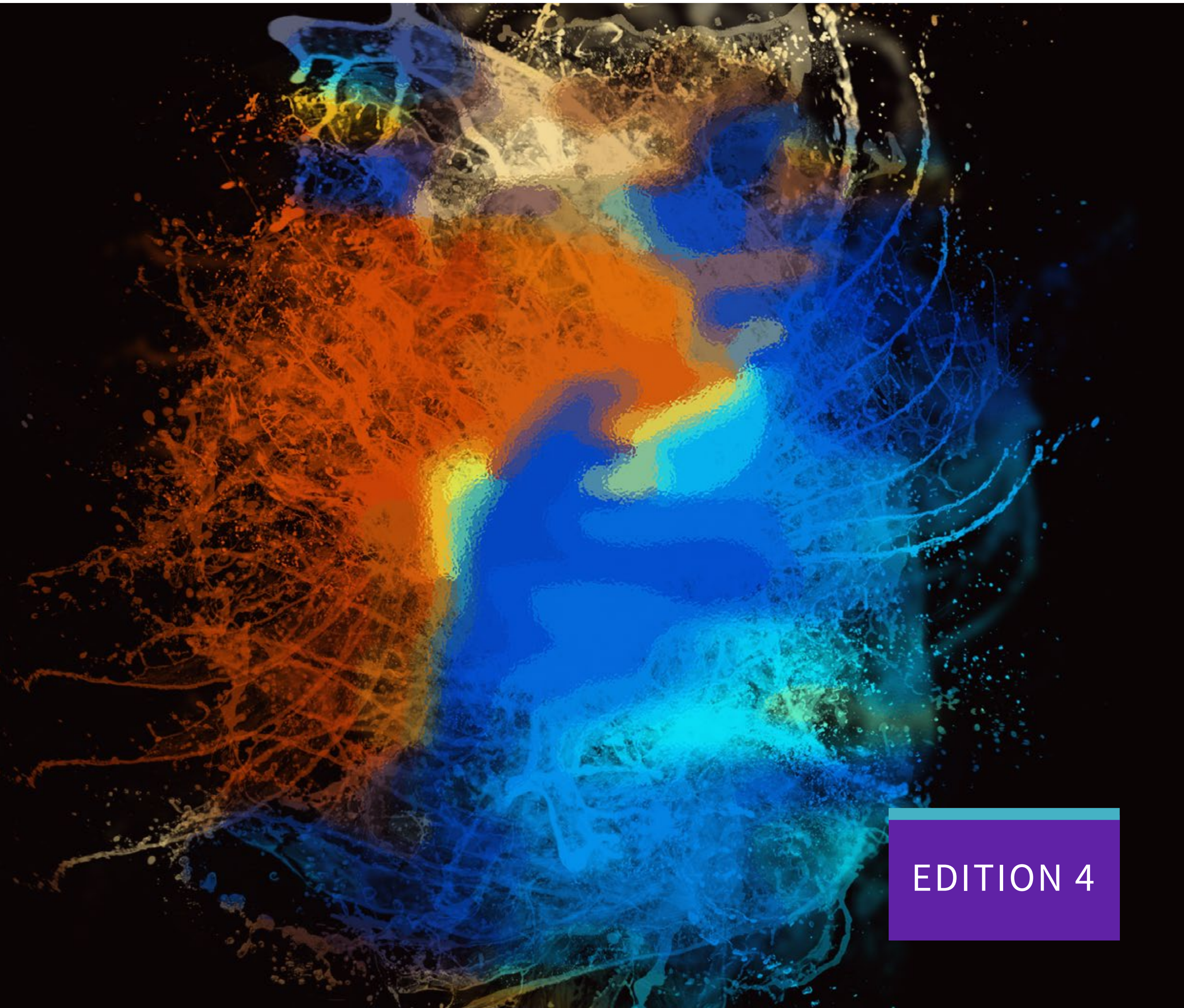
GE HealthCare

Vivid™ Magazine



EDITION 4

Dagfinn Saetre,
General Manager
Cardiovascular Ultrasound

Dear Reader,

Welcome to the latest edition of Vivid Magazine, where we dive into the world of the echo lab, exploring the pivotal intersection of cutting-edge technology and patient care. Through the lens of strain imaging, we unveil new insights into myocardial mechanics, equipping clinicians with a deeper understanding of cardiac health and disease.

In this edition, we are privileged to have Dr. Christos Mihos, an expert on strain imaging from the Columbia University Division of Cardiology at Mount Sinai Medical Center, for a discussion on the profound significance of this imaging modality, its transformative impact on cardiac care, and the importance of developing a training program to enhance healthcare professionals' strain mastery.

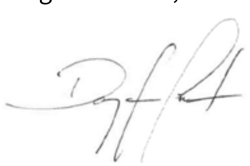
Join us as Dr. Jordan Strom from Beth Israel Deaconess Medical Center expands on the potential of artificial intelligence (AI) in reshaping workflows in the echo lab. He highlights how emerging technologies are revolutionizing efficiency and accuracy, offering reliable diagnostic information while mitigating user error through automation.

Furthermore, we are delighted to talk with Dr. Salima Qamruddin, a force in the cardiac ultrasound space from the Women's Cardiovascular Wellness Clinic at Ochsner Heart and Vascular Institute. In our in-depth Q&A session, she emphasized the importance of myocardial work in enhancing diagnostic accuracy and the potential to predict patient outcomes.

The innovative approaches discussed in this edition streamline diagnostic processes, enhancing the accessibility and safety of echocardiography. Our collective commitment to exploring these advancements propels us towards seamlessly integrating advanced imaging technologies, optimizing clinical efficiency—and ultimately—improving patient outcomes.

As we embark on this Edition's journey of discovery and innovation, I extend my gratitude to you for joining the GE HealthCare Vivid team in our pursuit of excellence. It is my hope that these stories resonate with you long after reading, fueling your continuous advancement in the field.

Dagfinn Saetre,



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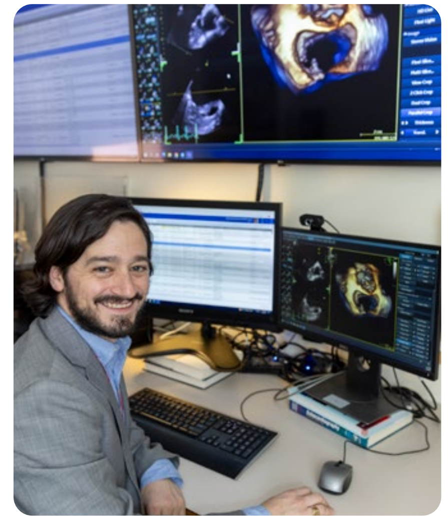
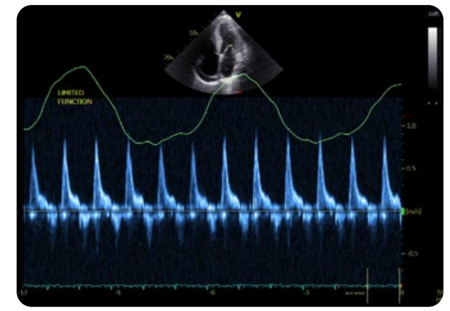




The power of AI in the echo lab

Redefining workflow efficiency through emerging technologies

Artificial intelligence (AI) isn't just growing – it's exploding in echocardiography. Leading cardiovascular centers all over the world are embracing new innovations that leverage AI to accelerate workflow, improve diagnostics, and deliver better patient care. The Cardiovascular Institute at Beth Israel Deaconess Medical Center (BIDMC) in Massachusetts, a major teaching hospital of Harvard Medical School, is one of them. Echocardiography Lab Director, Dr. Jordan Strom, sees the latest advancements as a possible answer to some of today's biggest challenges.

A shortage of cardiac sonographers is making it hard for hospitals and clinics across the United States to keep pace with an increasing number of patients and complex cases. BIDMC, with 600 beds, is consistently operating at maximum capacity. Besides heavy caseloads, this quaternary care center is spread out across several campuses—posing additional obstacles.

Dr. Strom oversees four busy echo labs that perform approximately 25,000 transthoracic echocardiograms a year. The team also conducts 2,000 stress echoes, and a little over 1,000 transesophageal echocardiograms annually, and those numbers are climbing. From acquisition guidance and automated measurements to new capabilities in manipulating data, a wide range of AI-based tools are powering new ways to simplify and speed up echo exams and post-processing.

Dr. Strom, who works closely with the American Society of Echocardiography (ASE) on AI initiatives, recently shared his views on how these emerging technologies are transforming echocardiography.

Why is artificial intelligence an important part of echocardiography as we move into the future?

Dr. Strom: *We are using AI all the time to assist in workflow solutions. It's built into the background of many of the tasks that we do on a daily basis. Simplifying routine and manual tasks with automation may help prevent user error and also gives reliable, consistent diagnostic information. As we get more information, it also helps our lab as a whole, and our patients by providing more diagnostic information up front. And it makes it easier for cardiologists to read echoes and other types of images.*

With AI, we're improving the reliability and reproducibilty of our measurements.[1] We're improving access to care and access to ultrasound, and ultimately streamlining what we do. There are enormous uses for these technologies, but I think we're just scratching the surface of what we can do.

The sonographer shortage and increased patient load are real challenges for many centers. How can AI and other Vivid technologies address some of these issues?

Dr. Strom: *We're always operating at maximum capacity and any bit that we can do to reduce those barriers is great. One way is making sure our echo protocols can adapt to the present time and the needs of the day-to-day workflows and efficiencies.*

> *"With AI, we're improving the reliability and reproducibilty of our measurements. We're improving access to care and access to ultrasound, and ultimately streamlining what we do.*

The traditional teaching has been you start with the parasternal long axis, but that's based on the era of M-mode where we were doing a lot of our measurements in the parasternal long axis view with M-mode. I think we've moved beyond that.

At our lab, we start our imaging with a triplane image from the apical view. A triplane image is essentially three simultaneous images at different angles, giving us a four, two, and three-chamber view, all on the same heartbeat. This allows us to visualize and access all aspects of the heart's walls, detect wall motion abnormalities, and measure global longitudinal strain using the AFI package. It also provides a biplane ejection fraction through AI view recognition and automated contouring, and it does so quickly. In addition to that, the triplane view allows us to assess image quality and immediately identify if we need echo contrast and can start planning ahead of time. When I tell people this they say, "Why did you start with that [view]?" I say, "Well, why did we start with the parasternal long axis?"

Triplane and AI is one example, another is utilizing 3D full volume clips. We acquire 3D of the left and right ventricle at the start of the exam and use the 4D Auto LVQ and RVQ packages to quantify ventricular function. Those 3D images also allow us to subsect or crop in multiple ways and verify assumptions in 2D imaging. In addition, both our sonographers and physicians use the AI Auto Measure function to trace Doppler waveforms and perform 2D measurements, on-cart or off, with just a button click, which gives us very reproducible results. Our ability to view the raw image files in EchoPAC™ allows us access to all these tools at any time. All of this allows us to do more with the information that we have and shortens the time for interpretation of a study. Even if we're doing a focused protocol, we get relevant data that answers the questions.

> *"The Auto Measure Spectrum Recognition AI tool is also great for a sonographer. It automatically measures the Doppler spectral tracings with just a button click.*

What ways are AI and automation helping deliver more reliable and consistent exams?

Dr. Strom: *Consistency is always challenging for labs in general. Developing set protocols and having the AI trigger the machine to move to the next view and the next setting can be really helpful for sonographers. It goes a long way in making sure they are following the set protocol and doing it with consistency. The AI Auto Measure Spectrum Recognition tool is also great for a sonographer. It automatically measures the Doppler spectral tracings with just a button click.*

How can AI tools make a difference in strain imaging and what is the impact?

Dr. Strom: *Strain is increasingly becoming a standard part of the examination. The ability to not only have auto view recognition, automatically place a region of interest, and auto calculate the speckle-tracking strain value through the AFI package is tremendous.*

We are in the process of building a new inpatient cancer hospital with the Dana Farber Cancer Institute. You can bet that AFI and strain will play a central role in our ability to monitor patients for cardiotoxicity. We also use it to screen our heart transplant patients, patients with suspected amyloidosis, and patients with structural heart disease. A couple of years ago, strain was made a category 1 CPT code and that means there is reimbursement for its use. We don't use strain on everyone, but it is helpful to have for selected cases where we deem it necessary.

