GE HealthCare

Accelerating 4D imaging adoption for better cardiac care

Vivid™ Pioneer helps make a clear case for everyday use in the echo lab

As cardiovascular care becomes more precise and personalized, demand is growing for imaging that delivers real-time, volumetric, and anatomically accurate insights into cardiac function and structure. Despite the demonstrated advantages of 4D transthoracic echocardiography (TTE) over conventional 2D imaging, adoption in routine practice remains limited. Experts increasingly point to advances in ultrasound technology as a critical step toward closing the gap between potential and everyday clinical use.[1]

Research shows that 4D TTE offers significant diagnostic and procedural advantages over traditional 2D TTE,[1] particularly in evaluating structural heart diseases. Studies demonstrate improved accuracy, precision, and reproducibility[2,3] — driven in part by enhanced visualization of cardiac structures. And unlike 2D echocardiography, which relies on simplified geometric models (like an ellipsoid shape) to calculate volumes, 4D TTE captures true chamber shapes and sizes, allowing direct measurement of cardiac chamber volumes and function.

Professor Luigi Badano and Professor Denisa Muraru of the Department of Cardiology and Unit of Integrated Cardiovascular Imaging Diagnosis in Auxologico, IRCCS, in Milan, are leading proponents of 4D transthoracic echocardiography in the echo lab. It's not only part of their routine use, but also the focus of ongoing research. This includes their recent study, Clinical Impact of the Volumetric Quantification of Ventricular Secondary Mitral Regurgitation by Three Dimensional Echocardiography.[4]

In addition to transthoracic echocardiography, the team at Auxologico performs transesophageal, as well as exercise and pharmacological stress echocardiography — conducting approximately 13,000 studies annually. The institution serves a diverse patient population with both acute and chronic cardiac conditions, including valvular heart disease, genetic cardiomyopathies, heart failure, arrhythmias, and pulmonary hypertension. Auxologico also houses a large cardiac rehabilitation unit, receiving many post-cardiac surgery referrals, myocardial infarction, and structural interventions for ongoing screening and follow-up.

Professor Muraru and Professor Badano were among the first to experience the new Vivid Pioneer cardiovascular ultrasound system. In a recent discussion, they shared their perspectives on the new ultra-premium platform.

How would you describe Vivid Pioneer's image quality as a foundational tool for valve and chamber assessment?

Prof. Badano: *Image quality is one of the most significant advancements we've observed with Vivid Pioneer. Both 2D and 4D imaging — in transthoracic and transesophageal echocardiography — show impressive improvements in quality. The use of 4D echocardiography provides a highly realistic and detailed view of cardiac structures. Vivid Pioneer is also easier to use than the Vivid E95 — producing 4D echocardiographic datasets with higher spatial and temporal resolution in a single-beat acquisition.*

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Prof. Muraru: *The latest echocardiography system brings unparalleled clarity in 2D, and particularly 4D, and Color Flow imaging. For me, the game changers are truly anatomic 4D imaging and automated quantitative tools with improved border detection. I have found that getting images with spectacular clarity and high definition is much easier on the first attempt with Vivid Pioneer. These improvements have enhanced our clinical confidence.*

You touched on Color Flow. What is your experience with the new Color Flow technology, including the Radiant*flow*™ feature?

Prof. Badano: *If I had to highlight the most impressive improvement on Vivid Pioneer, it would definitely be the 4D Color Doppler — remarkable in both transthoracic and transesophageal acquisitions. The changes in the Color Flow are one of the most awaited and noticeable improvements in the Vivid Pioneer release. This has really transformed the Color Flow, which used to be a bit pixelated and difficult to assess the contour of the jet. Now the Color Flow is really smooth — I would even say pictorial — and shows the origin and the extension of the jet very nicely and in a reliable way.*

The Radiantflow is very nice to see, but also clinically useful. In complex jets — especially multiple jets — it really helps differentiate the origin and the extension of each jet. This is particularly important for tiny jets and is especially important in patients with congenital heart disease, where the flow can be really complex to assess.

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You are both strong proponents of incorporating transthoracic 4D imaging into routine clinical practice, yet adoption remains somewhat limited. What do you see as the main advantages that should drive broader use?

