, and editor-in-chief for the upcoming 5th edition of "Anderson's Pediatric Cardiology" textbook.

1 YUJIN HU et.al. | AIDAN: An Attention-Guided Dual-Path Network for Pediatric Echocardiography Segmentation | Source https://ieeexplore.ieee.org/abstract/document/8979379

2 The content herein refers to 2022 release of Vivid portfolio. 9VT-D probe is exclusively available for Vivid E95 and Vivid E90. Vivid Ultra Edition is released as of 25th August 2022

Doctors are paid consultants for GEHC and were compensated for participation in this article. The statements described here are based on their own opinions and on results that were achieved in their unique setting. Since there is no "typical" hospital and many variables exist, i.e. hospital size, case mix, etc., there can be no guarantee that other customers will achieve the same results.

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