With AI, automation, and improved workflow technologies, do you think it's possible to add AFI strain and 3D volume measurements to a standard echo without creating a time burden on the sonographer?

Dr. Strom: *We are already doing strain and 3D acquisitions routinely on multiple exams and it hasn't really added a time burden because the EchoPAC suite allows us to manipulate the 2D and 3D dataset and obtain these measures offline. I think these technologies can help short cut and identify solutions for labs relatively easily, and help us get more robust information up front, early, and with less work.*

How is GE HealthCare's ViewPoint™ with EchoPAC Suite impacting your post-processing review and analysis with raw data?

Dr. Strom: *What we are used to looking at are DICOM® images, which are challenging to manipulate or change after they've been acquired. Raw data allows us to manipulate the data after the fact as we had just acquired it on the cart. We can do a number of different things, like measurements or* *pull up studies from years ago. We can then pull those measurements or studies into EchoPAC and use the data in new ways—let's say for a research project. We can then layer on newly developed technologies that weren't even around at the time the study was performed. So, not only do we have a PACS workstation that allows us to easily query studies and bring them up, but we have a really powerful robust software to manipulate those images and understand what we should be reporting.*

How has the integration of ViewPoint with EchoPAC Suite helped your readers stay efficient, especially with an institution that is spread out across campuses?

Dr. Strom: *By using EchoPAC as a plugin within ViewPoint, this allows us to essentially install a workstation capable of both viewing and image manipulation on basically any computer. We get requests all the time to put workstations in the CCU or other areas of the hospital so people can look at images or do data analysis in real-time. I have one in my office—many clinicians even can access theirs from their home. It's enormously helpful and allows for portability and a means to be able to view images across the entire network.*

How has the ability to review, analyze, and perform measurements at remote workstations impacted workflow and care?

Dr. Strom: *Our workflow is that we do the measurements and the AI more so on the workstation instead of the*

sonographer spending excess time doing the analysis on the machine. We would rather they focus on an accurate echo study and then shift to the next examination. The fine tuning can be done fairly easily in EchoPAC and we can also check on the sonographers' work. Our EchoPAC workflow allows us two-way communication between our sonographer group and our physician group, which really enables us to deliver the maximal standard of care.

Your echo fleet includes Vivid E95 and Vivid S70N ultrasound systems. What ways have they affected performance and productivity?

Dr. Strom: *About 80% of our studies are done portably, and a lot of our sonographers love the Vivid S70N because it's lightweight and ergonomically friendly. The Vivid S70N has been a great system for efficiency, allowing us to go to the patient's bedside and make real-time decisions on the fly. On the other hand, when you want the advanced workhorse for TEEs or structural heart procedures and all the functionality, the up-to-date 3D acquisition, etc., we use the Vivid E95 and have had good success. Really, that combination has served our institution very well.*

> *"The S70N has been a great system for efficiency, allowing us to go to the patient's bedside and make real-time decisions on the fly.*

Improving efficiency is universally appealing, but some clinicians are still hesitant to adopt AI. Do you have any advice?

Dr. Strom: *I think it's important for people to recognize that AI is part of our present and is used in many of our workflow solutions.*

Still, my advice is 'trust but verify.' You can use AI as a clinical decision support tool—not to replace your underlying judgement but to assist it. In fact, clinical decision-making is paramount. I think it's important to recognize that AI is just part of the greater arc of overall advancement in ultrasound technology that we can use to improve workflow, shorten time for echocardiograms, and really get more information in less time.

How do you see AI evolving in the future?

Dr. Strom: *I think AI is increasingly going to play a central role, particularly in imaging. The reason is that images themselves are really high-resolution data arrays containing pixel and location information. When you take sound, a video, or pictures and feed them into some of these future machine learning models, you're really able to get a much better prediction of patients likely to do well, patients likely not to do well, and patients likely to have a certain diagnosis.*

As we get more skilled and develop more data sets, AI algorithms are going to get better. I think ultimately, we will see great improvement in workflow, the ability to read studies quickly, and make reliable diagnoses.

GE HealthCare is a proud partner of BIDMC. What surprises you most about the Vivid products and services?

Dr. Strom: *One thing that surprises me is the degree of integration into the field—the personal touch. It's been really tremendous, and I think it's fairly unusual for large companies. For GE HealthCare, I think it's very personal for the people involved, the people making decisions, and the people you get to know. They really helped create the cutting edge technologies we use with our patients. I would want my study done with those kinds of technologies. I think it's great that we can provide the same kind of quality and standard of care to our patients, too.* ■

> *"AI is just part of the greater arc of overall advancement in ultrasound technology that we can use to improve workflow, shorten time for echocardiograms, and really get more information in less time.*

Dr. Jordan Strom is an Assistant Professor of Medicine at Harvard Medical School, Director of the Echocardiography Laboratory, and Director of Echocardiographic Research at Beth Israel Deaconess Medical Center in Boston, Massachusetts. Dr. Strom is also a Section Head for Cardiovascular Imaging Research at the Richard A. and Susan F. Smith Center for Outcomes Research in Cardiology. His research involves evaluation of the relationship of cardiac structure and function to health outcomes and the optimal use and timing of cardiac imaging in practice. Dr. Strom has published more than 90 papers and is a member of the Editorial Board of the Journal of the American Society of Echocardiography (ASE).

1 The Role of AI in Streamlining Echocardiography Quantification White Paper, Kristin McLeod and Jurica Sprem – JB20789XX.

JB28619XX

Triplane imaging

Courtesy of Dr. Jordan Strom, Beth Israel Deaconess Medical Center, U.S.

Patient history/ pathology

The patient is a 65-year old male with Type 2 diabetes mellitus, hypertension, prior cerebrovascular accident with residual right facial droop and mild dysarthria, longstanding persistent atrial fibrillation, chronic kidney disease, and prior seizure who presents with right upper quadrant abdominal pain. Cardiac biomarkers were mildly positive (troponin T 0.8 x 2). The patient's electrocardiogram sinus rhythm with inferior Q-waves suggestive of a prior myocardial infarction. In this setting, an echocardiogram was performed to evaluate for wall motion abnormalities.

Challenges

Challenges in this case included need for full endocardial border visualization, accurate quantification of left ventricular ejection fraction, as well as the need for speckle-tracking strain analysis to fully evaluate for subclinical systolic dysfunction. All was done in a busy clinical echocardiography laboratory with < 1 hour for examination due to the patient showing up 15 minutes late to his scheduled appointment.

System, probe & device used

Using a Vivid E95 echocardiograph with cSound™ and a 6Vc-D probe, we obtained diagnostic quality images. Offline post-processing of raw images was performed using the EchoPAC v206 plug-in through Viewpoint 2.0. The Automated Functional Imaging (AFI) package was used to determine global longitudinal strain as well as biplane left ventricular ejection fraction.

Step-by-step procedure

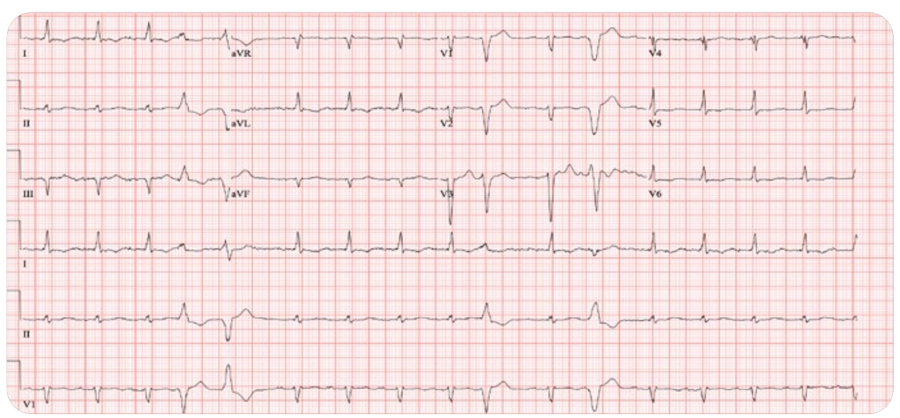
The procedure began with a triplane acquisition from the apical window. Easy AFI LV, auto-detected all relevant views, contoured the regions of interest, and calculated a reduced global longitudinal strain of -9.1% with relative sparing of the apex ("cherry-on-top" sign) and a moderately reduced biplane left ventricular ejection fraction (34%) all in the matter of seconds. Further imaging demonstrated a small pericardial effusion, left ventricular wall thickening, biatrial dilation, and restrictive left ventricular filling with a mitral L-wave and reduced TDI septal e' velocities.

Conclusion

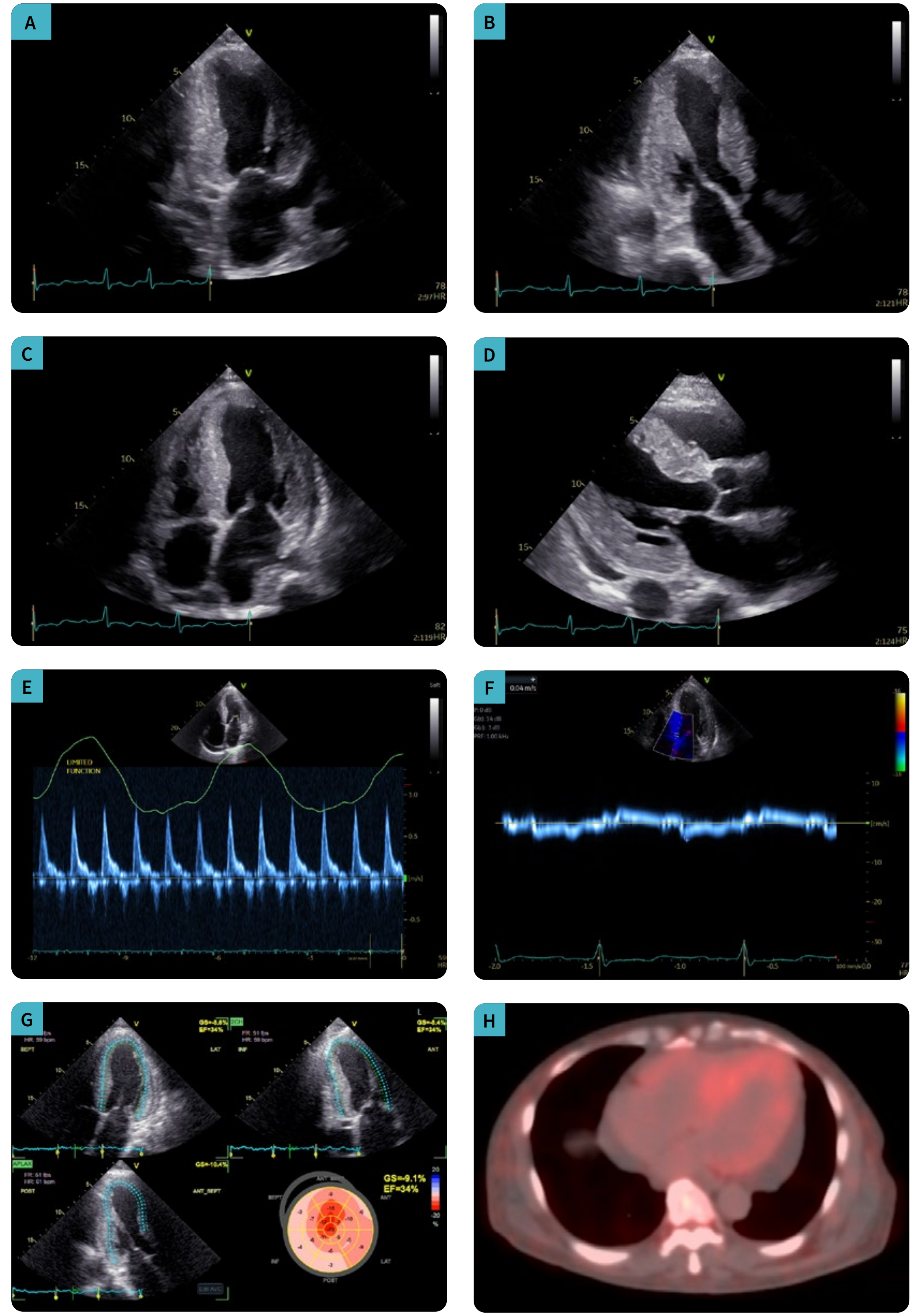
Starting an examination with an apical triplane view can be useful to assess image quality, visualize all cardinal wall segments, a global assessment of left ventricular ejection fraction, and determine global longitudinal strain, all from a single heartbeat (thus reducing variability in strain values due to differences in the heart rate across apical views). The AFI package facilitated rapid assessment of global longitudinal strain and an apical sparing pattern (apical/basal strain ratio = 1.7; normal < 1.0) which was highly suggestive of cardiac amyloidosis, allowing rapid diagnosis and treatment. ECG findings were felt to be due to a pseudo-infarct pattern.

