ESAOTE

MyLab

XSTRAIN OPTION

Doc # 29B65EN03

XSTRAIN OPTION

This section explains the XStrain option of **MyLab**. The section is organised as follows:

- Chapter 1: Strain and Strain Rate

  This chapter provides a brief explanation of the principles of Strain and Strain Rate imaging.

- Chapter 2: Acquiring Cardiac Cycles for Strain Imaging

  This chapter explains how to acquire the cardiac cycles required for Strain imaging.

- Chapter 3: How to Position the Edge Points

  This chapter explains how to position the edge points with **MyLab**.

- Chapter 4: How to Carry Out Strain Rate Analysis

  This chapter explains how to carry out Strain and Strain Rate analysis with **MyLab**.

- Chapter 5: Exporting Data

  This chapter explains how to export data.

- Appendix A: Bibliographic References

  The appendix lists the main bibliographic references for Strain and Strain Rate analysis.

- Appendix B: Fomulas and Bibliographic References

  The appendix lists the formulas and their bibliographic references.

In this manual, control panel keys and software keys are indicated using the following graphical conventions:

Control panel keys They are indicated by **BLUE CAPITAL LETTERS**. Multifunction keys (e.g. **CLIP IMAGE** on MyLab25 Gold and MyLab 30 Gold models) are indicated with the mention of the first function only (i.e. **CLIP** in this example).

Software keys   They are indicated by **BLACK CAPITAL LETTERS**

The confirmation key is always indicated throughout the manual as **ENTER**, while the menu context key as **UNDO**.

WARNING

In this manual a **WARNING** pertains to possible injury to a patient and/or the operator.

CAUTION

In this manual a **CAUTION** describes the precautions, which are necessary to protect the equipment..

Be sure that you understand and observe each of the cautions and warnings.

Table of Contents

Chapter

1

1 - Strain and Strain Rate

The quantitative assessment of the regional function of the left ventricle may be based on the mobility of the endocardium, of the epicardium and on wall thickening. Strain and Strain Rate imaging provides a quantitative method for assessing the regional function of the left ventricle.

The Strain and Strain Rate option requires a software licence (XStrain licence) to be installed on **MyLab**.

Principles

Strain is based on the concept of deformation. Displacement and velocity refer to movements while Strain and the Strain Rate concern deformations.

A moving object is not deformed as long as all its parts move at the same velocity; in this case, the shape of the object does not change. If different parts of the same object move at different velocities, the object's shape changes.
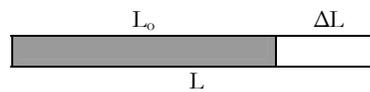
$$L_o \qquad \Delta L$$

$$L$$

Diagram by Støylen

Definition of Strain

If L_o is the initial length, ΔL the variation in length (deformation) and L the instantaneous length, at the time the measurement is made, **Strain** (**S**) may be defined as:

$$S = \frac{L - L_o}{L_o} = \frac{\Delta L}{L_o}$$

Strain is thus the deformation of the object with respect to its initial length. Negative strain shortens or compresses the object; positive Strain elongates or stretches it.
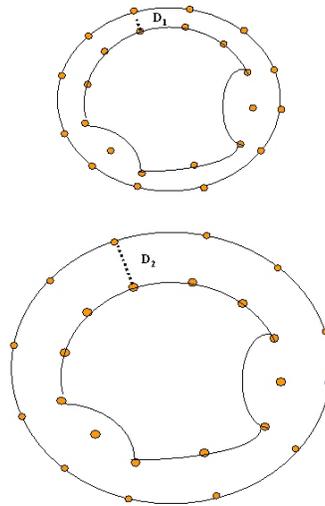
Definition of Strain Rate

The **Strain Rate** (**SR**) represents the frequency at which the deformation occurs, that is, Strain per unit of time.

$$SR = \frac{\Delta S}{t}$$

Regional **Strain** may be calculated by integrating the Strain Rate using the following formula:

$$\int_{t_0}^{t} SRdt$$

Radial Strain evaluates the tissue thickening in a perpendicular direction to the tissue itself

If D_1 is the distance between endocardium and epicardium at R wave, the radial Strain is:

S rad $= (D_2 - D_1)/D_1$

where D_2 is computed as endosystolic.

