GE Healthcare

2D Strain

Advanced research application for quantitative echocardiography

Introduction

2D strain is a uniquely advanced research tool that uses inherent features of a 2D image called "natural acoustic markers" for frame-to-frame tracking of the myocardial tissue in any direction within the tracking plane. In this way, 2D-strain capabilities of tracking and quantifying full, two-dimensional motion rival those utilized with tagged MRI.

GE Healthcare has introduced many breakthrough quantitative-ultrasound tools based on leading-edge technologies, such as Tissue Velocity Imaging (TVI), Tissue Tracking, Strain and Strain Rate Imaging, as well as Tissue Synchronization Imaging (TSI). These well-established Doppler-based techniques [for reviews see reference 1-5] provide precise, quantitative measurement of regional wall motion and function, while adding new parametric imaging displays. Applications include studies of regional function, stress echocardiography, diastolic function analysis, cardiomyopathy, cardiac resynchronization imaging and more.

However, Doppler-only-based techniques are limited due to angle dependence of the signal. As a result, certain myocardial areas are excluded. For example, the apex in the apical views, as well as large portions of the myocardium in the parasternal views and especially the short-axis views.

Until now, only magnetic resonance imaging (MRI) could provide full, two-dimensional motion analysis through tracking of magnetic tags [for reviews see reference 6, 7]. However, MRI is not widely available for clinical use because it is expensive and time consuming. Other limitations include relatively low spatial and temporal resolution of the magnetic tags, difficulties in analyzing the whole cardiac cycle due to the short persistence of the tagging, and its inability to analyze beat-to-beat variability. Similar in concept to MRI tagging, 2D Strain analyzes motion by tracking tags (natural acoustic markers) in the ultrasonic image in two dimensions. As with tagged MRI, one cannot expect the natural acoustic markers to persist throughout the entire cardiac cycle, mainly due to their movement in and out of the imaging plane. However, unlike MRI, in which the entire tagging fades out and limits the analysis time to only part of the heart cycle, ultrasound images have new acoustic markers which keep coming in as some of the previous markers fade out. This is illustrated in Figure 1. Myocardial motion and velocities are then analyzed by calculating frame-to-frame changes.

According to James Thomas, M.D., Director of Cardiovascular Imaging at The Cleveland Clinic, "2D Strain provides results that are comparable to those provided by tagged MRI. 2D Strain opens the capability to quantify the mechanical activity of the heart within the much wider world of ultrasound."

In addition to providing 2D motion analysis similar to MRI tagging, 2D Strain offers the same favorable properties as other echocardiography techniques, such as availability, affordability and safety. 2D Strain is a natural extension of one-dimensional motion analysis provided by Tissue Velocity Imaging (TVI). When Tissue Doppler data is available through TVI scans, 2D Strain optimally combines TVI to increase sensitivity.

Since 2D strain is image quality dependent, it has a built-in quality-assurance tool that automatically evaluates the reliability of the results. The use of powerful statistical analysis form the basis for the automatic tracking scoring system which looks at the variability of velocities in small tissue areas and chooses which acoustic markers to track to make the tool more robust than traditional "speckle tracking" products.

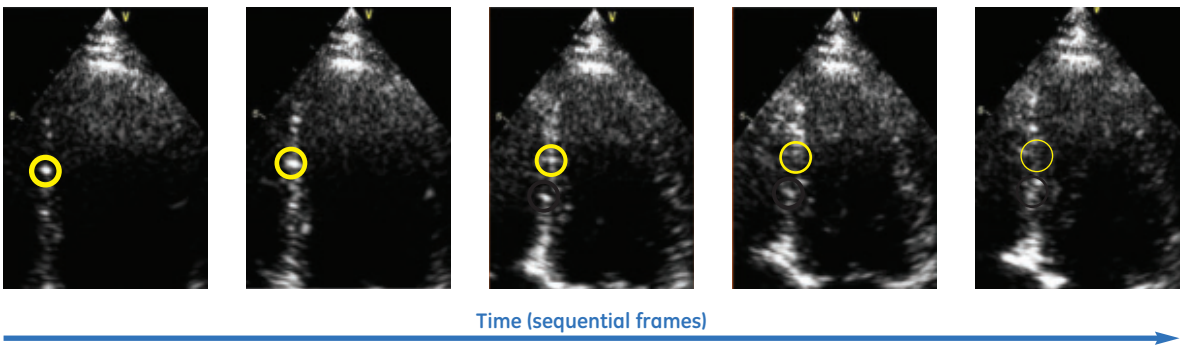


Figure 1.
Motion and velocities are analyzed by calculating frame-to-frame changes using "natural acoustic tagging." New features (orange circles) keep coming into the image as old ones (yellow circles) fade away.