Imaging follow-up

Based on the echocardiogram, there was suspicion for cardiac amyloidosis. The patient was referred for PYP-imaging which was highly suggestive for TTR cardiac amyloidosis. The patient was ultimately started on tafamidis with improvement in symptoms.



ECG demonstrating inferior Q-waves.



A) Apical 2-Chamber View.
B) Apical 3-Chamber View.
C) Apical 4-Chamber View.
D) Parasternal long-axis view demonstrating thickening of the left ventricular walls, valves, left atrial dilation, and a small pericardial effusion.
E) Pulsed wave Doppler sweep at the mitral valve tips demonstrating restrictive filling with a mitral L-wave.
F) TDI of the septal annulus demonstrates a reduced e' velocity of 4 cm/s.
G) Speckle-tracking strain in the AFI package demonstrating a reduced global longitudinal strain with apical sparing, and a reduced biplane left ventricular ejection fraction.
H) A follow-up PYP SPECT scan demonstrating a heart to contralateral ratio of > 1.5, highly suggestive for TTR cardiac amyloidosis.

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Strain imaging simplified

Changing cardiovascular care with a global learning experience

Right before Dr. Christos Mihos began his fellowship in advanced echocardiography at Massachusetts General Hospital in 2015, a mentor handed him the ASE guidelines for strain echocardiography and offered some stern advice, “Before you go to Boston, you’d better know this inside and out.”

The thick document was very intimidating for Dr. Mihos, who was a non-invasive cardiology fellow at the time. Like many other general fellowship programs, Dr. Mihos’ strain training only focused on the basics. So, he dug into the guidelines and a host of related literature and began his own self-directed learning program.

Dr. Mihos is now the Director of the Echocardiography Laboratory at the Columbia University Division of Cardiology at Mount Sinai Medical Center in Miami, Florida. He's also an expert on strain and is determined to teach other clinicians that it's an invaluable tool that can transform care.

"It's going to make you a better cardiologist and it's going to make you a way better echocardiographer," Dr. Mihos insists. "Strain is going to give you the opportunity to improve patient care. And you're going to save a life. No question. At some point, you will literally save a life."

> *"Strain is going to give you the opportunity to improve patient care. And you're going to save a life. No question.*

The power of strain

Strain can provide detailed information about the structure and function of the heart for a more confident diagnosis. Another major benefit is early detection of cardiac dysfunction before it progresses. Dr. Mihos says it's your warning sign. "Strain picks up the problem before the muscle develops overt dysfunction. That's before things go wrong. At that point, the cardiologist is behind the eight ball and you're dealing with a completely different substrate of patient."

With strain, you can also evaluate tissue damage or deformation to improve treatment planning. But even with all the advantages, it is still underutilized by the medical community. A recent worldwide survey from the European Association of Cardiovascular Imaging cited time constraints and lack of training as the biggest barriers.[1]

"Once you get comfortable with it, it can take less than a minute to do a full strain analysis," Mihos asserts. "We use AFI with EchoPAC™ from GE HealthCare and the automated features have really sped things up. I think time concerns have more to do with comfort and confidence and those can be fixed with training and mentorship."

And who better to teach strain than Dr. Mihos?

"Once you get someone to understand what they are looking at, what those measurements mean and say about the function of the organ, they start connecting the dots. It suddenly makes sense and actually becomes easier. The light bulb goes on and it just clicks."

The evolution of strain

What's the next emerging tool showing great promise in echocardiography? According to Dr. Mihos, "Myocardial work is the next level of strain. Once users become more comfortable with it, they will start using myocardial work. From a practice perspective, that is very exciting."

A Vivid idea for teaching strain

Dr. Mihos has experienced more of those meaningful moments collaborating with GE HealthCare to create the Vivid Learning Academy. Dr. Mihos developed all the content for the online series, distilling his learnings into a curriculum of 10 episodes, 45 minutes each, that teach strain from the ground up.

"The problem was that nobody was teaching it. There wasn't a resource out there, so I began working with GE HealthCare to change that." He continued, "I'm really proud that the Academy is available in a format that is so easy to access."

The series begins with basics and pitfalls. It then offers dedicated sessions on a variety of clinical use cases like ischemic heart disease and cardio-oncology. Each session consists of two sections: a presentation of the topic followed by discussions between renowned key opinion leaders sharing their experience and advice.

"I wanted to make something that was not intimidating to anybody and present these experts in a laid-back fashion. I wanted to facilitate the conversation and that's how we approached it. The entire idea was to make it inviting, welcoming and inclusive to anybody who wants to participate," he insists.

It's growing every day

Since its inception in 2022, Vivid Learning Academy has reached over 24,000 viewers across 25 countries. China recently signed on, reporting 10,000 users after just five episodes. The next step is taking the Academy on the road. Dr. Mihos will be leading several hands-on workshops on strain at upcoming congresses, building awareness and providing more personalized experiences for participants.

The growing impact is all the motivation Dr. Mihos needs.

"I see it as an organic process. We teach people and then they teach people, and it just keeps going. At the end of the day, all of that trickles down to our patients and allows us to provide better care."

Expand your capabilities with the Vivid Learning Academy

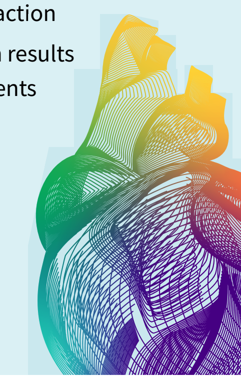
Take a deep dive into strain imaging in echocardiology with the Vivid Learning Academy. Check out our comprehensive episodes online.

You can also put your strain knowledge into practice, building skills at hands-on workshops.

- The American Society of Echocardiography (ASE) | June, U.S.
- Latin American School of Ultrasound L.A.S.U.S. | June, Miami, U.S.
- European Society of Cardiology (ESC) | August, London

Topics include:

- Explore strain & 3D imaging on real case examples
- Compare the superiority of strain imaging vs. ejection fraction
- Understand how strain results impact patient treatments
- Discover methods for monitoring disease progress over time



Look for updates and registration details coming soon.

Dr. Christos G. Mihos is the Director of the Echocardiography Laboratory at the Columbia University Division of Cardiology at Mount Sinai Medical Center. He also serves as an Assistant Professor of Clinical Medicine at Columbia University Irving Medical Center. Dr. Mihos is a non-invasive cardiologist and echocardiographer with board-certification in Cardiovascular Disease and level III board-certification in Adult Comprehensive Echocardiography. He has vast experience in clinical cardiovascular research and his academic focus includes valvular heart disease, inherited and acquired cardiomyopathy, and the use of strain echocardiography to study cardiac mechanics in health and disease.

1 Sade LE, Joshi SS, Cameli M, Cosyns B, Delgado V, Donal E, Edvardsen T, Carvalho RF, Manka R, Podlesnikar T, Popescu BA, Hanzevacki JS, Sitges M, Dweck MR. Current clinical use of speckle-tracking strain imaging: insights from a worldwide survey from the European Association of Cardiovascular Imaging (EACVI). *Eur Heart J Cardiovasc Imaging*. 2023 Nov 23;24(12):1583-1592. doi: 10.1093/ehjci/jead170. PMID: 37463125.

Non-invasive myocardial work; evaluating systolic function of the left ventricle

Uwe Lempetz, Global Clinical Development

Gunnar Hansen, Global Clinical Research Manager

Sten Roar Snare, Senior Manager Software Engineering

Introduction

Traditionally, clinicians have assessed left ventricular global performance using ejection fraction (EF). However, EF has limited ability to detect subclinical changes in ventricular function, as demonstrated, for example, in the follow-up of patients undergoing cancer therapy.[1,2]

Introduced to the market in 2004 as a pioneering technology by GE HealthCare, speckle tracking imaging with global longitudinal strain (GLS) is increasingly used to assess even subtle myocardial dysfunction. The resulting strain traces provide information about global function, dyssynchrony, and poorly contracting segments.

Automated Functional Imaging (AFI) uses speckle tracking to quantify left ventricular (LV) strain, providing users with the ability to track "natural acoustic markers" within the myocardial tissue in any direction within the imaging plane throughout the heart cycle.[3]

Through a series of breakthroughs, GE HealthCare has consistently pioneered the development of quantitative ultrasound-based technologies.

Although GLS is a well-validated method for clinically assessing cardiac diseases, one of its limitations lies in load dependency. Increasing the afterload may decrease GLS and lead to false conclusions about LV contractility. A meta-analysis of 24 studies showed that variations in afterload and blood pressure (BP) can impact the normal range of strain values.[4]

To quantify the efficiency of the left ventricle in the context of loading conditions a new index was introduced – Myocardial Work Index (MWI).

MWI augments Automated Functional Imaging (AFI) by incorporating dynamic LV pressure. This addition brings a crucial dimension to the assessment of LV function, aiding in the interpretation of strain traces in relation to LV pressure dynamics.[5]

Pressure-strain loop (PSL) analysis is an innovative echocardiographic method used to quantify myocardial work (MW). This approach combines information derived from speckle tracking strain imaging and a non-invasive estimate of the left ventricular pressure (LVP). The PSL-based analysis demonstrated strong correspondence with invasive measurements and directly measured myocardial work.[6]

By incorporating the left ventricular loading condition, PSL analysis provides a superior approach for assessing myocardial performance. It enables the quantification of both the global and regional contractile capacity of the myocardium, offering insights into its energetics and oxygen consumption. This in-depth evaluation allows for the detection of subclinical myocardial dysfunction.

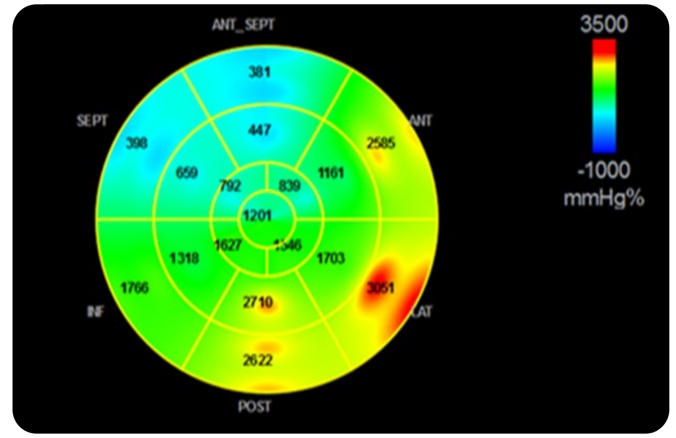


Figure 1: In the Myocardial Work bull's eye, blue represents areas of negative work, green indicates normal values, and red highlights areas of high work.