Determining Myocardial Strain Using the Edge Tracking Method

Myocardial deformation can be studied by tracking the movement of the edge of the walls within 2D cycles.

Note

Strain Rate imaging is carried out on 2D cardiac and pediatric cardiac cycles: the Clip licence is required.

Once the initial frame for tracking the edge has been selected, a series of points are to be positioned on the edge. Starting form these points the following parameters are calculated for every heart cycle:

- Distance covered by each point (displacement)

- Velocity

▪ Strain and Strain Rate

The velocity of the edge is estimated by tracking the movement of these points during synchronized 2D cycles. The analysis of the movement is based on the brightness of the set of points. The movements of these points can be measured in the cardiac cycles.

Depending on the view under analysis the following parameters are calculated:

Long Axis - Calculated parameters
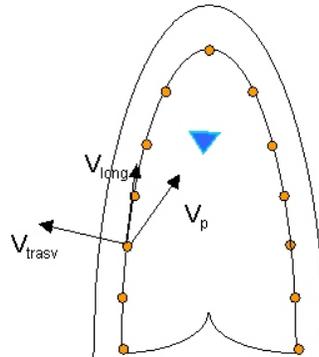
Paramaters	Label	Unit
Transversal displacement	Transv displ	mm
Longitudinal displacement	Long displ	mm
Transversal velocity	Transv vel	cm/sec
Longitudinal velocity	Long vel	cm/sec
View point velocity	Vp vel	cm/sec
Longitudinal Strain	Long Strain	%
Radial Strain (in endo- and epi-cardium analysis)	Rad Strain	%
Longitudinal Strain Rate	Long Strain Rate	1/sec
Radial Strain Rate (in endo- and epi-cardium analysis)	Rad Strain Rate	1/sec

Short Axis – Calculated parameters
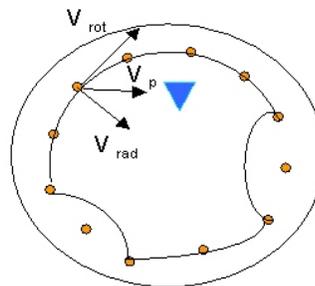
Parameter	Label	Unit
Rotational displacement	Rot displ	degree
Radial displacement	Rad displ	mm
Rotational velocity	Rot vel	degree/sec
Radial velocity	Rad vel	cm/sec
View point velocity	Vp vel	cm/sec
Circumferential Strain	Circ Strain	%
Radial Strain (in endo- and epi-cardium analysis)	Rad Strain	%
Circumferential Strain Rate	Circ Strain Rate	1/sec
Radial Strain Rate (in endo- and epi-cardium analysis)	Rad Strain Rate	1/sec

Note

Strain Rate imaging heavily depends on the quality of the 2D pictures and on their frame rate: the higher the picture quality and frame rate, the more accurate the Strain imaging will be.

Chapter

2

2 - Acquiring Cardiac Cycles for Strain Imaging

Strain imaging is carried out on 2D cardiac cycles.

> **Note**
>
> The XStrain option can only be enabled in the adult cardiac and in pediatric cardiac applications, on exams performed at rest and with a stable heart rate.
>
> In pediatric cardiac applications, the temporal resolution of the acquired loops might not allow an optimal analysis of the diastolic phase in patient with HR $\geq$ 140 bpm .

Strain imaging cannot be carried out on 2D-CFM or 2D-TVM cardiac cycles or on CnTI cycles. It requires cardiac cycles acquired with ECG synchronization.

Acquiring Cardiac Cycles for Strain Imaging

The cardiac cycles acquisition to be used for the Strain analyses follow a specific procedure. In this way, cycles with a frame rate and picture quality suitable for Strain imaging will be available for selection.

Procedure

- Press **START END** to view the Start Exam page.

- Enter the patient's data.

