



XStrain™ 4D

“2D STE represents a new approach to quantitative assessment of the cardiac function, delivering incremental prognostic information over traditional clinical parameters. By combining 2D STE data gathered from multiple cardiac views, we have developed a further step ahead in the interpretation of LV deformation index, making it easier and faster than ever”

Stefano Pedri, Product Planning, Esaote, Florence, Italy

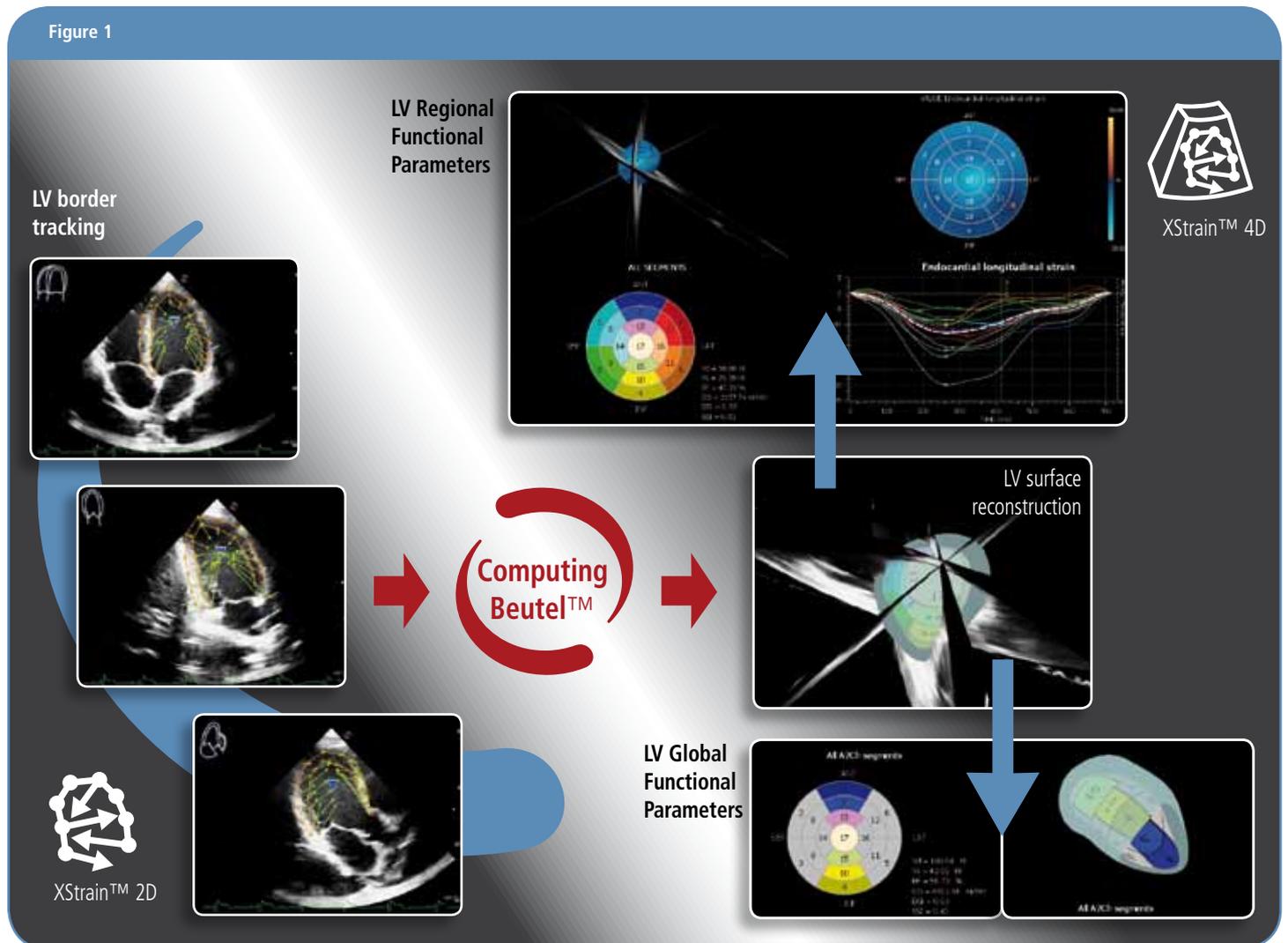
Background

Esaote is an established pioneer in 2D Speckle-Tracking Echocardiography (STE), and was the first company to introduce XStrain™ technology on portable devices in 2006. In 2009, the new technology saw the addition of AHS - Aided Heart Segmentation. Esaote is now introducing a further breakthrough in car-

diovascular ultrasound imaging: the new XStrain™ 4D. XStrain™ 4D merges Esaote's XStrain™ advanced technology with TomTec GMBH's 3D/4D rendering and Beutel™ computation capabilities.

Utilizing LV border tracking obtained with XStrain™ 2D on standard Apical 4Ch, 2Ch, and Apical LAX views, XStrain™ 4D delivers a more complete picture of cardiac function.

Figure 1



Providing:

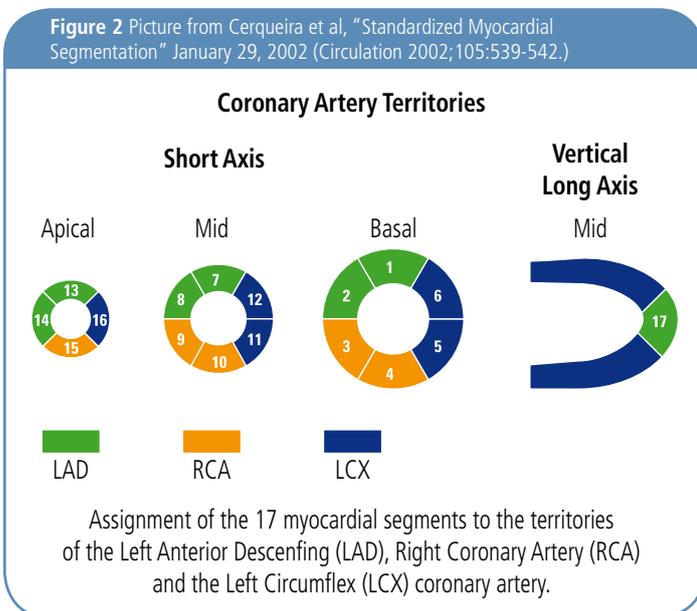
1. **LV surface rendering and reconstruction.**
2. **Global and regional volume curves, including EDV, ESV, SV and EF.**
3. **Regional parameter distributions, including strain and strain rate**

The software creates a LV model in 3D space, which ensures both smooth contours in the spatial domain and continuous motion in the temporal domain. The aim of this new tool is to provide an additional and intelligent solution to correlate and quantify several components of cardiac function in a 3D environment.

The heart's longitudinal and transversal contractility can be evaluated quickly and intuitively by providing the ability to analyse the data grouped by segment as well as by coronary artery distribution (as shown in Figure 2, the 17 segments of the heart are assigned to one of the 3 major coronary arteries).

This approach simplifies the overall data interpretation, with no additional time or computations needed during exam data acquisition.

Figure 2 Picture from Cerqueira et al, "Standardized Myocardial Segmentation" January 29, 2002 (Circulation 2002;105:539-542.)



The Expert Consensus Statement¹ paper published by the Journal of the American Society of Echocardiography (JASE) re-affirmed the importance of longitudinal strain stating that "Global longitudinal strain obtained from apical views was used as an index of cardiac function, with an incremental prognostic value over clinical parameters and LV EF."

XStrain™ 4D, simplifies the interpretation of global longitudinal strain, and is a reliable solution that correlates with the most updated results coming from clinical research in this field.