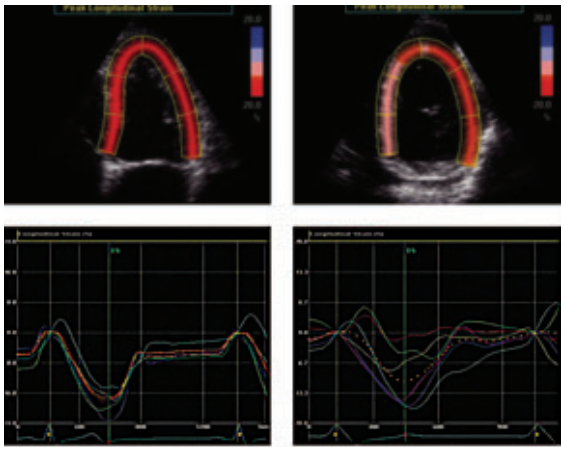
Parametric imaging

One of the major achievements in 2D Strain is the ability to include the entire myocardium for quantitative evaluation. Coupling this with the previously validated and published indices of TVI, 2D Strain offers new tools for a more comprehensive analysis. For example, in cases where TVI Doppler has been applied, 2D Strain can also be applied to increase the sensitivity.

Beyond obvious indices, such as Peak Strain, End Systolic Strain or Peak Strain Rate, etc., which have been tested in a variety of clinical applications,[8-12] more sophisticated and less obvious indices have been proposed and evaluated clinically using TVI. Kukulski et al.[8,13] proposed the Post-systolic Strain Index (PSI) for the identification of acutely ischemic myocardium. Abraham et al [14] proposed time-to-zero strain rate (which is equivalent to time-to-peak strain) as an index for detection of ischemia during DSE.

Example 1: Peak longitudinal strain

Peak systolic strain in a normal case (left) and a pathological case (right). Top images display parametric color overlay. Bottom graphs show segmental traces.

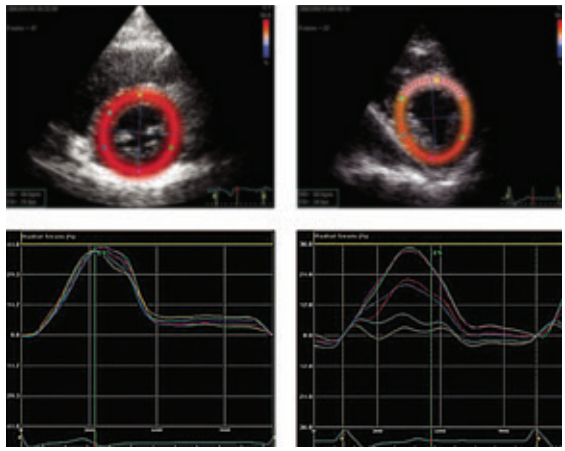


Normal: The entire muscle has a high negative peak strain value (dark shade of red)

Abnormal: Decrease strain value (shade of pink)

Example 2: Peak radial strain

Radial strain in a normal case (left) and a pathological case (right). Top images display parametric color overlay. Bottom graphs show segmental traces.

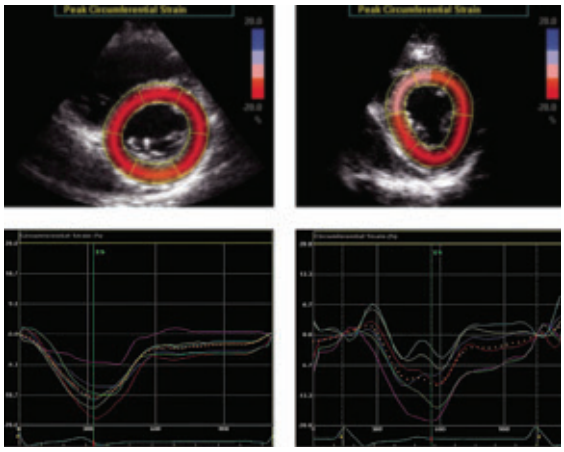


Normal: High strain values (dark shade of red)

Pathologic: Peak radial strain values are low especially in the anterior wall.