- Select the adult cardiac application and press OK to confirm.

- Make sure that the patient's ECG is displayed correctly.

- Use the depth and frequency controls to regulate the picture quality and frame rate.

> **Note**

Strain Rate imaging depends heavily on the quality of the 2D pictures and on their temporal resolution (frame rate).

The image quality is optimal when all miocardial segments can be clearly identified on each single frame of the clip to be analyzed.

The higher is the frame rate, the more accurate will be the Strain imaging. To increase the frame rate, optimise the scan angle and the depth (an acquisition frame rate of 38-40 Hz is suggested).

To analyze clips with more then 3 cardiac cycles, be sure that the heart rate is constant.

- If necessary, set the clip duration (**CLIPS DUR** software key) to 3 cardiac cycles.

- Start scanning and press the **ACQUIRE** key to select the desired cycles: the system automatically shows in cine mode the last acquired loops.

- If necessary, set the velocity to 1 (**SPEED** software key).

- Using the trackball, scroll the memories to select the desired sequence.

- Press **CLIP** to save the sequence.

High frame rate clip symbol (Clip ART)

The clips acquired in this way (clips with high frame rate) are identified by a specific symbol, shown on the left, to distinguish them from the other clips. Only clips marked with this symbol may be used with the XStrain option.

> **Note**
>
> The Clip ART symbol is not assigned to clips whose frame rate is too low for Strain imaging. In this case, the acquisition must be repeated with an increased frame rate.

Optimal Configuration for Strain Acquisition

Only on MyLabFive, MyLab25, MyLab30 and MyLab50 models

To speed up the selection of cardiac cycles for Strain imaging, the user can act on some specific parameters.

Procedure

- Press **MENU**.

- Select the "General Preset" option and then "Cine mode" option.

- Set the options as indicated in the table below:

Option	Configuration
Cine mode	1 or 3 cycles
Automatic play	OFF
Cine speed	RT

- Press OK to confirm.

Using this configuration, the system automatically shows, in Freeze, the sequence set in cine mode at real-time velocity.

3 - How to Position the Edge Points

Clip ART symbol

Procedure

The Strain analysis can be performed both in exam review and in archive review.

Before starting the Strain analysis, make sure that you have acquired cardiac cycles marked with the Clip ART symbol.

- Press **EXAM REV** or **ARCHIVE REV** to access saved or archived cycles.

- Select the desired cardiac cycle.

- Press the **TOOLS** key to start the Strain analysis.

The system automatically starts the Strain analysis.

Points Positioning

The points on the edge of the wall must be indicated. The points can be positioned manually or in semi-automatic way (**MODE** key). In the first case each point has to be manually placed; in the latter case the **Aided Heart Segmentation** (**AHS**) tool suggests the selection of the myocardial points (landmarks) to be tracked.

The system displays the following software keys:

Software Keys

BORDER	NEW TRACE
EXIT	PLAY
FRAME	PROCESS
GAMMA	TRACE
MODE	

Manual Procedure

Strain imaging may be carried out if at least three tracking points have been positioned; to ensure that the Strain analysis is well readable, we recommend to use the number of points indicated the table below:

View	Points N°
A4C, A2C, A3C	13 points (3 for each ASE segment, 7th point on the ventricle apex)
SAX MV, SAX PV	12 points (3 for each ASE segment)
SAX AP	8 points (3 for each ASE segment)

Procedure

- Using the **TRACE** key, select the type of view, i.e. short or long axis. The icon displayed on the left gives an easy reference of the active selection. The edge is closed in a short-axis view or remains open in a long-axis view.

> **Note**
>
> Check that the image orientation is the same of the selected icon so that the data processed for the Strain and Strain Rate analysis correctly correspond to the different cardiac segments.

- Using the **FRAME** key, select the initial frame.

- Using the **GAMMA** key, select the best gray map to display the border.

- Using the trackball, position the first edge-tracking point and press **ENTER** to confirm.

- Repeat the operation to position all other desired points.

> **Note**
>
> In case of an apex view, the two ends of the traced edge must be positioned at the sides of the mitral annulus.