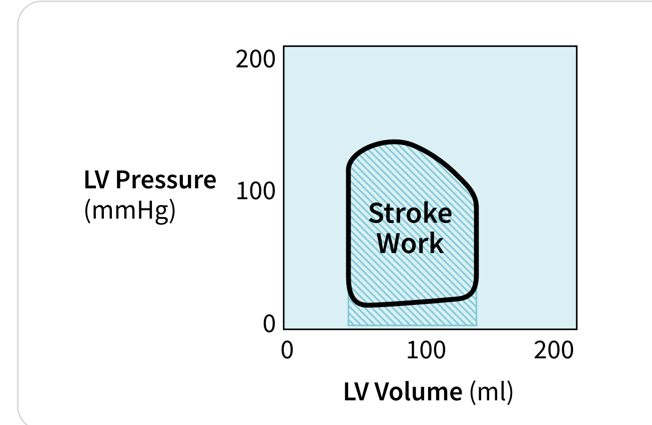


Figure 2: Stroke work, the area of the LV pressure-volume loop. The figure also indicates the systolic stroke work (larger than stroke work as negative work during diastole is not included).

Myocardial Work

The Myocardial Work module in AFI prompts the user to input blood pressure (BP), preferably recorded at the end of the exam to minimize the "white coat effect" on BP, and valvular event times. Only the systolic cuff pressure measurement is used in the calculation as an estimate of peak LV pressure. The results are presented in a bull's eye (Figure 1) displaying segmental myocardial work values along with global values.

Work is assessed from Mitral Valve Closure (MVC) to Mitral Valve Opening (MVO), encompassing mechanical systole, including isovolumetric relaxation (IVR). The global values are determined as the average of all segmental values.

MWI features four distinct components that enhance the understanding of LV mechanics: the global work index (GWI), the global wasted work (GWW), the global constructive work (GCW), and the global work efficiency (GWE), representing the proportion of constructive to total work. Each component offers unique insights into LV mechanics.

Global Work Index (GWI)

GWI quantifies the indexed total work performed by the LV throughout the entire mechanical systole. Notably, systolic stroke work is larger than overall stroke work, as negative work during diastole is not included. Visually represented by the area enclosed by the PSL, GWI corresponds to the translation of myocardial energy into mechanical energy between mitral valve closure (MVC) and opening (MVO). Positive work results from the shortening of the myocardium, while negative work results from the lengthening of the myocardium.

Global Constructive Work (GCW)

GCW represents the positive work that contributes to LV ejection. This includes isovolumic contraction (IVC) and the negative work during isovolumic relaxation (IVR) that results from lengthening of the myocardium. GCW quantifies the energy consumed by the myocardium that effectively contributes to cardiac output (CO) by facilitating LV ejection.

Global Wasted Work (GWW)

GWW represents the LV work that does not contribute to LV ejection. This encompasses negative work during isovolumic contraction (IVC) and systole, where the myocardium undergoes lengthening, as well as positive work during IVR when the myocardium undergoes shortening. GWW quantifies the energy consumed by the myocardium that is wasted and does not contribute to CO.

Global Work Efficiency (GWE)

GWE is the ratio between constructive work and total (constructive and wasted) work. It reflects the net percentage of MW performed that is translated into CO (Figure 3).

The formula for GWE is GCW divided by the sum of GCW and GWW [GCW (GCW+GWW)].[7]

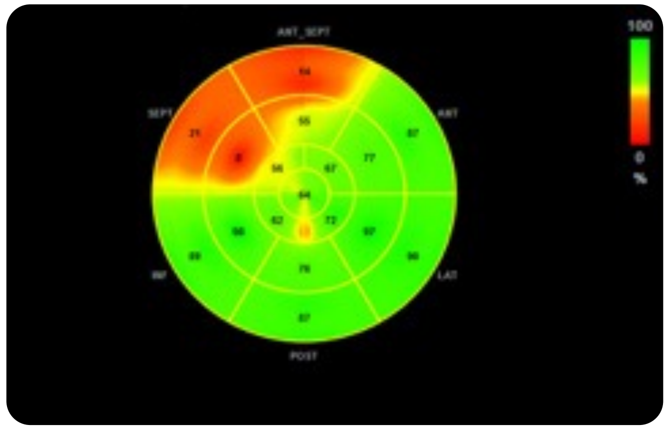


Figure 3: Myocardial Work Efficiency.
These values are unaffected by peak LV pressure. Specifically, 0 Wasted Work results in 100% Myocardial Work efficiency, equal amounts of Wasted and Constructive Work yield 50% Cardiac work efficiency, and 0 Constructive Work will give 0% efficiency.

Normal Reference Values of Myocardial Work Indices

The software-generated MW indices were published as part of a multicenter study involving participants enrolled in “The European Association of Cardiovascular Imaging Normal Reference Ranges for Echocardiography (NORRE).” The study included 226 middle-aged healthy subjects (45 ± 13 years). Results from this study demonstrated that GWI and GCW increased with age in women. GWW was higher in men than in women, while GWE was higher in women than men.[8]

The NORRE study’s reference values are widely adopted as normal reference values in routine practice across many echocardiography departments.

In another study involving 1926 subjects from the STAAB cohort, the analysis of Myocardial Work (MW) components based on age and sex was conducted. These components were compared with conventional echocardiography parameters, such as ejection fraction (EF) and global longitudinal strain (GLS). The findings indicated that, in this study[9]:

- All values, except for Global Work Index (GWI), remained independent of sex and stable until the age of 45.
- GWI was higher in women compared to men.
- Global Constructive Work (GCW), Global Work Efficiency (GWE), and Global Wasted Work (GWW) did not exhibit significant differences between women and men.
- With increasing age, GWW showed an upward trend, leading to a decrease in GWE, while GWI and GCW demonstrated a modest increase at the age of 45 but not in older patients.

> *The NORRE study’s reference values are widely adopted as normal reference values in routine practice across many echocardiography departments.*

Clinical applications

Generally, MWI may offer an in-depth evaluation of myocardial systolic performance, spanning various physiological and pathological conditions beyond the scope of traditional echocardiographic techniques. Estimation of LV systolic function is essential in all cardiac diseases, with EF remaining the most frequently used parameter. Although speckle tracking echocardiography with GLS provides more detailed information about global and segmental systolic function, enabling the detection of subclinical dysfunction, it is important to note that it remains load-dependent.[10]

MWI, on the other hand, is a less load-dependent tool for assessing LV function, as it incorporates LV afterload. MWI provides a preliminary estimate of the work generated by each segment of the LV throughout the cardiac cycle. This work is influenced by the strength of the myocardial fiber contraction, LV loading conditions, and the wall stress applied to LV segments.

> *MWI has demonstrated greater sensitivity as an index of segmental and global LV performance when compared to EF and GLS.*

MWI has demonstrated greater sensitivity as an index of segmental and global LV performance when compared to EF and GLS. This finding was confirmed in a study involving hypertensive patients, revealing that under acute pressure overload, EF remains unaffected, GLS decreases, and MW indices show an increase.[11]

Cardiac Resynchronization Therapy (CRT)

For patients with severe LV dysfunction and wide QRS complex, cardiac resynchronization therapy is effective in restoring mechanical efficiency through contraction resynchronization. However, a notable limitation exists, as approximately 30% of patients exhibit no improvement and may even experience worsened symptoms after device implantation. As such, the identification of predictors for poor outcomes following CRT is of paramount importance.[12]

MWI was first described and validated in patients undergoing cardiac resynchronization therapy. The presence of a dyssynchronous ventricular septum results in substantial wasted work. Following a positive response to this treatment, WW decreases, leading to an increase in the global work index and LV performance.[13]

In a prospective multicenter study involving 200 recipients of CRT, it was demonstrated that work difference between the septum and LV lateral wall served as a predictor of CRT response and was associated with a reduced risk during long-term follow-up.[14]

In another prospective multicenter study involving 130 patients referred for CRT implantation, it was observed that there is an acute redistribution of segmental work between septal and lateral work, which is a strong determinant of LV reverse remodeling.[15]

Conclusion

The assessment of MW indices in CRT candidates suggests that residual contractility, as a potential source, plays a crucial role in restoring LV function. Additionally, the redistribution of regional myocardial work might be a vital mechanism in resynchronization therapy. The analysis of MW holds potential as a method for exploring cardiac dyssynchrony and monitoring CRT response.

Cardio-oncology

Peak GLS is a robust echocardiographic measure for evaluating LV systolic function. Given its high reproducibility and the ability to detect early changes in LV function, the use of GLS is recommended by cardio-oncology guidelines when monitoring patients for cancer therapy-related cardiac dysfunction (CTRCD).[16]

> *...demonstrated the superiority of MWI over GLS in early detection of cancer therapy-related cardiac dysfunction (CTRCD).*

However, a limitation of GLS is its load dependency. Cancer patients undergoing cancer therapies may experience fluctuations in blood pressure, which may impact GLS measurements even in the absence of myocardial function change due to load dependency.

In a large retrospective study that examined LVEF, GLS, and MWI parameters before, during, and after anthracycline chemotherapy, the study demonstrated the superiority of MWI over GLS in early detection of cancer therapy-related cardiac dysfunction (CTRCD). A 15% decline in GWW and GWI preceded CTRCD, as defined by GLS. Moreover, the changes in GWI and GCW were directly proportional to the cumulative dose of anthracyclines administered.[17]

In a prospective study involving 136 women undergoing anthracycline and trastuzumab treatment for HER2+ breast cancer, MW indices did not improve identification of subsequent Cardiovascular Magnetic Resonance CMR)-defined CTRCD beyond the knowledge of GLS changes. However, the combined use of a change in GLS and GWI proved useful for diagnosing concurrent CTRCD in selected patients who exhibited a small absolute GLS change (<3.3%) but a substantial reduction in Systolic Blood Pressure (SBP) (~21 mm Hg).[18]

Conclusion

The distinction between true cardiotoxicity secondary to chemotherapy and alterations in LV function resulting from afterload variations may be of prognostic significance. By providing a measure of myocardial performance independent of LV afterload, MWI may be an important advance in the diagnostic workup in patients receiving anticancer treatment. The increasing role of GLS in the cardiac monitoring of chemotherapy could be complemented by the use of MWI in some situations.

Coronary Artery Disease (CAD)

Evaluating patients with coronary artery disease becomes challenging when there are no wall motion abnormalities (WMA). Echocardiography relies on subjective methods with visual assessment of segmental and global myocardial dysfunction and ischemia detection.

GLS has demonstrated to be a strong predictor of stable ischemic cardiomyopathy even in the absence of wall motion abnormalities.[19]

However, the contractile patterns of ischemic myocardium are significantly influenced by loading conditions, leading to immediate changes from hypokinesis to dyskinesis following an acute elevation in afterload.[20]

MWI is a promising tool that has demonstrated better sensitivity and accuracy compared to EF and GLS in detecting patients with single- or multivessel coronary artery disease. GWI was found to be significantly reduced in severe CAD patients compared to those without CAD, demonstrating the ability to predict significant CAD with high sensitivity and specificity, surpassing GLS.[21]

In a single-center study, 507 patients with ST-segment-elevation myocardial infarction were retrospectively analyzed. Global LV myocardial work efficiency was measured by transthoracic echocardiography within 48 hours of admission. The study found that reduced global LV myocardial work efficiency (<86%) in patients with ST-segment-elevation myocardial infarction was independently associated with worse long-term prognosis.[22]

MWI was also studied in 126 patients with non-ST-segment acute coronary syndrome before coronary angiography. The presence of a region with reduced MWI was shown to be superior to all other echocardiographic parameters (GLS, LVEF, etc.) in identifying acute coronary artery occlusion. The authors suggest that this method may be an important tool to identify ACO in patients with NSTE-ACS in the emergency department.[23]

Conclusion

While coronary artery disease may not directly affect the loading conditions of the LV, the impaired oxygen metabolism in ischemic myocardium can have an impact on the myocardial work. Existing studies have demonstrated that MWI is a promising tool for the diagnosis, treatment, and prognostication of CAD.

Cardiomyopathies and fibrosis

Cardiomyopathies are a heterogeneous group of heart muscle diseases associated with structural changes and electric and mechanical dysfunction that cannot be explained by ischemic coronary artery disease or abnormal loading conditions. As such the potential of MWI was studied in several distinct patient cohorts.