Prof. Badano: *For many years we have advocated for the more frequent use of transthoracic 4D echocardiography in clinical routine because it allows precise morphology assessment of patients with valvular or congenital heart disease. It also provides more reliable, accurate, and reproducible quantitation of the geometry and the size of the cardiac structures.*

Actually, we've seen that with the latest technology and improvements in image quality of 4D TTE, we depend less than we used to on transesophageal echocardiography to assess the anatomy and the severity of conditions like valve diseases. This benefits patients — reducing healthcare costs and reducing the need for transesophageal echo when we've already decided to refer the patients for repair procedures.

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Prof. Muraru: *Transthoracic echocardiography remains our frontline tool — not only because of its accessibility, but also because, when performed with high image quality and the right technology, it provides comprehensive anatomical and hemodynamic information in a single, non-invasive session. It now offers a level of precision that, in the past, could only be obtained with transesophageal echocardiography.*

Building on this, the possibility to routinely apply transthoracic 4D echocardiography to measure chamber volumes — rather than just diameters — and to assess ejection fraction and quantify valve regurgitation using the 4D volumetric method will, in my opinion, significantly improve diagnostic accuracy. This approach can help avoid unnecessary additional testing and delays in treatment that prolong management of the patient, and increase costs.

In everyday practice, many decisions need to be made immediately at the patient’s bedside — particularly during the night — when the fellow may not have access to a supervisor or the support of another imaging modality. Transthoracic echocardiography needs to be able to provide that information, and it needs to be reliable. We can’t afford to make mistakes.

How has your research supported this approach, and what are the key insights that have emerged from your work?

Prof. Badano: *The Doppler PISA method, which quantifies the severity of mitral regurgitation, relies on numerous geometric and fluid dynamic assumptions — such as the shape and size of the orifice and the timing of regurgitation during cardiac systole. Unfortunately, these assumptions are rarely met in real patients.*

Our research demonstrates that transthoracic 4D echocardiography is highly accurate in measuring the volumes of the left and right ventricles. We have tested the accuracy of measuring the regurgitant volume of the mitral and tricuspid valves by calculating the difference between the 4D echocardiography stroke volumes of the right and left ventricles, or between the 4D echocardiography left ventricular stroke volumes and the left ventricular outflow tract Doppler stroke volume.

This method quantifies regurgitant volume independently of any geometric and temporal assumptions, making it particularly useful for assessing residual regurgitation after transcatheter valve repair procedures.

Prof. Muraru: *We strongly advocate for the adoption of 4D VCA (Vena contracta area) and 4D volumetric methods to obtain more reliable metrics of MR, particularly in cases of secondary MR and after TEER. The limitations of current 2D methods — for both deriving left ventricular volumes and PISA — carry significant implications for clinical trials and for their ability to demonstrate a mortality benefit following device implantation. We know and we discuss how important it is to do 4D VCA, but it is rarely adopted in routine practice.*

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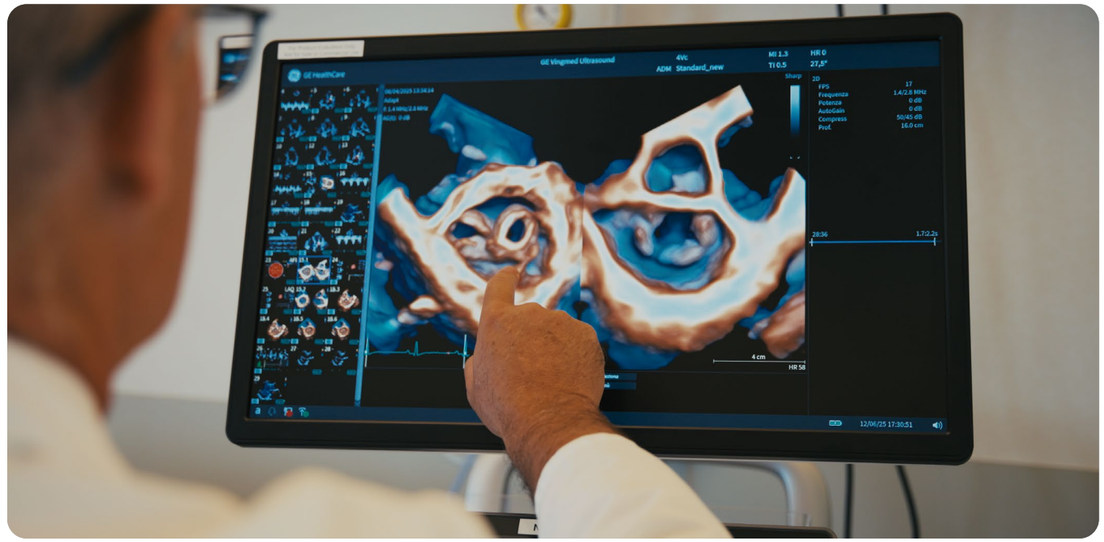
4D echocardiography enables more accurate quantification of valve stenosis and regurgitations, provides more reproducible quantification of LA and LV volumes and function.