- Press **UNDO** to position the last point and to end the procedure: the system displays the traced border.

Semi-Automatic Procedure

Aided Heart Segmentation (AHS)

- Using the **TRACE** key, select the type of view, i.e. short or long axis. The icon displayed on the left gives an easy reference of the active selection. The traced edge is closed in a short-axis view, while stays open in a long-axis view.

> **Note**
>
> Check that the image orientation is the same of the selected icon, so that the data processed for the Strain and Strain Rate analysis correctly correspond to the different cardiac segments.

- Using the **FRAME** key, select the initial frame.

- Using the **GAMMA** key, select the best gray map to display the border.

- Using the trackball, follow the instructions to position the anatomical landmarks and press **ENTER** to confirm.

- Once the landmarks have been placed, the system overlays a guideline grid on the 2D image: the lines on the image indicate the suggested directions where points are to be placed.
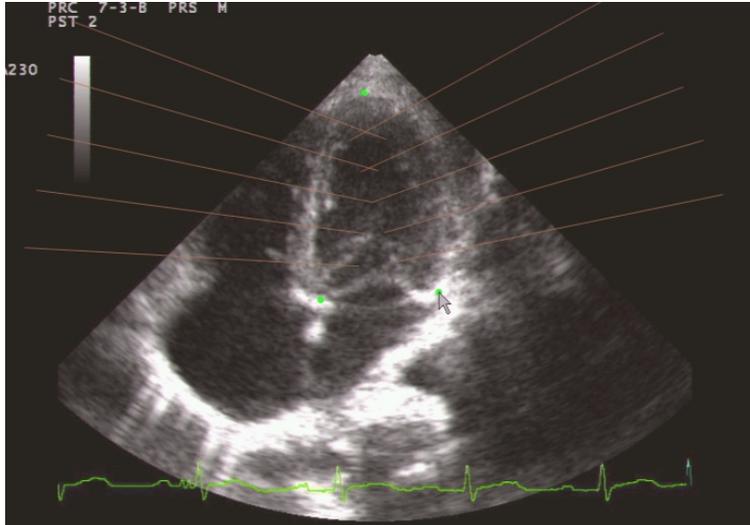
- Using the trackball place the cursor and press **ENTER** to position the first point along the suggested direction.

- Repeat the operation to position all points.
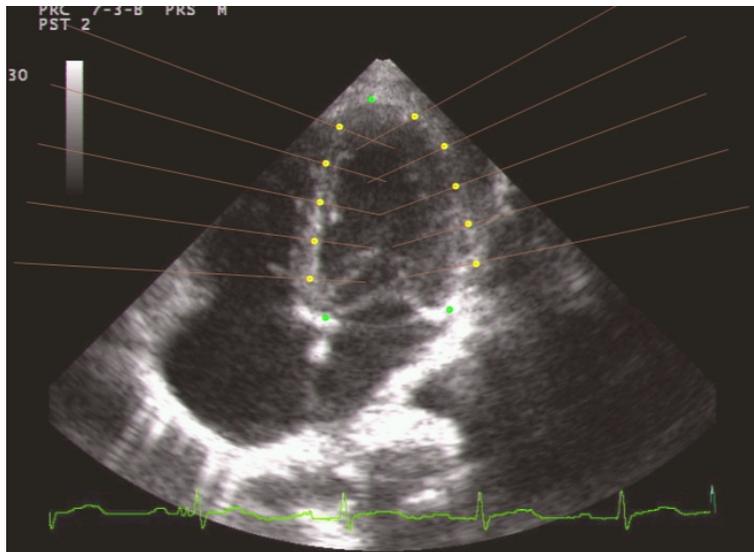
- Press **CONFIRM** to display the traced border.

Regardless of the followed procedure, to move a tracking point, place the cursor on it, press the **ENTER** key and, keeping it pressed, position the point with the trackball; press **ENTER** again to confirm.

The **NEW TR** key may be used to enter a new set of points.