Rationale of the Technology

2D Speckle-Tracking Echocardiography (STE) is a method in which ultrasound speckles within the echocardiographic images are tracked over time and Myocardial Velocities, Strain, Strain Rate are determined by the displacement of such tracking points in relation to each other. For this reason this technology is able to provide an angle-independent assessment of the myocardial function.

Recently, Esaote has developed 3D/4D data elaboration as a technology that provides the physician with an easier and more interactive method of viewing and analyzing cardiac function.

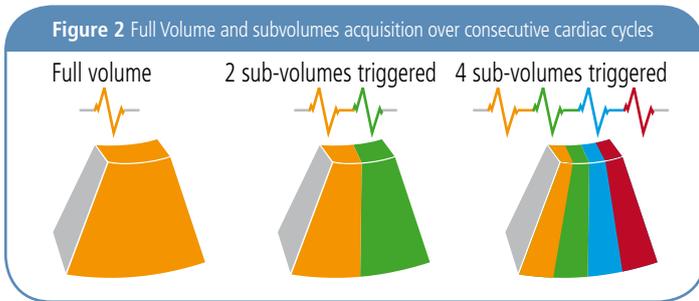
Recently, 3D STE has been introduced by applying Speckle-tracking technologies to 3D echocardiographic images. Images are acquired using a matrix-array transducer, from the apical position in a wide-angled acquisition "full-volume" mode. In this mode, a number of wedge-shaped sub-volumes are acquired over consecutive cardiac cycles during a single breath hold and stitched together to create one pyramidal volume sample.

Although with the latest technologies available, full volume acquisition of the complete heart is possible in one cardiac cycle, the combination of multiple sub-volumes into one dataset is still a common clinical practice (especially when a dilated heart must be analyzed) as shown in Figure 3.

A major limitation of 3D STE to date is the temporal resolution of the Volumetric Pyramidal data sets. Usually the rate of acquisition does not exceed 20-30 volumes/seconds. In most cases, to obtain higher temporal resolution, the field of view needs to be considerably narrowed.

1. EXPERT CONSENSUS STATEMENT: Current and Evolving Echocardiographic Techniques for the Quantitative Evaluation of Cardiac Mechanics: ASE/EAE Consensus Statement on Methodology and Indications. Endorsed by the Japanese Society of Echocardiography. Victor Mor-Avi, PhD, FASE,*, (J Am Soc Echocardiogr 2011;24:277-313.).

Figure 2 Full Volume and subvolumes acquisition over consecutive cardiac cycles



According to current clinical literature on 2D STE technology, single plane acquisition must be performed with a temporal resolution ranging from 50 up to 80-90 frames/sec. For instance, temporal resolution is very important in the evaluation of the diastolic contractility properties of the heart, characterized by faster and less intense movements compared to the systolic ones.

2D STE temporal resolution is **two to three times higher** than 3D STE resolution.

The JASE's Expert Consensus Statement* document reports that *"the much slower frame rates of 3D STE compared with 2D STE may limit analysis of rapid events such as isovolumic contraction and relaxation."*

Another important aspect is the image quality of a single plane acquisition, obtained by the segmentation of the 4D echocardiography volume, has lower quality resolution compared to native 2D imaging.

JASE's Expert Consensus Statement goes on to say "The major pitfall of 3D STE is its dependency on image quality. Random noise and relatively low temporal and spatial resolution affects its ability to define the endocardial and epicardial boundaries. These issues likely affect the frame-to-frame correlation of local image features and contribute to suboptimal myocardial tracking".

In view of this, Esaote's concept is to combine high-quality and temporal resolution 2D Speckle Tracking Echocardiography (STE) with 4D elaboration (namely XStrain™ 4D) providing the physician with a reliable, intuitive and easy-to-use tool for the quantification of regional myocardial function. Moreover, the use of standard 2D ultrasound technology relies on the fact that it is the most widely used and simple technology for Myocardial Quantification Imaging.

Further, the rationale to use standard 2D ultrasound technology for this project relies on the fact that it is the most affordable and simplest technology to bring Myocardial Quantification Imaging to the "real point-of-care" market. The technology is feasible everywhere and anytime as opposed to MRI based technologies or other more expensive ultrasound technologies.