Example 3: Peak circumferential strain

Circumferential strain in a normal case (left) and a pathological case (right). Top images display parametric color overlay. Bottom graphs show segmental traces.

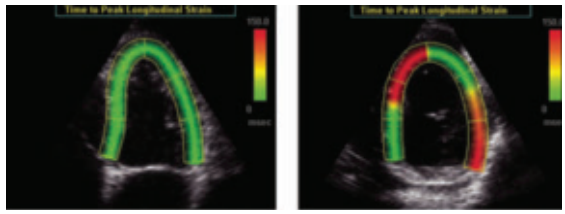


Normal: Segment traces display High values (dark shade of red)

Pathologic: Peak circumferential strain values are low, especially in the anterior-septal wall.

Example 4: Time-to-peak strain (onset of regional relaxation)

Time to onset of regional relaxation in a normal case (left) and a pathological case (right). Top images display parametric color overlay. Bottom graphs show segmental traces.



Normal

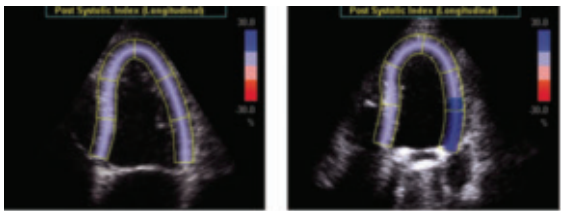
Late onset of regional relaxation (red segments)

Regional delay in the onset of myocardial motion is an important marker of ischemia, in addition to regional wall thickening and thinning characteristics, and the amplitude and direction of the wall motion.

This regional delay has been shown to precede changes in regional myocardial systolic amplitude of motion,[15] and the visual detection of small differences in regional asynchrony is poor.[16] An interesting regional-myocardial parameter based on timing, with respect to electrocardiography, was successfully applied from animal models in order to clinically demonstrate regional asynchrony in the presence of resting and induced ischemia.[14, 17, 18] The time from R-wave on electrocardiography, to transition from regional systole to early diastolic lengthening (TR), was attenuated with acute ischemia. Normally, the mean TR of the mid-segments was shorter than in the apical or basal segments. During Dobutamine stress, the normally detected TR change from baseline was blunted in ischemic segments. In a TVI-based study, Abraham et al. showed a change of >20% in TR patients identified with ischemia during Dobutamine stress, with a sensitivity of 92% and a specificity of 75%.[14] The method has since been restricted to zones accessible with TVI, due to Doppler limitations. 2D Strain could potentially extend the utility of the method, and allow a comprehensive study of the entire myocardium in apical views (to which TVI is usually applied), as well as in short-axis views.

Example 5: Post-systolic Strain Index

Post-systolic Strain Index in a normal case (left) and a pathological case (right). Top images display parametric color overlay. Bottom graphs show segmental traces.



Normal

Larger than normal post-systolic index at the lateral base suggesting post-systolic shortening

Post-systolic Compression (PSC) is an abnormality in the onset of early relaxation. A timely onset of diastolic relaxation requires the uptake of cytoplasmic calcium by the sarcoplasmic reticulum, which is an energy demanding process. Alteration of this active process is an established predictor of myocardial dysfunction at the level of the myocyte metabolism.[20, 21, 22] At the tissue level, regional myocardial asynchrony characterizes these diastolic-functional abnormalities, which are known to occur during acute ischemia, even in the absence of changes in systolic function.[23, 24] Therefore, quantitative temporal and spatial assessment of PSC could be an early measurable indicator of ischemic – yet viable – myocardium.

Kukulski et al.[8, 13] have defined the Post-systolic Strain Index (PSI) as a new marker that combines systolic and early diastolic-deformation values as a quantitative measure of PSC.

PSI = 100*(PS - ESS)/PS ESS = End Systolic Strain at AVC PS = Peak Strain over whole beat.