In a study involving 110 patients with nonobstructive hypertrophic cardiomyopathy (HCM) presenting different phenotypes, it was shown that MWI was reduced in these patients compared to controls. This reduction correlated with maximum LV wall thickness and significantly associated with a worse long-term outcome.[24]

These findings are supported by another study involving 82 HCM patients, where GCW was significantly reduced and identified as the sole predictor of myocardial fibrosis as confirmed by CMR.[25]

Another potential clinical application of MW indices lies in the diagnosis and prognosis of patients with cardiac amyloidosis (CA). Studies have demonstrated that in a population with CA, the magnitudes of MW indices are significantly reduced compared with healthy control subjects. These differences become even more pronounced during exercise.[26]

The potential value of MWI was substantiated by a study involving 83 CA patients. Specifically, GCW demonstrated independent diagnostic value for detecting CA, whereas GLS did not. The authors discuss the importance of adjusting the measures of LV systolic function for afterload in CA patients, who often present with low blood pressure, potentially leading to an overestimation of LV systolic function according to other measures such as LV ejection fraction and LV GLS.[27]

> *Myocardial work indices in several heart muscle diseases [show] promising results.*

Conclusion

Myocardial work indices have been studied in several heart muscle diseases with promising results and should be further evaluated with regards to their diagnostic and prognostic values.

Valvular heart disease

MWI measurements are based on the estimation of non-invasive LV pressure from SBP measured with a cuff manometer. Therefore, the evaluation of MWI is not recommended in pathological conditions such as aortic stenosis (AS), where SBP may not accurately represent LV peak systolic pressure.

> *New parameter demonstrated a high correlation with invasively measured LVSP.*

However, MWI could prove useful in patients with AS, since in these patients LVEF remains preserved until late stages of the disease, while GLS, which is a well-known predictor of worse prognosis, has shown to have important load dependence.[6]

To account for the higher peak intraventricular pressure compared to the peripheral SBP, a method was introduced. This method combines the mean gradient over the aortic valve, measured by echocardiography, with arterial SBP, creating a new parameter for the non-invasive estimation of the LVP in AS patients.[28]

This new parameter has demonstrated a high correlation with invasively measured LVSP and that non-invasive assessment of myocardial work can be performed in patients with aortic stenosis.[29] These findings sparked interest in assessing the potential prognostic power of MWI in the context of transcatheter aortic valve replacement (TAVR).

In a study involving 73 consecutive patients with symptomatic severe AS scheduled for transcatheter aortic valve implantation (TAVI), it was demonstrated that myocardial work indices serve as independent prognostic predictors of adverse clinical outcomes.[30]

In another study involving patients with severe AS, the non-invasive myocardial work variables – GWI, GCW and GWE – were the only variables that changed significantly with the correction of severe AS through TAVR. Both GWI and GCW were able to predict an improvement of GLS after TAVR, suggesting potential prognostic value.[31]

Conclusion

By combining AV mean gradient with arterial SBP, myocardial work indices can be assessed in patients with aortic stenosis. Myocardial work indices may offer additive value over GLS in the early identification of patients who would benefit from aortic valve intervention.

Summary

Myocardial Work Index augments GE HealthCare's speckle tracking technology (AFI) by taking dynamic LV pressure into account.

GE HealthCare was the first company to provide speckle-based strain technology to help clinicians diagnose with higher confidence and to drive standardization of the technology across the industry.

GE HealthCare continuously extends its portfolio of speckle-based strain tools to help solve clinical problems.

As of 2023, 54% of publications and research studies related to Myocardial Strain Imaging use GE HealthCare's speckle tracking technology, making it the most widely cited. The second most cited technology accounts for 18%.

This is attributed, in part, to the extensive validation of the algorithms by numerous clinical research groups. GE HealthCare takes additional measures in strain processing to enhance accuracy.

The introduction of GE HealthCare's exclusive noninvasive Myocardial Work Index module has shown initial benefits. It provides an additional measure for assessing LV systolic function by incorporating afterload and LV strain concurrently. It improves upon LVEF and GLS calculations by reducing the limitations associated with the load dependency of these parameters.

In recent years, a growing body of evidence has emerged, demonstrating the favorable feasibility and reproducibility of MWI. This supports its application in various clinical scenarios, including disease state follow-up.

Visit the GE HealthCare webpage at *https://www.gehealthcare.com/products/ultrasound/vivid* to learn more the Vivid cardiovascular ultrasound portfolio.

If interested in strain imaging in echocardiography, please explore at the Vivid Learning Academy program (sponsored by ASE) at *https://www.gehealthcare.com/products/ultrasound/vivid/vivid-learning-academy*.

The series is composed of **ten episodes**, beginning with basics and pitfalls, followed by dedicated sessions featuring various clinical **use cases**. Each session is divided in two sections: a presentation of the topic and discussions among **renowned key opinion leaders** who will share their experiences, tips, and tricks. Episode 9 is specifically focused on the use of Myocardial Work.

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The power and promise of myocardial work

Examining diagnostic accuracy and the potential to predict patient outcomes

Myocardial work (MW) to assess cardiac performance is rapidly gaining awareness, acceptance, and application. Supported by a growing body of evidence, myocardial work is emerging as a promising tool for detection, diagnosis, treatment, and prognostication of cardiovascular diseases.[1] This non-invasive method has been validated in a variety of clinical conditions, including coronary artery disease and heart failure patients undergoing cardiac resynchronization therapy.[1]

Myocardial work integrates strain measurement with LV systolic pressure and is less load dependent. It augments AFI by taking pressure into account, assessing total stroke work of the heart, and adding another dimension to the assessment of LV function. The introduction of innovative software for non-invasive MW calculations, including speckle tracking imaging with global longitudinal strain (GLS), has made it possible to utilize this method in many different clinical settings.

Ochsner Medical Center's Heart and Vascular Institute in New Orleans was an early adopter of MW, and the tool has played a valuable role as a support tool in patient assessments and critical clinical decisions done by physicians. Embracing innovation is part of Ochsner's DNA. It has been a pioneer in heart and vascular care for decades, inventing percutaneous atrial septal defect closure, implanting a pacemaker in the youngest patient on record, and leading the way in using a smartwatch to help manage high blood pressure.

Technical Director of Echo Quality and Research, Dr. Salima Qamruddin is exploring the value of MW in everyday practice. Her work includes examining the utility of MW in reducing the rate of false positives in stress testing. She is also studying MW parameters in predicting outcomes in patients with low flow aortic stenosis undergoing TAVR.

Dr. Qamruddin has another important role at Ochsner Heart and Vascular Institute. The cardiologist serves as Director of the Women's Cardiovascular Wellness Clinic. Myocardial work is also having an impact on patients there. Dr. Qamruddin is investigating MW as a predictor of women at high risk for myocardial infarction and heart failure.

We recently asked Dr. Qamruddin to share her insights on the utility of myocardial work in the echo lab, and how she's using the tool to drive awareness and prevention of cardiovascular disease in women.

Can you describe the cardiac program at Ochsner Medical Center and your role in the echo lab?

Dr. Qamruddin: *Ochsner Heart and Vascular Institute is the only heart transplant and high acuity cardiac surgical center in the Gulf South, making for a high-volume echo lab with complex cases, including structural TEEs for percutaneous interventions. We are also a center of excellence for complex diseases such as hypertrophic cardiomyopathy and cardiac amyloid.*

Our echo lab has a volume of about 100 echocardiographic studies per day. I oversee all quality aspects of our lab, including sonographer training and physician reading. In my position, I am passionate about using strain and 3D echocardiography to improve diagnostic accuracy of diseases.

You have been a champion of AFI strain imaging within the echo community. What is the value of incorporating strain into your workflow?

Dr. Qamruddin: *Myocardial strain gives true deformation of the myocardium and ejection fraction calculations can be volume and geometry dependent. A myriad of studies has shown the prognostic utility of global longitudinal strain in heart failure and valvular heart disease. I believe we are not using this technique to the fullest. GE HealthCare's automation of strain and artificial intelligence techniques will significantly enhance patient care—as it can help the physician detect subclinical dysfunction, evaluate total stroke work of the heart, and prognosticate disease.*

For example, say you have a patient with a normal ejection fraction with concentric remodeling, advanced diastolic dysfunction and poor GLS. The composite of the above parameters suggests high risk for heart failure (HF) admission. Hence, aggressive up-titration of medications in this patient can prevent HF hospitalization. This improves patient care and decreases the burgeoning cost of health care.

> *GE HealthCare's automation of strain and artificial intelligence techniques will significantly enhance patient care—as it can help the physician detect subclinical dysfunction, evaluate total stroke work of the heart, and prognosticate disease.*

The latest version of Vivid introduced Easy AFI LV, which leverages artificial intelligence and View Recognition to perform strain and biplane EF automatically. How has artificial intelligence impacted workflow?

Dr. Qamruddin: *This has significantly improved the efficiency of the workflow. The best example is a breast cancer survivor that needs a follow-up echo after getting chemotherapy treatment that may be toxic to the heart. Easy AFI LV will give both GLS and EF within seconds.*

At times we have to adjust the contours manually. Despite that, in a busy echo lab these time efficient tools are helping physicians report GLS more often, which is prognostically important. Auto EF has reduced time for biplane EF and gives an added tool, but physicians can still choose to do manual EF.

Uncovering invisible illness in women's health: Sarah's story

Imagine being 29 and suffering a heart attack. Watch one woman's powerful story and discover the role of ultrasound in a special BBC Storyworks production.

The utility of GLS has also been cited in the literature for cancer patients, especially those who have received cardiotoxic chemotherapeutic agents. Subclinical left ventricular dysfunction may be detected with GLS and in cases of low GLS, cardioprotective agents may be initiated.[2]

Utilizing AFI, it's now possible to estimate myocardial work non-invasively. How would you describe myocardial work?

Dr. Qamruddin: *Myocardial work is an advanced assessment of GLS analysis that can reduce the afterload-dependent limitation of GLS by incorporating left ventricular afterload into the analysis of GLS.*

> *"Adding MW parameters at peak stress to standard dobutamine stress echocardiography (DSE) images improved diagnostic accuracy of the DSE from 45 to 81%. Patients with significant coronary artery disease had a significant drop in GLS, MW and Myocardial efficiency (ME) at peak stress.*

For example, we know that GLS drops with increased afterloads in patients with hypertension and aortic stenosis, when in fact the overall stroke work of the heart increases. MW assesses total stroke work of the heart in each cardiac cycle that includes systolic ejection, isovolumetric contraction, and isovolumetric relaxation. That provides a more robust analysis of the total work done by the heart in health and various diseases.

MW has been validated with invasive measures and it correlates well with oxygen consumption and regional myocardial glucose metabolism.[3] Myocardial work has been shown to be reduced in several diseases with reduced global myocardial work efficiency (GWE), which is the ratio of the constructive compared to wasted work, and hence greater wasted work.[3]

There's a growing body of research on MW. What are some of the applications?

Dr. Qamruddin: *One of the areas where MW has been studied is its use in chronic resynchronization therapy. Patients with elevated constructive work responded better to therapy.[3] MW is currently being studied in amyloid, hypertrophic cardiomyopathy, and aortic stenosis. This may help us prognosticate patient outcomes better than GLS and improve stratification for certain therapies.*

Myocardial work (MW) and global work efficiency (GWE) that are derived as a product of systolic blood pressure with peak GLS of each segment, have been shown to be superior in diagnosing significant obstructive coronary artery disease. The research shows similar results in those having acute coronary syndrome presenting to the emergency department.[4]

How has MW improved diagnostic accuracy in assessments?

Dr. Qamruddin: *Adding myocardial work and global work efficiency (GWE) during stress echocardiography can help reduce false positive studies[5] and reduce downstream cost of additional testing. We presented this data at the 33rd American Society of Echocardiography scientific sessions in Seattle, WA. Adding MW parameters at peak stress to standard dobutamine stress echocardiography (DSE) images improved diagnostic accuracy of the DSE from 45 to 81%. Patients with significant coronary artery disease had a significant drop in GLS, MW and Myocardial efficiency (ME) at peak stress.[5]*

How have you utilized myocardial work in low flow aortic stenosis patients?