XStrain™ 4D: Get the Whole Picture

By fusing 2D Speckle tracking information obtained from standard Apical 4CH, 2CH and Apical LAX views, XStrain™ 4D aims to make Myocardial Quantification Imaging interpretation easier and faster. Ultimately this technology, now mostly reserved for clinical research, can be easily adopted for daily routines and improve the quality of the diagnosis delivered to the patient.

This expectation is based on the following considerations:

1. Culture and Knowledge impact:

XStrain™ 4D relies on basic and widely spread physician's training, knowledge and comfort with standard 2D echocardiography. The physician simply has to acquire standard views. No special acquisitions are required and no extra training is needed.

2. Economical impact:

XStrain™ 4D requires neither special probes (Matrix/volumetric probes) nor special tools such as high end, costly ultrasound systems. XStrain™ 4D provides a high-level of diagnosis with limited investment.

3. Diagnostic Level

The dynamic heart requires high temporal resolution image acquisition for precise assessment of cardiac contractility and synchronicity. This seems to be a major drawback, in addition to the costs, of 3D-4D real-time technology, especially in the case of particular disease processes such as Dilated Cardiomyopathies or Myocarditis. Esaote's exclusive XStrain™ 4D solution addresses these criticalities and limitations.

HOW XStrain™ 4D Works²

XStrain™ 4D consists in three (3) different environments:

1. Selection Window

In this environment, the system prompts the clips that are available for XStrain™ 4D processing arranged by cardiac views. The user can select the views to be processed in XStrain™ 4D. A dynamic preview of both endo and epicardial border tracking is provided to let the practitioner select the best “tracked” clips. One clip for projection is required.

2. Main Application Window

This is the main application window where global values from Diastolic and Systolic data sets including Volumes, EF, CO, DSI (Diastolic Sphericity Index), SSI (Systolic Sphericity Index) and regional contractility data is provided. This data is provided only after, spatial alignment of the 3 standard views in 3D space with adaption of a dynamic LV surface model, and temporal compensation of heart rate variations has been performed.

The User interface is divided into 4 Quadrants (Figures 4 and 5). The first quadrant, on the top left side of the screen, is devoted to the 3D/4D reconstruction of the LV. The user can freely rotate and zoom the beutel, can superimpose the echographic scanning planes to better evaluate the contractility properties of the LV.

The second quadrant, located in the top right side of the screen, provides the user with a Dynamic color coded Bull’s eye

representation of the parametric values provided while in play mode. During the volume by volume scroll of the dataset, the individual segmental values are shown in the same area.

The third quadrant, on the left bottom part of the screen, is devoted to the so called Static Bull’s eye and to the global values computed by the module. With evaluation of the Bull’s eyes, the user can select which segment they want to analyze. The selection can be completely free or used according to standard ASE projection and Coronary territories segmentation.

The last quadrant, located in the lower right, displays the trend over time of all the segments selected by the user acting on the Static Bull’s Eye placed in the third quadrant.