If we focus on the tricuspid valve, how has 4D TTE impacted your approach to assessments?

Prof. Badano: *Tricuspid valve disease has been neglected and underrated for so many years, particularly because it’s very difficult to assess the anatomy of the tricuspid valve apparatus, as well as the severity of the disease, using conventional 2D and Doppler echocardiography.*

One of the major contributions of 4D is making echocardiography a reliable technique to assess right heart structures. Since we added 4D, there has been an increasing appreciation of the importance of the tricuspid valve in terms of patient outcomes, and we completely changed our approach to the tricuspid valve — both in assessing the anatomy and quantitating the severity of the disease.

Let’s delve deeper into the mitral valve. How essential has 4D echocardiography become in your daily practice?

Prof. Badano: *Even though tricuspid valve disease is gaining more attention, mitral valve disease — particularly mitral regurgitation — is still a clinically relevant and highly prevalent condition. We need to assess the anatomy of the mitral valve in order to plan the procedures effectively, and we need to evaluate the severity of the regurgitation to determine the correct treatment indications.*

In this regard, 4D echocardiography is essential for identifying the patients that should be referred to the heart team or monitored closely.

How does Vivid Pioneer perform when it comes to capturing critical anatomical details of the mitral valve and subvalvular apparatus, and how would you compare it to other systems?

Prof. Badano: *Vivid Pioneer’s transthoracic 4D images — particularly in volume rendering and Color Doppler — are superior quality compared to other echocardiography systems available on the market. I think this is one of the main breakthroughs with Vivid Pioneer. There has been so much improvement in the quality of the volume rendering and better, more precise Color Flow to assess the origin of the regurgitant jet and mechanism of the mitral regurgitation. This advantage allows us to rely less on transesophageal approaches to assess valve anatomy and regurgitation severity in our patients.*

Prof. Muraru: *Vivid Pioneer is a revolutionary scanner that allows us to obtain very detailed information about cardiac anatomy. This is fundamental because, in valvular heart disease, the issue isn't only functional, it's the underlying anatomy that causes the problem. So the surgeon or the interventionalist isn't just interested in understanding the functional significance of the anomaly, they need very in depth, granular information. It's not only about the leaflets, which we can see with 2D, but also understanding the anatomy in depth, the fine anatomic details, and the spatial relationships with surrounding structures. These precise measurements are essential for choosing the right device.*

Nowadays with the evolution of treatments with devices, we are also very interested in examining the subvalvular apparatus — like the papillary muscles, how far they are from the valve itself, and whether we can measure it. These details are crucial for choosing the right repair and replacement technique. All this information requires excellent image clarity — not just in 2D, but especially with 4D echocardiography.

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Hypertrophic cardiomyopathy (HCM) patients often present with complex anatomy. How does this affect your echocardiography approach, and what are some of the key challenges in assessment?

Prof. Muraru: *In HCM, the anatomy is highly variable, and the hypertrophy is often asymmetric — localized in different segments of the myocardium. But beyond the myocardium, the mitral valve apparatus plays a critical role in the symptoms experienced by many patients, particularly those with obstruction. Elongated leaflets, anterior displacement of papillary muscles, and accessory chords are frequent findings that can contribute to SAM, mitral regurgitation, or LVOT gradients.*

Many times, it's not only about the abnormal thickening of the myocardium, but also about these morphological abnormalities of the mitral valve — features that are essential to diagnose before a patient undergoes septal reduction therapy. The surgeon needs to know clearly whether there is organic involvement of the mitral valve apparatus, or if it's a functional effect due to LVOT obstruction.

The problem with hypertrophic cardiomyopathy is that, many times, it's difficult to diagnose — particularly in the early phases. You need to have a very crisp image in order to obtain reliable measurements of the thickness across all segments, not just the basal septum. That includes the apex, as well as the anterior and inferior wall. This can be challenging if the image quality isn't very good.