Dr. Qamruddin: *Even with TAVR, low flow aortic stenosis is a challenging condition and mortality is up to 30% at two years. One of the questions is who best benefits from TAVR? Newer data suggests that contractile reserve does predict outcomes in this group.*

Women's heart health

Your other role at Ochsner Heart and Vascular Institute is Director of the Women's Cardiovascular Wellness Clinic. How are myocardial work and strain imaging impacting work with cardiac disease in women?

Dr. Qamruddin: *Women who have hypertensive disorder in pregnancy and lower GLS have been associated with preterm delivery and small for gestational age neonate. These women are also at an increased risk of myocardial infarction and heart failure later in life.[6-8]*

Since GLS is load dependent incorporating MW may identify women with lower stroke work and greater subclinical LV dysfunction, and these women may be at significantly higher risk of heart failure called peripartum cardiomyopathy immediately or at higher risk of developing heart failure later in life. We are working on incorporating GLS into the workflow for these patients.

We are also seeing use of GLS in women with identifying non-obstructive artery disease, which is a cause of heart attack in 10-15% of women. Incorporating MW and ME may give a better assessment of the total stroke and efficiency of the heart, and flag patients that have chest pain in setting of ischemic of non-obstructive coronary artery disease.[4]

You are a huge advocate for women's heart health and combating heart disease. What are some of the statistics people need to know?

Dr. Qamruddin: *One in five women die of heart disease. It kills six times more than breast cancer—yet screening for heart disease is minimal. Cardiovascular disease is the leading cause of death among breast cancer survivors. Women's risk factors include high blood pressure and diabetes in pregnancy, premature ovarian failure, and polycystic ovarian syndrome. Another risk factor is inflammatory disease, such as lupus and rheumatoid arthritis, which are 10 times more common in women.[9]*

What are some of the issues surrounding awareness?

Dr. Qamruddin: *Unfortunately, only 56% of women are aware that they are at risk of heart disease, and this statistic has decreased over the past decade. There are not enough awareness campaigns in the community—schools, colleges, and workplaces. Until we get young women to engage in this conversation, we will continue to see these staggering numbers because heart disease starts at least two decades before it manifests. I thank companies like GE HealthCare that are collaborating with physicians to raise these concerns and spread awareness.*

How do you partner with the Women's Health team at your hospital?

Dr. Qamruddin: *I partner with obstetrics and gynecologists and focus on prevention, especially in young women. I see women with high blood pressure in pregnancy soon after they have delivered to discuss long term complications that include heart attacks, strokes, and heart failure. I also see menopausal women and breast cancer survivors and assess their risk for downstream heart disease.*

What are the different types of heart attacks seen in younger women?

Dr. Qamruddin: *There are two types of heart attacks that are seen specifically in young women. MINOCA is myocardial infarction of non-obstructive coronary artery disease and accounts for 15-20% of heart attacks in women under age 50. It occurs when there is a blockage in smaller arteries of the heart that may not be seen with an angiogram and may require greater testing (PET, CMR). The other heart attack is called SCAD or spontaneous coronary artery dissection. It affects 40% of women before the age of 50 and tends to occur right after giving birth or within the first six weeks following delivery. High blood pressure, infertility treatments, and autoimmune disease can increase the risk of SCAD.*[9]

What do you want women and clinicians to know about heart disease?

Dr. Qamruddin: *Women with gender specific (premature menopause, hypertension and diabetes in pregnancy, preterm delivery, inflammatory and autoimmune disorder) along with traditional risk factors (smoking, hypertension, Diabetes, high cholesterol, family history of premature heart disease) must see a preventive cardiologist to assess their risk. Calcium scores and other tests may flag high risk individuals early and prevent future heart disease. Prevention is the best cure.*

Dr. Salima Qamruddin, M.D., serves as the Director of Echocardiography Quality and Research and Director of Women's Cardiovascular Wellness Clinic at Ochsner Heart and Vascular Institute in New Orleans. She is also a senior lecturer at the Ochsner Clinical School, University of Queensland, Australia. Dr. Qamruddin has numerous publications in the field of cardiac ultrasound. Her research interests include heart valve disease predominately in women and new technologies that improve diagnostic ultrasound. Dr. Qamruddin's work in women's cardiovascular wellness revolves around raising awareness through media and lectures and utilizing novel technologies for heart disease prevention in women of all ages. She has a special focus on heart attacks in women, preeclampsia, breast cancer survivors and menopause.

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Powering a new level of cardiovascular care in Colombia

The progressive technology transforming an evolving echo lab

Echocardiography has long been the cornerstone for cardiology patient diagnosis and management, but in recent years, innovations in imaging technology have made it possible to provide greater diagnostic precision and critical insights in less time. These advancements are shaping today's echo labs—expanding reach and advancing cardiovascular care across the globe.

One of the best examples is the evolving cardiovascular unit at Los Cobos Medical Center, a level 3 complexity care private institution in Bogotá, Colombia. Dr. José Julián Carvajal, who specializes in echocardiography, has been leading the charge to build and expand the cardiology program. In 2018, it was a fledgling cardiac clinic that relied on two ultrasound systems and manual exam transcriptions, but under Carvajal's guidance it has progressed into a high-volume unit with a multidisciplinary team in echocardiography, electrophysiology, and hemodynamics.

In just six years, the unit has incorporated advanced technology to drastically change and streamline workflow—reducing exam times by an average of 40 percent. Physicians have refined the process to ensure a constant flow of patients with almost no machine downtime. The innovations have also allowed the unit to eliminate some unnecessary tasks and expenses. Most importantly, Dr. Carvajal says his unit is able to reach more patients and consistently deliver optimal care.

We recently spoke with Dr. Carvajal about his efforts to build and grow the Los Cobos Medical Center's cardiovascular program. He also talked about the transformative technology that has improved efficiencies at the Bogotá institution.

What were the main objectives in creating the cardiovascular program in 2018?

Dr. Carvajal: *We wanted to establish an organized cardiac clinic that offers high-complexity cardiology services. Our goal was to grow the institution, going beyond occasional patient services, recognizing that cancer and cardiovascular diseases are the most prevalent diseases we face. From the outset, it was evident that we needed to be a multidisciplinary, comprehensive, and high-complexity group.*

Can you describe your patient population?

Dr. Carvajal: *We have a network of institutions or outpatient units referring complex patients, some for general cardiology and others for specific units like heart failure. We typically see around 600 patients a month between cardiologists and clinicians in the area. There is a notable demand for advanced imaging, not only for interventional procedures but also for diagnostics.*

In level 3 institutions like Los Cobos MC, a key challenge is educating primary institutions on identifying patients who truly benefit from accessing such facilities. We guide primary institutions in determining patient approach, necessary exams, and referral criteria. It's crucial for hypertensive, diabetic, or certain age group patients to undergo an electrocardiogram, and if needed, an echocardiogram, to ascertain if referral to a level 3 institution is warranted. Misdirected referrals, especially underdiagnosed patients, can burden both patients and institutions.

What pathologies do you treat and what is the role of echocardiography?

Dr. Carvajal: *In the past, cardiologists primarily focused on ischemic heart disease rather than cardiomyopathies. However, the landscape has changed. About a year ago, the European Society of Cardiology (ESC) introduced a dedicated chapter for managing cardiomyopathies. Previously, while we could diagnose cardiomyopathies, treatment options were limited. Now, with advancements in this area, accurate diagnosis has become more critical. Cardiac imaging plays a crucial role in achieving precision and accuracy in diagnosing and managing these pathologies.*

Echocardiography is essential for initial cardiology assessments and recommended alongside an electrocardiogram for all patients. Its accessibility and reliability make it invaluable for precise patient management.

What imaging technology did you rely on when you creating the unit?

Dr. Carvajal: *From the beginning, Los Cobos MC chose GE HealthCare and invested in many technologies, including echocardiographs, MRI, and CT scans. Our unit performed exams with two Vivid T8 machines. Personally, I think other brands are too complex and don't have the same quality and resolution.*

What were some of your initial challenges in echocardiography when you began your cardiovascular unit?

Dr. Carvajal: *In 2018, we created reports using manual transcription because we had low patient volume. Manual transcription often led to errors and necessitated frequent training, primarily due to staff rotation, disrupting what should be a straightforward process. It was also time-consuming for the assistant transcribing the information and the echocardiographer, who had to wait to review and sign exams.*

As the unit grew, there were other challenges. As a large cardiology group with a high volume of exams, it was necessary to optimize resources. In addition to supporting echocardiography, we needed the assistants to transfer patients to different parts of the hospital and assist other patients. Everything became so complex, and the process was becoming very expensive. That highlighted the need for a new workflow.

What technology did you introduce to meet those challenges?

Dr. Carvajal: *GE HealthCare's EchoPAC™ software offered a solution, integrating multiple tasks and saving valuable time. It really optimized the echocardiographer's time. EchoPAC allowed for more studies and increased focus on complex exams that demanded more attention. It also freed up our assistants.*

With guidance from a GE HealthCare's clinical specialist on EchoPAC's streamlined report automation and analysis, we were able to complete a standard exam in 2 or 3 clicks. For complex cases, I was able to take measurements and analyze in the EchoPAC station, just like working directly on the console. This completely changed my workflow, allowing me to better redistribute resources, reduce expenses and staff time, without compromising the ability to deliver optimal patient care.

We later invested in more EchoPACs to support our three echocardiologists performing transthoracic exams and treating hospitalized patients at the same time. Even covering exams from previous days, EchoPAC enables us to calmly review these studies, focused on processing and results. We can focus on the present—examining exams from the same day. We can consider the past by refining delayed exams, and we are also thinking about the future by considering the patient's prognosis.

How did these advancements help you create an entirely new workflow?

Dr. Carvajal: *As the unit grew, we decided to acquire the Vivid E95. At this point, we had greater visibility and planning capacity, and we also had an outpatient population. With better resource management and excellent technology, we needed to be more productive. This led us (by the institution's policy) to begin implementing the 'mirror workflow'.*

Every morning, we have two rooms available for the echocardiologist. While one room is being used for the echo, another patient is being prepped in the second room. This allows for a constant flow of exams with the reassurance that post-processing and analysis will be done in more detail with EchoPAC in the afternoon.

The Vivid E95 and EchoPAC complement my work very well. I can take all the necessary 4D images and then analyze and report from EchoPAC with tools like the mitral and tricuspid package features. It gives me the flexibility to invest the time I consider necessary, without thinking that I have a patient waiting.

> *"We're talking about a reduction of approximately 40% of time. When considered individually per exam, 10 to 20 minutes may not seem like a major impact, but in a workday of 6 to 8 hours, it allows for more patients and has an impact on patient care.*

How much time are you saving with the new mirror workflow?

Dr. Carvajal: *Previously, a transthoracic exam in a non-complex patient could take us 45 minutes. That was start to finish, including measurement generation, report with an assistant, signing and uploading to the system. Today, thanks to the configuration of my workflow with the Vivid consoles and EchoPAC, I can do up to 10 patients in 3 hours. Then in the afternoon, I sit down to do absolutely all the measurements and analysis in the EchoPAC, ensuring zero downtime with the ultrasound machines. So, when my colleague arrives to do exams on outpatient patients, the equipment is already available.*

We conducted an exercise with EchoPAC at the institution before deciding to invest. We simulated two exams with non-complex patients. One was done with an assistant typing the report and the other was done with post-processing in EchoPAC. The examination that included the transcription, review and signature was 40 minutes. The exam and report with EchoPAC was performed in 25 minutes.

> *"Thanks to the configuration of my workflow with the Vivid consoles and EchoPAC, I can do up to 10 patients in 3 hours...then I can do all of the measurements and analysis in the EchoPAC, ensuring zero downtime with the ultrasound machines.*

It means we're talking about a reduction of approximately 40% of time. When considered individually per exam, 10 to 20 minutes may not seem like a major impact, but in a workday of 6 to 8 hours, it allows for more patients and has an impact on patient care.[†]

Can you elaborate on the impact of the new workflow and why it's so important?