Figure 3 Selection Window

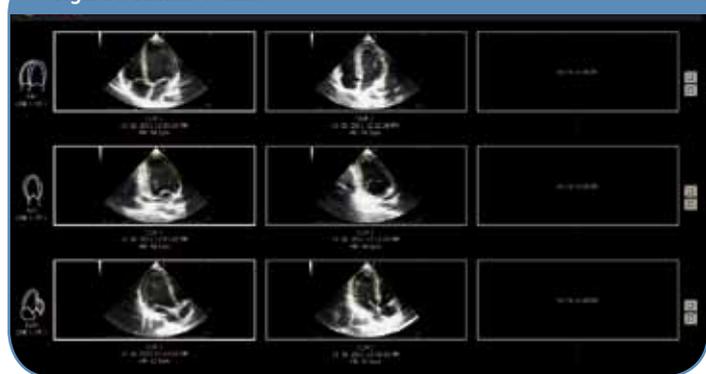


Figure 4 Endocardial Strain values of the LAD segments

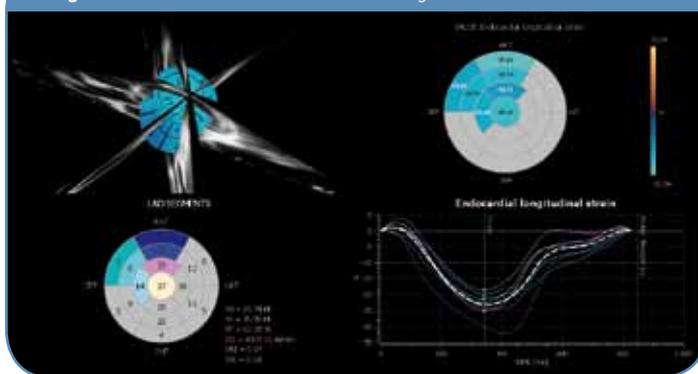
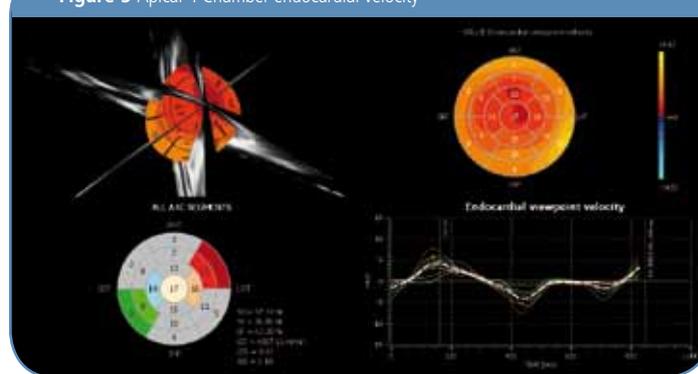


Figure 5 Apical 4 Chamber endocardial velocity



2. Specification subject to change without notice

Case Study n. 1

45 year-old male with anterior myocardial infarction treated with PTCA

3. Full Interactive Report page

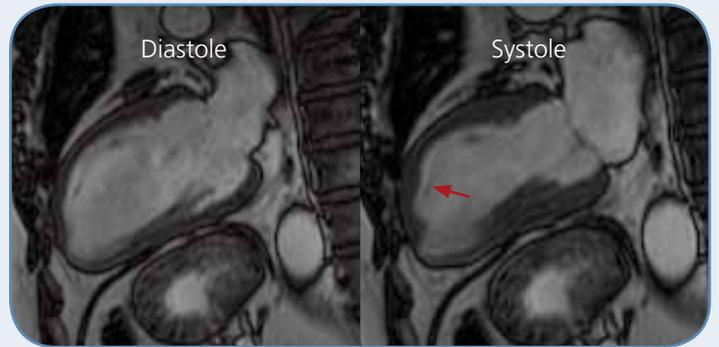
An interactive report page is automatically generated with a “what you see is what you get” approach. Using the touch-screen commands, the parametric peak values and related time to peak are stored in the report page. In case of multiple storage performed on the same parameter, a FIFO (First in First Out) approach is used to make available the latest measurement performed.

The report provides an intuitive summary and is organized in Basal, Mid and Apical layers. Averaged Global as well as segmental values are provided both for peak parametric values and related time to peak.

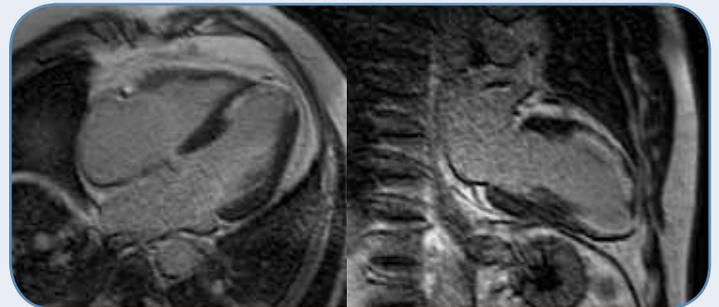
The report is interactive as the user can delete one full data section as shown in Figure 6.