This is the reason why we often have to rely on CMR measurements, but we know those can also be quite variable depending on the operator. In addition, many patients are unable to undergo CMR due to implanted devices that are incompatible. So, if we're able to obtain accurate measurements from high-quality images — like those provided by Vivid Pioneer — we can better stratify risk in patients with HCM.

We know there's an added layer of complexity in diagnosing HCM — how does 4D TTE imaging help make it easier?

Prof. Muraru: *There are some forms of hypertrophic cardiomyopathy — like apical hypertrophic cardiomyopathy — where patients may develop apical aneurysms over time. Historically, we've said that 2D echocardiography often misses these apical aneurysms because they tend to be small and the images are frequently foreshortened. Another challenge is that images are often affected by artifacts at the apex, which can obscure a reliable evaluation.*

However, with a next-generation scanner like Vivid Pioneer, if you can obtain high-quality 4D echocardiographic acquisitions, you're able to reposition the planes and image the real apex. And once you know an aneurysm might be present, you can use 2D echocardiography to confirm it or switch to a different probe for better evaluation.

> *"If we're able to obtain accurate measurements from high-quality images — like those provided by Vivid Pioneer — we can better stratify risk in patients with HCM."*

How does Vivid Pioneer's new 6Sc-D probe enhance your ability to assess HCM?

Prof. Muraru: *The 6Sc-D probe improves image quality and reduces apical noise, allowing for better visualization of the LV apex. Its ability to reach higher frequencies with improved spatial resolution — specifically for the apical region or in slim patients — helps us better evaluate the presence of thickening or other morphological abnormalities suggestive of HCM.*

This can be especially useful when scanning family members of patients with HCM, as these young subjects often have a smaller body size and tight intercostal spaces. We've had several cases where the 6Sc-D probe improved the image quality of the anterior LV wall.

I had the impression when using the 6Sc-D probe in several patients — particularly women with tight intercostal spaces — that it really helped improve visualization of the more apical segments, so having the option to switch probes and use a higher frequency one can be very helpful.

> *“The 6Sc-D probe improves image quality and reduces apical noise, allowing for better visualization of the LV apex. Its ability to reach higher frequencies with improved spatial resolution helps us better evaluate the presence of thickening or other morphological abnormalities suggestive of HCM.”*

You have both made a strong case for using 4D TTE in routine clinical practice. In your view, how could Vivid Pioneer help drive broader clinician adoption of 4D TTE, particularly when it comes to image quality?

Prof. Badano: *We used to work with older 4D systems and relied heavily on multi-beat acquisition to achieve high temporal and spatial resolution. This was challenging because not all patients could hold their breath long enough for multi-beat acquisition, and a sizable number of patients with arrhythmias, like atrial fibrillation, couldn’t be examined using this technique. Vivid Pioneer, with the high temporal and spatial resolution achievable from a single-beat acquisition, makes it much easier to obtain a 4D dataset—just like we were used to doing with 2D echocardiography. If coupled with improved automation in quantitation — like the new software packages for the left ventricle, the left atrium, and also for quantifying the anatomy and leaflets of the mitral valve — it will represent a super breakthrough and make it much easier to incorporate 4D imaging into the routine assessment of every patient in the lab.*

Prof. Muraru: *It all comes down to the time required and confidence in the measurements. If a measurement takes too long to obtain, or if the operator is concerned about the reliability of the results — whether due to poor image quality or border-tracking issues — it simply won’t be used in routine practice. If we want to raise the quality of echo exams, we need to incorporate 4D and strain wherever feasible and the AI-enhanced solutions coupled with excellent image quality of Vivid Pioneer will encourage echocardiographers to adopt them in their routine examinations.*

How have improvements in Vivid Pioneer’s image quality impacted your productivity?

Prof. Badano: *The improved image quality of 2D imaging — particularly in patients with fair or poor acoustic windows — reduces the time needed to obtain diagnostic-quality images.*

Additionally, the higher spatial and temporal resolution of single-beat 4D echocardiography makes it clinically valuable for patients with atrial fibrillation or other arrythmias, where multi-beat acquisition may not be feasible due to stitching artifacts. This is a significant advantage given that approximately 30% of patients with heart failure and 60-70% of those with severe atrioventricular valve disease, have atrial fibrillation. Accurate quantification of the geometry and function of cardiac chambers is essential for effectively managing these patients.