Dr. Carvajal: *The ability to process raw data and optimize exam time is fundamental because most of our patients are complex patients with heart failure or vascular conditions. First, to reduce risk to the patient who is under sedation. It's also important for resource management because anesthesiologists are present for all transesophageal exams. Lastly, productivity is essential. Why should I spend an hour doing one exam when I could do three? (Except for reasons inherent to the patient.)*

So, during the exams, our focus is on obtaining the best images and then utilizing EchoPAC for post-processing. This is important for our workflow and also for the patient's safety.

In post-processing, what are the most beneficial tools to increase efficiencies?

Dr. Carvajal: *The automation and artificial intelligence tools are very helpful, especially for less complex patients, because these features provide excellent image quality and streamline reporting in just a few clicks. This efficiency allows me to focus more time on refining exams for complex patients.*

In routine echocardiograms, automated flow assessment in Cardiac Auto Doppler is pivotal. With a single click, the equipment can produce gradient measurements for mitral and aortic flows, saving time and ensuring precision. I can customize the tool to provide the necessary measurements effortlessly.

When dealing with complex cases, especially for mitral valve assessment, 3D echocardiography has become essential. It's not only valuable for evaluating valves but also for strain measurement and assessing 3D volumes. For oncology patients, pre-chemotherapy ventricular function measurement using 3D echocardiography has become the gold standard.

Additionally, the importance of assessing the right ventricle, once overlooked, has been underscored with the adoption of 3D echocardiography. Overall, the Vivid E95 enables me to make complex decisions, particularly in valvular heart diseases, as it facilitates comprehensive 3D assessments.

You mentioned MRI as the gold standard. How do you decide which patients or pathologies need to be referred for an MRI?

Dr. Carvajal: *It all depends on the patient. MRI is fundamental in cardiomyopathy studies because it helps with complex decisions like adjusting costly therapies such as cardio defibrillators or pacemakers. It's also important when treatment responses are unclear so I can improve differential diagnoses. While not all patients require MRI, it's essential for those showing limited improvement despite treatment or unclear diagnoses. It helps confirm or rule out the need for device implantation.*

And even though echocardiography offers real-time functional insights, it can be limited by poor anatomy. As a result, approximately 10% to 20% of patients with ventricular dysfunction are referred for MRI to determine the etiology of a cardiomyopathy.[†]

As you look towards the future, what types of technology will drive your progress?

Dr. Carvajal: *The pandemic taught us that it is possible to work remotely. For the past few years, we have also seen the power of artificial intelligence. It can streamline routine exams, allowing us to dedicate more time to complex cases. That is where our doctors make the most difference.*

In an ideal world, we have highly trained cardiologists and sonographers, supported by artificial intelligence, to handle the large volume of exams. Tools like EchoPAC plug-in play an important role, especially with the possibility of connecting remotely.

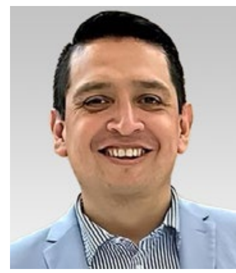
Remote support would allow cardiologists to guide sonographers who may have questions during echo exams. It would enable us to give measurements or imaging instructions in real-time for quick decisions.

What is the impact of AI and other technologies on cardiovascular care in Colombia?

Dr. Carvajal: *I believe that in recent years there has been a significant change in the healthcare sector in Colombia. Previously, it was more static, but now we see a trend towards the adoption of advanced technologies and process optimization. Medical institutions, both large and small, are incorporating high-quality equipment and understanding the importance of post-processing practices. In addition, the international training of medical professionals has contributed to improving care systems.*

However, we still face challenges, especially in conducting exams and interpreting results. This is where artificial intelligence and connectivity can play a key role. It is necessary to carry out an economic analysis and determine the return on investment to then understand the needs of the institution and offer comprehensive solutions. For example, it's great help to the institution if artificial intelligence can help evacuate a number of exams because they are considered normal.

In summary, I think we are at a moment of change and growth in the healthcare sector, but there are still areas that require attention and improvement.



Dr. José Julián Carvajal is a cardiologist at Los Cobos Medical Center in Bogotá, Colombia. His background includes advanced studies in cardiovascular imaging, with extensive pathophysiological, clinical, and epidemiological knowledge in different areas of cardiology. Dr. Carvajal uses a bio-psycho-social approach to treating pathologies, placing great value on integrity and ethics. Dr. Carvajal's top areas of interest are 3D echocardiography and cardiac magnetic resonance imaging, and he has co-authored more than a dozen articles.

† 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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Exploring the value of myocardial work in Cardiac Resynchronization Therapy

Invaluable insights that could potentially improve outcomes

There is a growing interest in sophisticated echocardiography methods, including myocardial work, for their potential in predicting cardiovascular outcomes. Researchers are exploring the value of myocardial work (MW) in identifying markers that could help with patient selection, and guide treatment and management across a range of indications.

Professor Jing Yao at Nanjing Drum Tower Hospital in Nanjing, China has adopted myocardial work to help assess responsiveness to Cardiac Resynchronization Therapy (CRT). These insights are particularly important because CRT has been shown to increase the quality of life and survival in patients with ventricular asynchrony and reduced left ventricular ejection fraction.[1] However, approximately 30% of CRT patients exhibit no improvement.[2]

Professor Yao's work is keeping Nanjing Drum Tower Hospital at the forefront of cardiovascular care. The large-scale institution, with roots dating back more than a century, is known for its scientific research, medical technical excellence, and medical education. The Department of Ultrasound Medicine, which serves 400,000 patients annually, encompasses various subspecialities, including cardiovascular, abdominal, musculoskeletal, small part and superficial organs, and interventional ultrasound. The Department of Cardiothoracic Surgery performs nearly 3,000 cardiac surgeries every year.

Professor Yao recently shared her views on the added value of myocardial work, which incorporates left ventricular afterload into global longitudinal strain analysis. She also detailed evidence that supports MW in identifying CRT responsiveness.

What demographic or patient population does your institution primarily serve, and are there any unique characteristics or health considerations specific to this population?

Prof. Yao: *Our hospital primarily serves residents of Nanjing, a city with a population of over 9 million, as well as individuals from surrounding areas. We also attract patients from across the country. A significant portion of our patient population includes those with challenging, complex, and critical conditions. Many of them may have previously sought treatment in multiple hospitals without success before turning to our institution for care. This places a considerable demand on the clinical capabilities of our medical professionals, contributing to the enhancement of our overall expertise.*

Could you describe the range of echocardiography exams typically performed? Are these primarily diagnostic, monitoring, or post-procedural exams?

Prof. Yao: *In our center, the application scope of echocardiography primarily includes routine examinations and follow-ups for patients in the departments of cardiology and cardiovascular surgery. We focus on perioperative assessment and intraoperative monitoring for cardiovascular surgery, and monitoring and guidance during interventional procedures for structural heart diseases. Among these, diagnostic examinations constitute the largest proportion, but a significant amount of time is dedicated to intraoperative monitoring during thoracic surgeries and guiding interventions for structural heart diseases.*

We also perform echocardiography exams on patients from other departments requiring cardiac assessment.

You use myocardial work in asynchrony patients to identify potential candidates for Cardiac Resynchronization Therapy. Can you start by explaining what CRT is and how it's used in the management of patients with ventricular asynchrony?

Prof. Yao: *Cardiac Resynchronization Therapy is a pacing intervention primarily used in the management of patients with heart failure and ventricular asynchrony.*

This device has three leads that are placed in the right atrium, right ventricle, and coronary sinus respectively. The lead in the coronary sinus allows for pacing of the left ventricle. CRT is implanted to synchronize the contractions of the heart's ventricles and optimize the pumping efficiency of the heart.

> *We have also observed that parameters related to myocardial work, such as left ventricular overall myocardial work efficiency, constructive work, wasted work, as well as the difference in the mentioned parameters between the interventricular septum and the left ventricular lateral wall, demonstrate significant predictive value in assessing the responsiveness after CRT implantation.*

What type ventricular asynchrony or cardiac disease typically qualifies patients for CRT? What criteria do you use to identify CRT candidates?

Prof. Yao: *A patient displaying a left bundle branch block (LBBB) on the electrocardiogram (QRS ≥150 ms) and evidence of intraventricular and interventricular dyssynchrony on echocardiography typically qualifies for CRT. Experienced echocardiographers may identify crucial indicators through visual observation, with septal flash and apical rocking serving as significant diagnostic markers.*

Can you share any studies or clinical evidence supporting the use of myocardial work in predicting the efficacy (ventricle functional restoration) after CRT in patient follow-up?

Prof. Yao: *In recent years, with the growing recognition of the concept of myocardial work in clinical practice and the application of analytic techniques, an increasing number of clinical studies have been reported regarding the predictive role of myocardial work in the effectiveness of CRT.*

For instance, Riolet et al. published a study[2] in 2021 in the Journal of JASE, involving a large prospective cohort of patients with heart failure (HF) and reduced ejection fraction who underwent CRT. The study aimed to assess the relationship between preprocedural global work index (GWW) and treatment outcomes. The findings indicated that a low preoperative GWW (<200 mm Hg%) is associated with the absence of CRT response in candidates and is linked to a relatively increased risk for all-cause.

Another example is the Aalen et al. report[3] on a prospective randomized trial, performed in 200 patients recruited in five European centers, to explore the use of regional left ventricular (LV) myocardial work differences as a predictor of response to cardiac resynchronization therapy (CRT). This investigators show that the difference between myocardial work performed by the septum (S) and LV lateral wall (LW) predicted CRT response with an area under the curve (AUC) of 0.77 [95% confidence interval (CI) 0.70–0.84].

In our clinical practice, we have also observed that parameters related to myocardial work, such as left ventricular overall myocardial work efficiency, constructive work, wasted work, as well as the difference in the mentioned parameters between the interventricular septum and the left ventricular lateral wall, demonstrate significant predictive value in assessing the responsiveness after CRT implantation.

What limitations exist in incorporating MW assessment into the follow-up of CTR patients?

Prof. Yao: *The reproducibility of myocardial work measurements is not adequate.*

What would you say to other clinicians that have not incorporated myocardial work into their practice? Would you encourage them to use it?

Prof. Yao: *Myocardial work is an intriguing quantitative method for assessing cardiac function. Its analysis is built on two-dimensional speckle tracking with the addition of blood pressure parameters. You should give it a try in your clinical practice. You might fall in love with it.*

Where do you see the future of myocardial work assessment in the context of CRT patient selection and follow-up? What about tool adoption in everyday clinical practice?

Prof. Yao: *We look forward to additional clinical research to further clarify the use of myocardial work parameters in selecting and monitoring CRT patients. Additionally, it is crucial to establish corresponding thresholds to guide clinical diagnosis and treatment. In the future, if myocardial work analysis technique based on three-dimensional speckle tracking imaging can be developed, its parameters may be even more accurate and reliable.* ■

Professor Jing Yao is Director of Ultrasound Medicine at Nanjing Drum Tower Hospital. For more than two decades, she has been actively engaged in clinical work, teaching, and scientific research of echocardiography. Dr. Yao's area of expertise is ultrasound diagnosis of cardiovascular diseases including valvular disease, cardiomyopathy, and coronary heart disease. She is a member of several medical committees and associations and has hosted multiple National Natural Science Foundation and Provincial Scientific Research Projects.

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3 Aalen JM, Donal E, Larsen CK, et al. Imaging predictors of response to cardiac resynchronization therapy: left ventricular work asymmetry by echocardiography and septal viability by cardiac magnetic resonance. Eur Heart J. 2020;41(39):3813-3823. doi:10.1093/eurheartj/ehaa603

Case study

Intraventricular dyssynchrony

Courtesy of Professor Jing Yao, Nanjing Drum Tower Hospital

Patient history

The patient is a 80-year-old male with chest tightness accompanied by mild lower limb edema for the past two years and a history of hypertension for over 20 years. ECG reveals sinus rhythm and complete left bundle branch block (CLBBB) with QRS duration 178 ms. Transthoracic echocardiography (TTE) indicates left ventricle dilation and dysfunction, asynchronous left ventricular contraction, moderate functional mitral and tricuspid regurgitation, and a small amount of pericardial effusion.