Coronary angiography shows a left anterior descending coronary with a stenosis of 90% of the proximal segment.



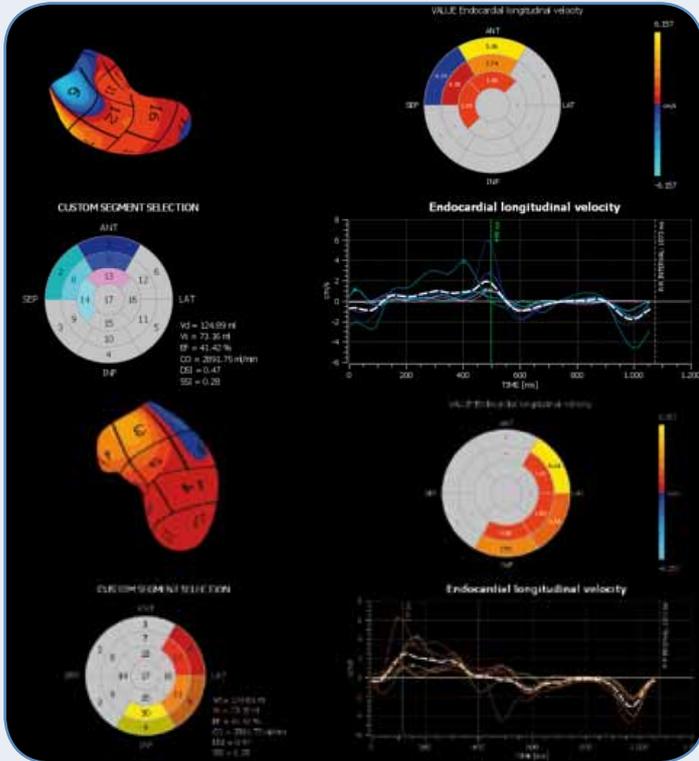
Cine CMR images show akinesia of LV mid segment of anterior wall, distal segments and apex.



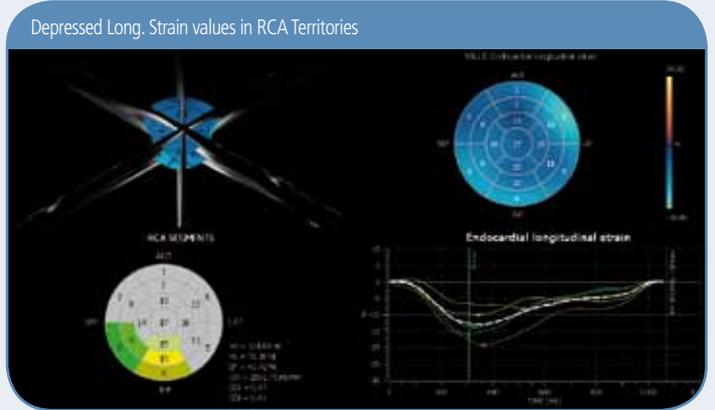
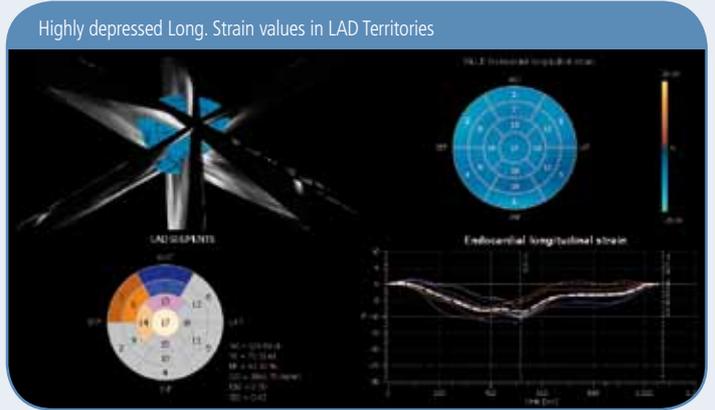
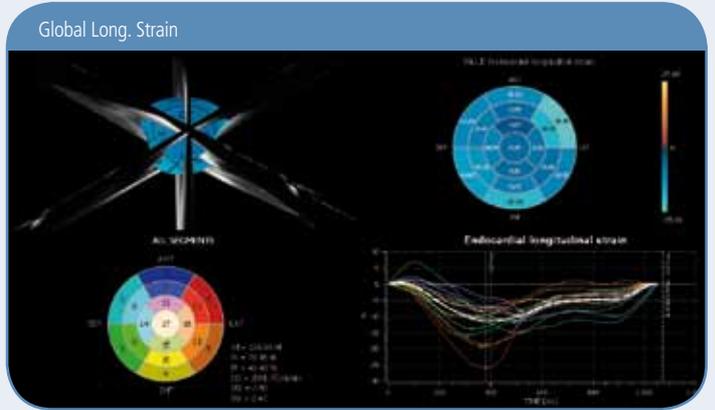
CMR with delay enhancement technique shows myocardial infarction with scar involvement of mid segment of anterior wall and distal segments of anterior, septum and inferior walls.