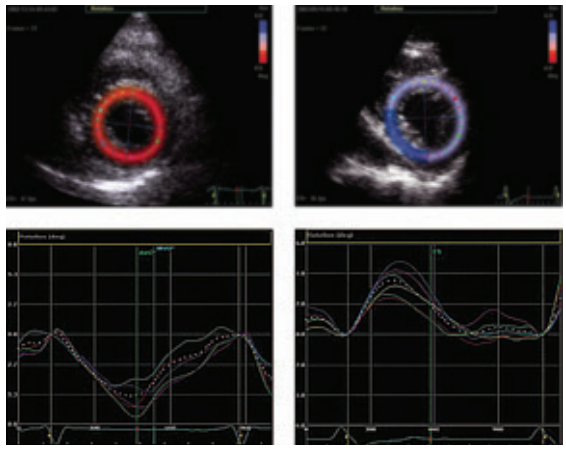
They found that Post-systolic Strain Index had a sensitivity of 95% and a specificity of 89% in the identification of acutely ischemic segments during coronary occlusion.

Voight et al. [24, 25] have shown that this index defines stress-induced ischemia in DSE with a sensitivity and specificity of 86% and 89% respectively, as compared to perfusion scintigraphy as a "gold standard."

Understanding the difference between Post-systolic Compression (PSC) and Post-systolic Index (PSI)

Post systolic compression is a poor marker of viability. Post-systolic Index PSI, takes into account the end systolic strain (ESS) as well and therefore has a much higher potential as a viability marker. Normal segments with PSC will have high ESS and therefore low PSI. Diseased segments with PSC have low ESS and therefore high PSI.

End systolic rotation in two different patients.



Patient 1

Patient 2

Cardiac contraction is very complex in nature, and involves twisting and untwisting of the helically wrapped myocardial fibers during contraction and relaxation. 2D Strain is a natural tool for measuring torsion, which is defined as the difference in rotation of the apical and basal short-axis LV planes. 2D Strain's ability to process short-axis views in real time is key to its ability to measure torsion. According to James Thomas, M.D., Director of Cardiovascular Imaging at The Cleveland Clinic, "2D Strain gets us away from the inherent fundamental limitation of Tissue Doppler, and is much easier to use, thus making it an available tool for the clinic."

2D Strain also includes the Torsion Calculation tool. After processing the Parasternal short-axis view at the Mitral Valve level (SAX-MV) and the Parasternal view at the apical level (SAX-AP), the torsion button will be available.

You can display the torsion calculation as rotation [Figure 1] or rotation rate [Figure 2].