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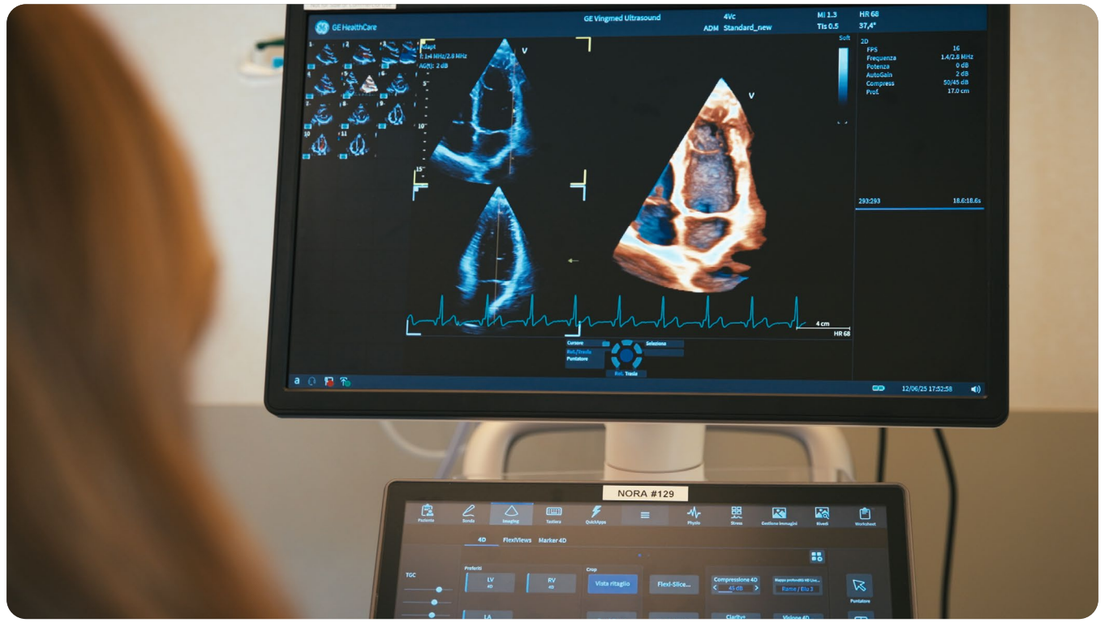
In what ways has the user experience brought more ease and efficiency to your workflow?

Prof. Muraru: *I was impressed by the system. The compact design and the simplified console make it easier to operate, as many of the redundant buttons and TGC have been moved to the touchscreen. I also appreciated the more intuitive controls, where written functions have been replaced by symbols — eliminating translation issues that can be difficult for foreign researchers or colleagues to interpret.*



Prof. Badano: *Thanks to the simplification and streamlining of the user interface — along with a reduction in buttons and controls — it’s now very easy to obtain the desired dataset using both transthoracic and transesophageal modalities.*

Also, the 4D Auto LHQ feature is user-friendly and fast, providing 4D measurements of left ventricle (LV) and left atrial (LA) volumes, as well as LV strain analysis — now faster and more reliable.

The Easy AFI feature provides immediate calculations of LV longitudinal strain and offers automated quantification of LV ejection fraction, which has proven reliable when compared to 4D echocardiography in the same patient. This is particularly useful for internal checks.

Let’s end by looking at the big picture. How would you describe the potential impact of the new Vivid Pioneer on clinical practice and patient care?

Prof. Badano: *I would say that Vivid Pioneer has changed the paradigm of 4D echocardiography, making it simpler, more reliable, and faster to be introduced into the routine of the echo lab.*

Prof. Muraru: *Vivid Pioneer is not just an update or another new scanner. It’s an evolution. It’s a transformation. We are evolving towards a patient-centered, anatomically sound assessment — with increased accuracy, streamlined workflows, and a detailed assessment of the cardiac morphology and function in real time. This allows us to improve our diagnostic capabilities for the better care of our patients.* ■

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Denisa Muraru, FESC, FACC, MD, PhD, is a cardiologist at Istituto Auxologico Italiano, IRCCS, San Luca Hospital, and Associate Professor of Cardiology at the University of Milano-Bicocca, Milan, Italy. She is an international expert in 3D and strain echocardiography, with extensive experience in valve disease, right heart imaging, and cardiomyopathies. Her research focuses on tricuspid regurgitation, right ventricular remodeling, and advanced echocardiographic techniques. Prof. Muraru has co-authored over 270 peer-reviewed publications and 70 book chapters.

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