Figure 6

PATIENT DATA			
LAST NAME	Baratt	FIRST NAME	One
BIRTH DATE	12 12 1966	AGE	24 y
SEX	M	WEIGHT	80 kg
HEIGHT	180 cm	DIA PRESS	
SYS PRESS	2 mm		
IDENTIFICATION	18784240	EXAM DATE	18 05 2011
ACCESSION NUMBER		REFERRING PHYSICIAN	
OPERATOR		ADR DIAGNOSES	
PERFORMING PHYSICIAN		REPORT DATE	18 05 2011
REGIONAL CURVES ANALYSIS XSTRAIN40			
A004 ACQUIRED AT 19 05 2011 A204 ACQUIRED AT 19 05 2011 ALAX ACQUIRED AT 19 05 2011			
PEAK LONGITUDINAL STRAIN ENDOCARDIUM			
ATTACHED ON 29 07 2011 08:08:13 PM			
GLOBAL VALUE	-21.21 %	GLOBAL MAX DELAY	29 ms
SEGMENT	VALUE (%)	TIME TO VALUE (ms)	DELAY (ms)
1-B42 ANT	-20.24	304	
4-B42 SUP	-20.55	304	0
2-B42 POST	-20.15	305	
3-B42 POST	-23.41	308	18
4-B42 LAT	-19.02	296	
3-B42 SEP	-25.38	296	
GLOBAL BASAL LEVEL	-21.38	MAX DELAY BASAL LEVEL	15
7-MID ANT	-24.56	315	
10-MID INF	-19.55	304	19
4-MID ANT SEP	-22.81	306	
11-MID POST	-26.1	303	19
12-MID LAT	-18.87	296	
3-MID SEP	-21.48	306	18
GLOBAL MID LEVEL	-20.23	MAX DELAY MID LEVEL	29



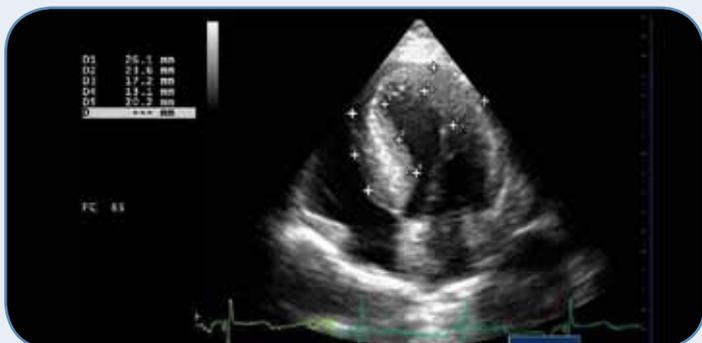
Dyssynchrony reported in XStrain™ 4D: Delayed Peak Longitudinal Endocardial velocity in anterior and anterior septal walls in the upper picture versus correct systolic peak velocity for lateral walls in the lower picture correlating with myocardial infarction with scar involvement.