Figure 1. Torsion displayed as rotation

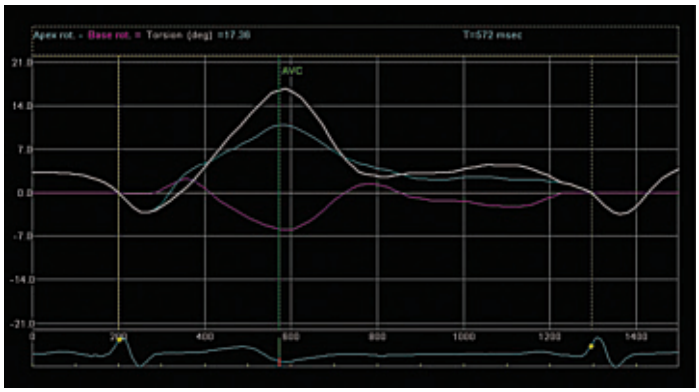


Figure 2. Torsion displayed as rotation rate

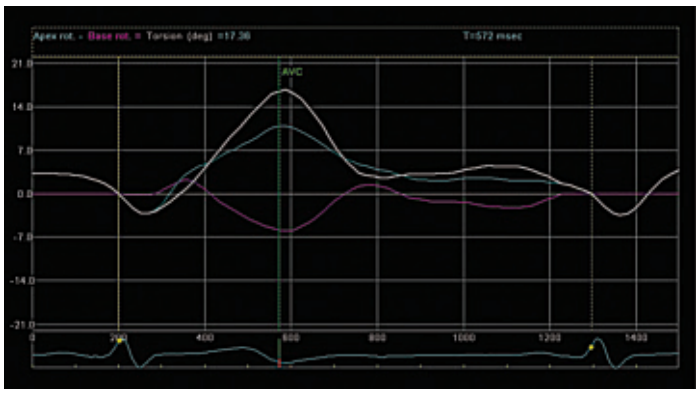


Figure 1. APLAX view

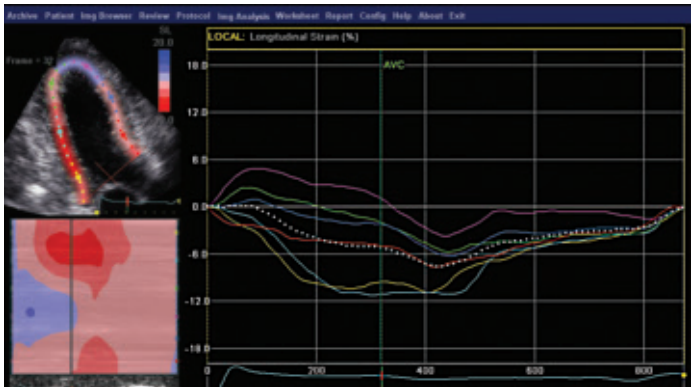


Figure 2. 4CH view

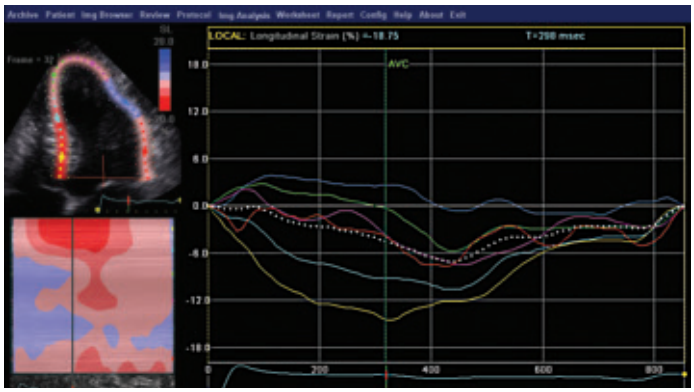


Figure 3. 2CH view

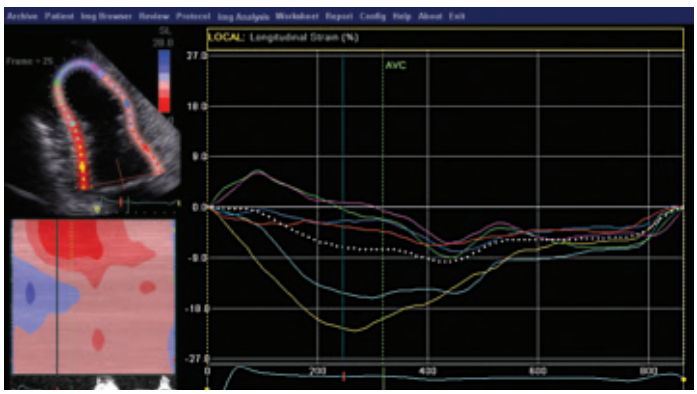
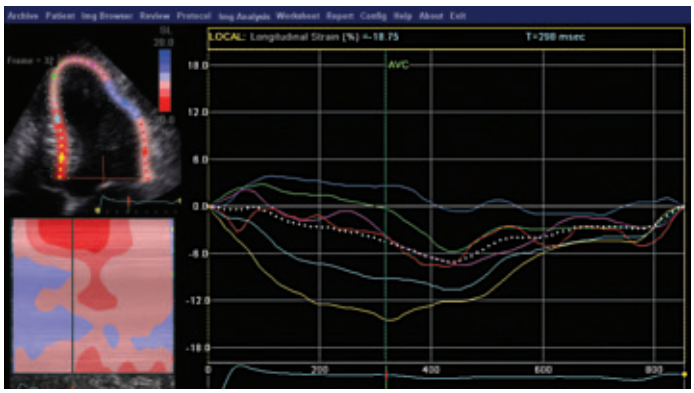


Figure 4. Bull's-eye display



Diagnosis at a glance

Bull's-eye display of Peak Systolic Strain

When all 3 apical views have been processed [Figure 1, 2 and 3] the result is shown as one single bull's-eye display [Figure 4], with colorization according to the Peak Systolic Strain for each segment. A value displayed as numerical number inside the segment. This layout could be switched-on upon pressing the bull's-eye button.