Challenges

The patient is presenting for the first time with left ventricle dilation and dysfunction, and concomitant CLBBB. The course of CLBBB is unclear. It is challenging to determine whether the patient has dilated cardiomyopathy with CLBBB or CLBBB-induced cardiomyopathy.

System, probe & device used

The system used is the Vivid E95 Ultra Edition and a M5sc-D probe.

Step-by-step procedure

Cardiac dyssynchrony analysis with TTE:

1. **Intraventricular dyssynchrony:** Septal flash on the colour M-mode, PSD = 220msms, myocardial work parameter: GWE = 55%.
2. **Interventricular dyssynchrony:** Interventricular mechanical delay (IVMD) = 110ms.
3. **Atrioventricular dyssynchrony:** E and A waves are merged. Termination of the A wave occurs after QRS onset.

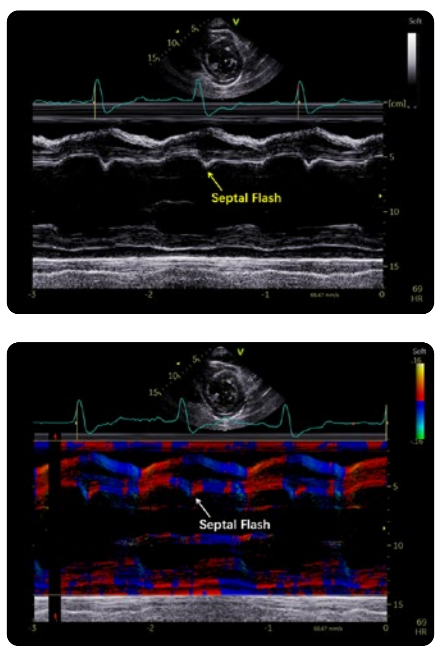
Conclusion

The analysis of conventional echocardiography and speckle tracking imaging techniques reveals significant intra-ventricular, inter-ventricular, and atrioventricular dyssynchrony in this patient. The myocardial work parameters, particularly, provide a more intuitive display of abnormalities in both segmental and global myocardial performance.

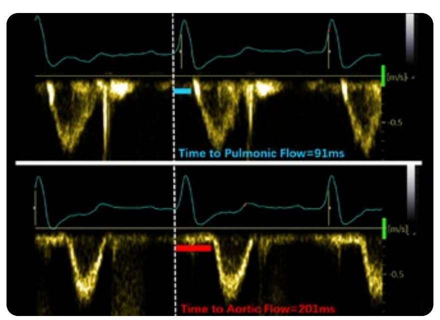
Imaging follow-up

One week post-implantation, the patient's symptoms improved, and the echo showed improvements in left ventricular dimension, function and myocardial work parameters. In the follow-up examination after four months, the patient remained asymptomatic, and various echocardiographic parameters continued to show further improvement.

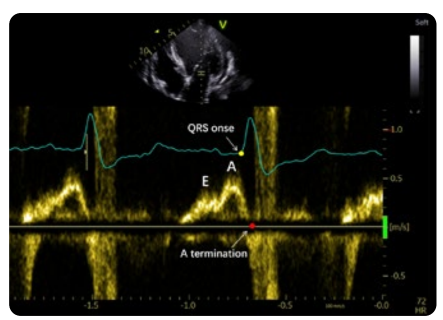
Intraventricular dyssynchrony: Septal flash demonstrated on the M-mode (left) and colour M-mode (right).

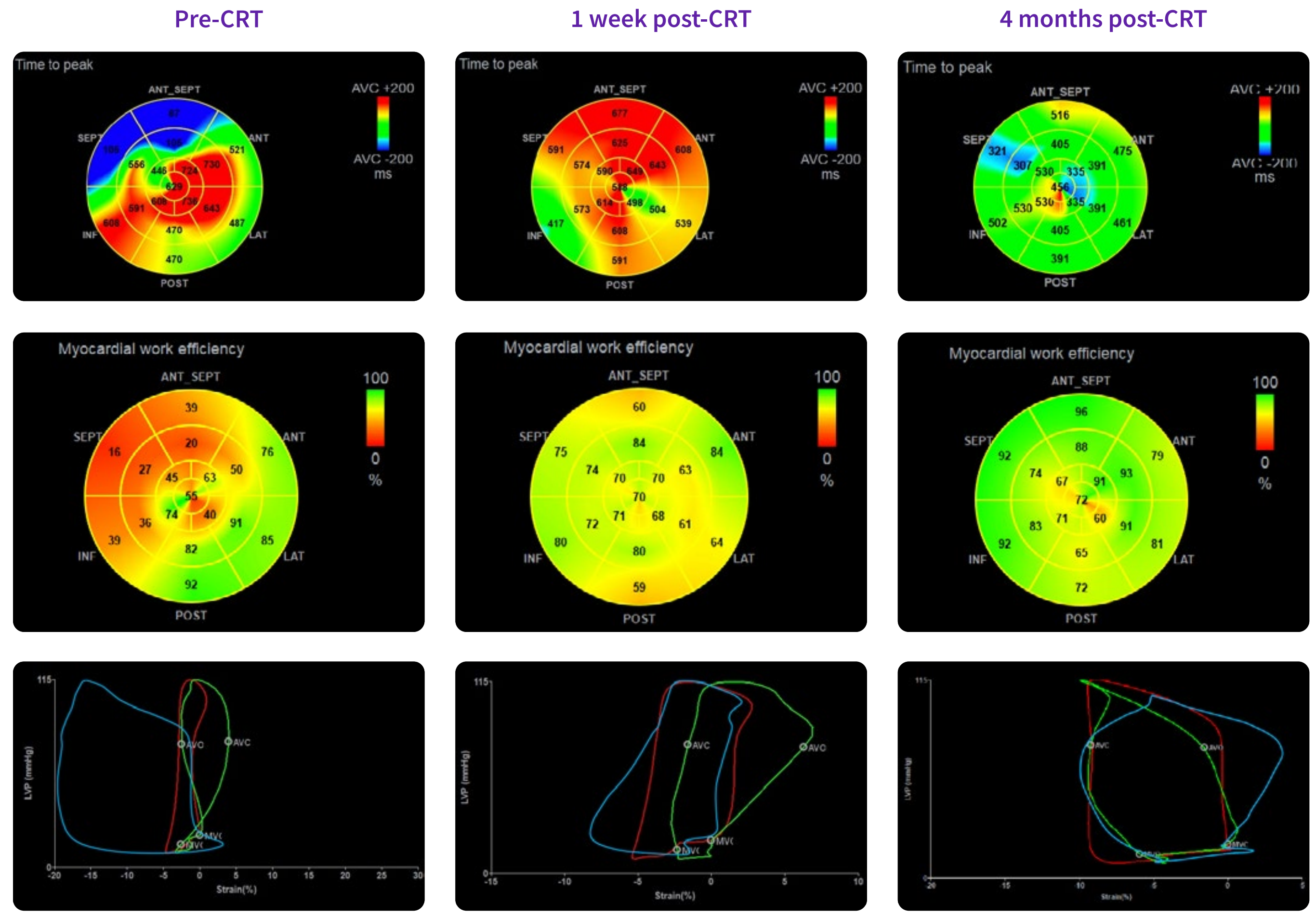


Interventricular dyssynchrony: Interventricular mechanical delay (IVMD)=110ms.



Atrioventricular dyssynchrony: Pulse Doppler mitral inflow (sample volume at mitral annular) revealed the fusion of E and A waves. The termination of the A wave occurs after QRS onset.





Bullseye plots of segmental strain peak timing (the first row), segmental myocardial work efficiency (the second row) and the pressure-strain loop for the left ventricle (red), basal septum (green) and basal lateral segment (blue) before (left column), one week after (middle column), and four months after (right column) CRT implantation.

Parameter	Pre-CRT	1 week post-CRT	4 months post-CRT
LVDd (mm)	67	62	44
LVEDV (ml)	230	211	120
LVEF (%)	25.4	34.5	52.3
GLS (%)	-5	-6	-10.2
PSD (ms)	220	-75	-18
Twist (°)	0.89	0.69	8.95
Torsion (°/cm)	0.10	0.08	1.10
GWI	403	671	898
GCW (mmHg)	920	1163	1198
GWW (mmHg)	679	502	283
GWE (%)	55	71	80

The changes in left ventricular structure and functional parameters before and after CRT implantation

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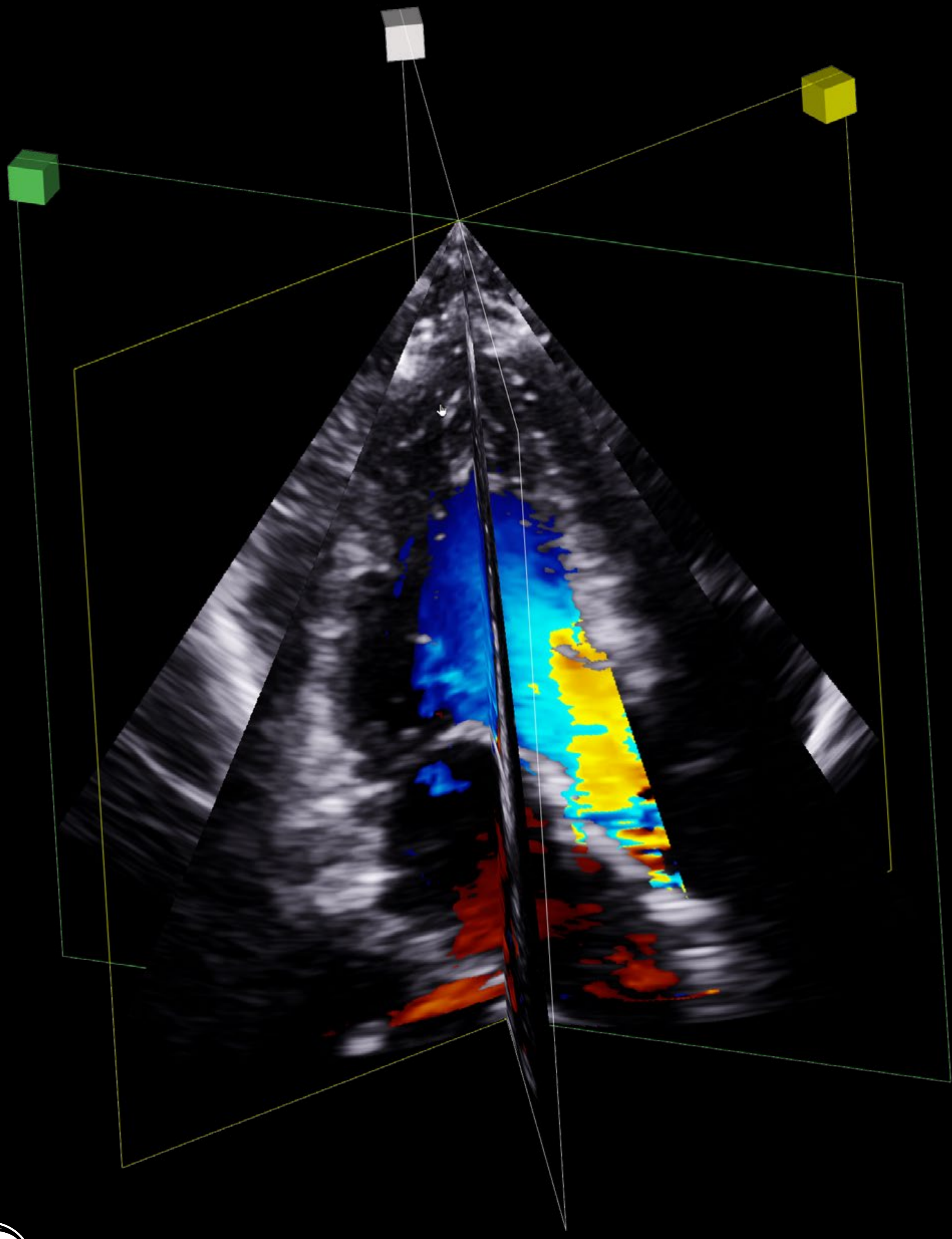

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