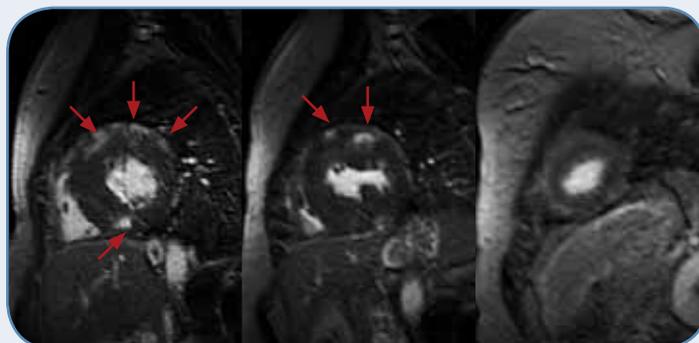
XStrain™ 4D: Global Longitudinal strain compared with depressed segments of Left Anterior Descending (LAD) Coronary Artery and Right Coronary Artery territories involving Anterior, septum and inferior walls.

Case Study n. 2

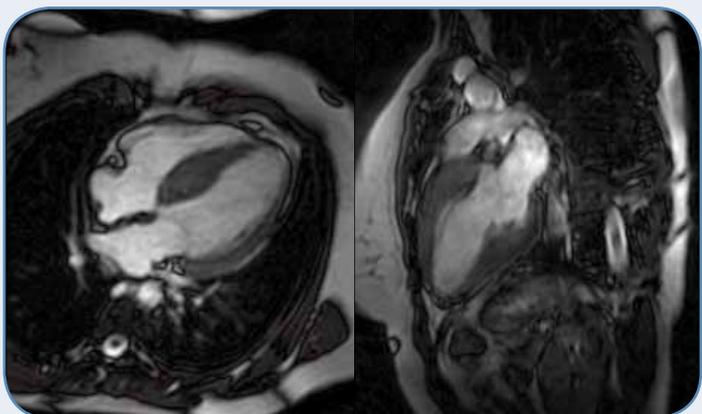
68-year-old female with dyspnea



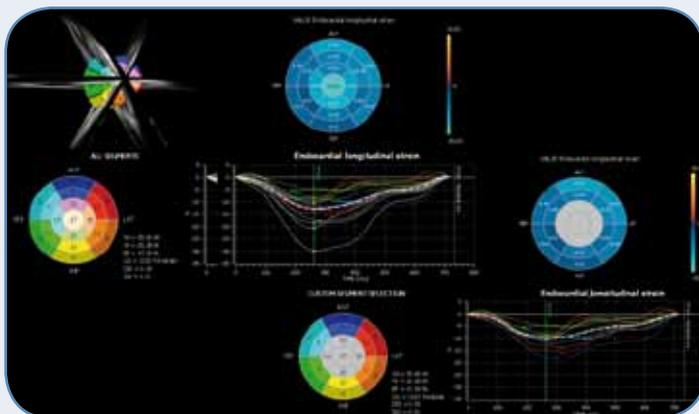
Echocardiography shows left ventricular (LV) hypertrophy suggesting an hypertrophic cardiomyopathy (HCM).



CMR with delay enhancement technique reveals LV fibrosis located at the junction of the right ventricle and interventricular septum (basal level) and in anteroseptum and anterior wall (mid level).



Cine Cardiac Magnetic Resonance (CMR) images show an HCM with LV hypertrophy in mid and basal segments of LV septum, anterior and inferior walls.



XStrain™ 4D revealing Longitudinal strain values depressed in basal and mid segments of left ventricle.



Case studies courtesy of Dr. Gianluca Di Bella,
Researcher of Cardiology in the Faculty of Medicine
and Surgery at the University of Messina, Italy.

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