Workflow Tips

ROI Tracking Quality

Built-in automatic validation and verification are essential for a reliable diagnosis. The 2D Strain algorithm automatically evaluates the tracking quality at each myocardial location over time, and provides the tracking quality of each segment as either “acceptable” (V) or “non-acceptable” (X) in a table just below the image. Moving the pointer into the box and clicking it will allow the user to change the score depending on one’s visual assessment of the tracking.

Defining the Region of Interest (ROI)

Two choices are available for defining the ROI.

Semi-automatic ROI: [Figure 1]

This method requires the user to outline the internal border of the myocardium. The ROI border should be parallel to anatomical direction of the longitudinal contraction and relaxation as suggested in the online “quick tips.”

Adaptive ROI: [Figure 2]

This method requires the user to place two points at the annulus and one at the apex. The algorithm will assess the placement of the points, and if needed, override the placement and correct the position of the points. Note: This method is only applicable to apical views.

Not all features may be available in your current software package. Please consult your sales representative to inquire about additional features for your Vivid 7 Dimension or your EchoPAC.

ROI Tracking

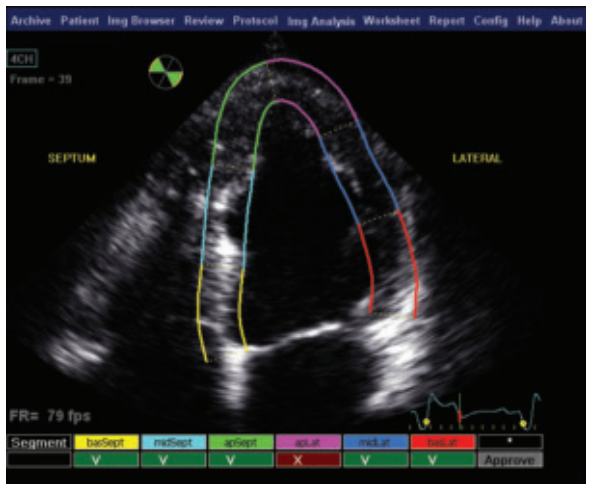


Figure 1.
Region of Interest (ROI) Manual

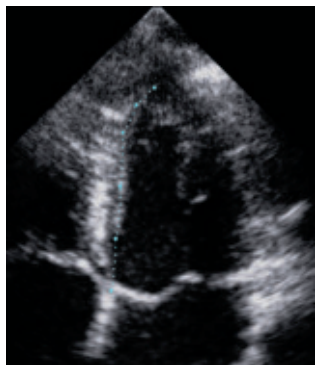
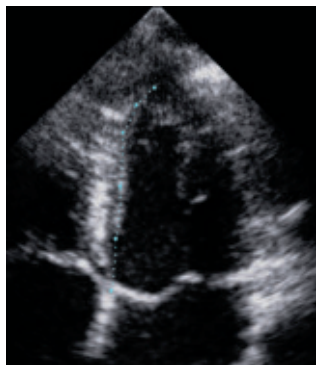


Figure 2.
Region of Interest (ROI) Auto



References and Publications:

1. Sutherland, G.R., Di Salvo, G., Claus, P., D'hooge, J., Bijnens, B. "Strain and strain rate imaging: a new clinical approach to quantifying regional myocardial function." J Am Soc Echocardiogr. 2004 Jul; 17(7): 788-802.
2. Voigt, J.U., Flachskampf, F.A. "Strain and strain rate: New and clinically relevant echo parameters of regional myocardial function". Z Kardiol. 2004 Apr; 93(4): 249-58.
3. Yip, G., Abraham, T., Belohlavek, M., Khandheria, B.K. "Clinical applications of strain rate imaging." J Am Soc Echocardiogr. 2003 Dec; 16(12): 1334-42.
4. Pislaru, C., Abraham, T.P., Belohlavek, M., "Strain and strain rate echocardiography". Curr Opin Cardiol. 2002 Sep; 17(5): 443-54.
5. D'hooge, J., Heimdal, A., Jamal, F., Kukulski, T., Bijnens, B., Rademakers, F., Hatle, L., Suetens, P., Sutherland, G.R. "Regional strain and strain rate measurements by cardiac ultrasound: principles, implementation and limitations." Eur J Echocardiogr. 2000 Sep; 1(3): 154-70.
6. Castillo, E., Lima, J.A., Bluemke, D.A. "Regional myocardial function: advances in MR imaging and analysis." Radiographics. 2003 Oct; 23 Spec No: S127-40.
7. Moore, C.C., McVeigh, E.R., Zerhouni, E.A. "Quantitative tagged magnetic resonance imaging of the normal human left ventricle." Top Magn Reson Imaging. 2000 Dec; 11(6): 359-71.
8. Kukulski, T. et al. "Identification of Acute Ischemic Myocardium Using Ultrasonic Strain Measurements." J Am Coll Cardiol 2003; 41: 810-9.
9. Davidavicius, G., et al. "Can Regional Strain and Strain Rate Measurement Be Performed During Both Dobutamine and Exercise Echocardiography, and do Regional Deformation Responses Differ With Different Forms of Stress Testing." J Am Soc Echocardiography 2003; 16: 299-308.
10. Jamal, F., et al. "Can Changes in Systolic Longitudinal Deformation Quantify Regional Myocardial Function After Acute Infarction? An Ultrasonic Strain Rate and Strain Study?" J Am Soc Echocardiography 2002; 15: 23-30.
11. Voigt, J.U., et al. "Assessment of Regional Longitudinal Myocardial Strain Rate Derived from Doppler Myocardial Imaging Indexes in Normal and Infarcted Myocardium." J Am Soc Echocardiography 2000; 13: 588-98.
12. Hoffman, R., et al. "Strain Rate Measurement by Doppler Echocardiography Allows Improved Assessment of Myocardial Viability in Patients With Depressed Left Ventricular Function." J Am Coll Cardiol 2002; 39: 443-9.
13. Kukulski, T., et al. "Acute Changes in Systolic and Diastolic Events During Clinical Coronary Angioplasty: A Comparison of Regional Velocity, Strain Rate, and Strain Measurement." J Am Soc Echocardiography 2002; 15: 1-12.
14. Abraham, T.P., et al. "Time to onset of regional relaxation: feasibility, variability and utility of a novel index of regional myocardial function by strain rate imaging." J Am Coll Cardiol 2002; 39: 1531-7.
15. Kvitting, J.P., Wigstrom, L., Strotman, J.M., Sutherland, G.R. "How accurate is visual assessment of synchronicity in myocardial motion? An in vitro study with computer-simulated regional delay in myocardial motion: clinical implications for rest and stress echocardiography studies." J Am Soc Echocardiogr 1999; 12: 698-705.
16. Pislaru, C., Belohlavek, M., Bae, R.Y., Abraham T.P., Greenleaf J.F., Seward J.B. "Regional asynchrony during acute myocardial ischemia quantified by strain rate imaging." J Am Coll Cardiol 2001; 37: 1141-8.
17. Belohlavek, M., Pislaru, C., Bae, R.Y., Greenleaf, J.F., Seward, J.B. "Real-time strain rate echocardiographic imaging: temporal and spatial analysis of systolic compression in acutely ischemic myocardium." J Am Soc Echocardiogr 2001; 14: 360-9.
18. Brown, M., Morris, R., Takayama, M., White, H. "Post-systolic shortening: a marker of potential for early recovery of acutely ischemic myocardium in the dog." Cardiovasc Res 19877; 21: 703-16.
19. Ehring, T., Heusch, G. "Left ventricular asynchrony: an indicator of regional myocardial dysfunction." Am Heart J 1990; 1047 57.19. Ehring, T., Heusch, G. "Left ventricular asynchrony: an indicator of regional myocardial dysfunction." Am Heart J 1990; 120: 1047-57.
20. Tian, R., Ingwall, J.S. "Energetic basis for reduced contractile reserve in isolated rat hearts." Am J Physiol. 1996; 270(4 Pt 2): H1207-16.
21. Lamb, H.J., Beyerbacht, H.P., van der Laarseb, A., Stoel, B.C., Doornbos, J., van der Wall, E.E., de Roos, A. "Diastolic Dysfunction in Hypertensive Heart Disease Is Associated With Altered Myocardial Metabolism." Circulation 1999 4; 99(17): 2261-7.
22. Kolev, N., Zimpfer, M. "Impact of ischemia on diastolic function: clinical relevance and recent Doppler echocardiographic insights." Eur J Anaesthesiol. 1995 Mar; 12(2): 123-6.
23. Kondo, H., Masuyama, T., Ishihara, K., Mano, T., Yamamoto, K., Naito, J., Nagano, R., Kishimoto, S., Tanouchi, J., Hori, M., Hiroshi Takeda Inoue, M., Kamada, T. "Digital Subtraction High-Frame-Rate Echocardiography in Detecting Delayed Onset of Regional Left Ventricular Relaxation in Ischemic Heart Disease." Circulation. 1995; 91: 304-312.
24. Voigt, J.U., Exner, B., Schmiedehausen, K., Huchzermeyer, C., Reulbach, U., Nixdorff, U., Platsch, G., Kuwert, T., Daniel, W.G., Flachskampf, F.A. "Strain-rate imaging during Dobutamine stress echocardiography provides objective evidence of inducible ischemia." Circulation. 2003 Apr 29; 107(16): 2120-6.
25. Voigt, J.U., Lindenmeier, G., Exner, B., Regenfus, M., Werner, D., Reulbach, U., Nixdorff, U., Flachskampf, F.A., Daniel, W.G. "Incidence and characteristics of segmental post-systolic longitudinal shortening in normal, acutely ischemic, and scarred myocardium." J Am Soc Echocardiogr. 2003 May; 16(5): 415-23.
26. Mor-Avi, V. V., Godoy, I.E., Lang, R.M. "Color Kinesis: New Technique or Just Another Display of Acoustic Quantification?" Echocardiography. 1999 Jan; 16(1): 95-103.
27. Notomi, Y., Setser, R.M., Shiota, T., Martin-Miklovic, M.G., Weaver, J.A., Popovi, Z.B., Yamada, H., Greenberg, N.L., White, R.D., Thomas, J.D. "Assessment of Left Ventricular Torsional Deformation by Doppler Tissue Imaging: A Validation Study using Tagged Magnetic Resonance Imaging." Circulation 2005, In Press.
28. Yuichi Notomi, Y., Lysyansky, P. M., Setser, R.M., Popovi, Z.B., Martin-Miklovic, M.G., Weaver, J.A., Oryszak, S.J., Shiota, T., Greenberg, N.L., White, R.D., Thomas, J.D. "Measurement of Ventricular Torsion by 2D Ultrasound Speckle Tracking Imaging." JACC, In Press.
29. Modesto, K., Cauduro, S., Dispenzieri, A., Khandheria, B., Marek Belohlavek, Lysyansky, P., Friedman, Z., Gertz, M., Abraham, T. "A Novel Two-Dimensional Strain Imaging Modality Closely Correlates With Tissue Doppler Derived Strain Measurements." ASE-04.
30. Belohlavek, M. et al. "2D Strain - A Novel Doppler Independent Ultrasound Method for Quantification of Regional Deformation: Comparison to Sonomicrometry in a Model of Acute Myocardial Ischemia." ASE-04.
31. Sutherland, G.R. et al. "Validation of a New Approach for Quantifying Myocardial Deformation Based on Automated Anatomical Regional Tracking of Gray-scale Data," ESC-04.
32. Marwick, T. et al. "A New Speckle-Tracking Approach to Strain and Strain-Rate – The Solution to the Angle-Dependence of Tissue Doppler?" CSANZ-04.
33. Ashraf, M., Rein A.J.J.T., Lysyansky, P., Salvador de la Cruz, J., Perles, Z., Jensen, A.J., Nelson, S.L., Li, X., Bhat, A.H., Sahn, D.J. "Improved Delineation of Myocardial Twist by a New Two-Dimensional Strain Analysis Method: An in Vitro Study." ASE-04.
34. Reisner, S.A., Lysyansky, P., Agmon, Y., Mutlak, D., Lessick, J. "Computerized Eyeballing - a Novel Method for the Assessment of Left Ventricular Function." ACC-03.
35. Leitman, M., Lysyansky, P., Sidenko, S., Shir, V., Peleg, E., Binenbaum, M., Kaluski, E., Krakover, R., Vered, Z. "Two-dimensional strain – a novel software for real-time quantitative echocardiographic assessment of myocardial function." J Am Soc Echocardiogr. 2004 Oct; 17(10): 1021-9.

GE Healthcare
9900 Innovation Drive
Wauwatosa, WI 53226
U.S.A.

www.gehealthcare.com

For details, please contact your GE Healthcare representative today.

imagination at work

ULTC-0195-12.07-EN-US