Once the procedure is completed, a viewpoint (represented by a triangle) is shown in the selected cycle: the **view point velocity** is calculated basing on the movement of the wall edge from this point.

The viewpoint may be moved anywhere. Position the cursor over the triangle: press and hold down the **ENTER** key, shift the probe to the desired point using the trackball and then release the **ENTER** key.

Select the border (**BORDER** key): the available options allow to select the endocardium only (**ENDO**) or both the endo- and epicardium (**EPI**). In the latter case both borders are displayed by the system.

> **Note**
>
> The epicardium border can be selected and modified only if the endocardium border has been traced.

4 - How to Perform a Strain Analysis

The Strain and Strain Rate analysis is activated by pressing the **PROCESS** key: the system displays both the loop with its traced border and the vectors in cine mode. The **MODIFY** key resets the analysis: the system shows the menu for point positioning. The **EXIT** key quits the Strain analysis.

The **VIEWP VEL** option of the **VECTORS** key displays the view point velocity.

The system processes the cardiac cycle once the **CONFIRM** key has been pressed: the following images are shown.

Graphs presentation
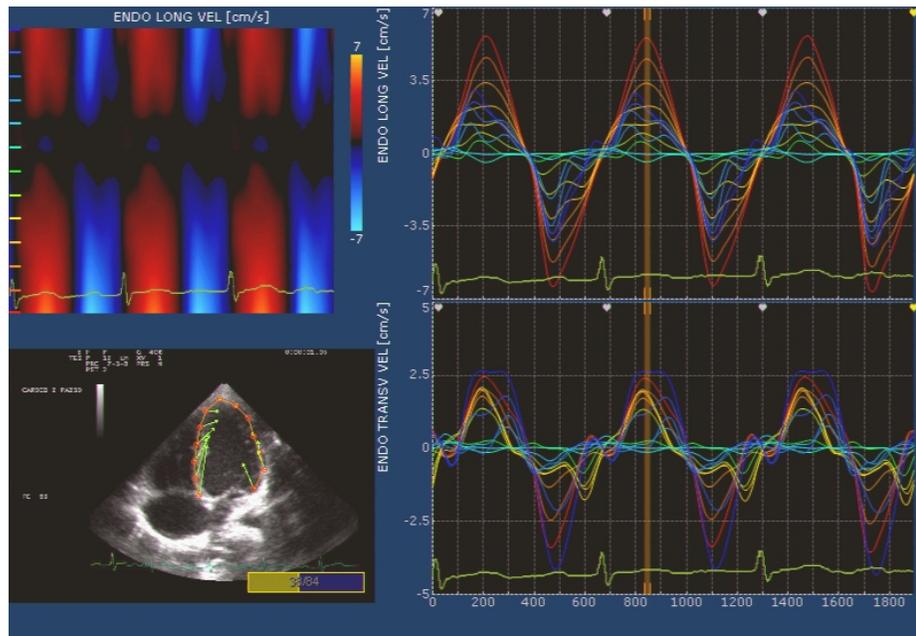
The left lower image shows the view with the test points (**vectorial view**). The movement of the points is indicated by vectors. The length of the vectors is proportional to the wall motion. The "Endo" and "Epi" labels indicate the parameters calculated respectively in the endocardium and in the epicardium.

Refer to the first charter for further information

Depending on the analized view, the velocity vector can be analyzed and shown:

- in the direction from the viewpoint to the tracking point (**VP** option of **GRAPHS**).

- in the rotational and radial directions in short axis or in transversal and longitudinal direction in long axis (**VEL** option of **GRAPHS**).

The graphs on the right represent the velocity, in the components provided with the selected view. To make the graphs easier to read, the curves are shown in different colours: each point is assigned a specific colour.

By passing the cursor over the graphs, the user can view the corresponding value of the parameter on each point: the value is shown above the graph.

> **Note**
>
> The values depend on the quality of clip acquisition and on the correct positioning of the tracking points. When images are reconstructed with mathematical patterns, the average error is less than 10% with the exception of the Strain Rate whose average error is about 20%.

MyLab enables the display of the single graphs of different tracking points. In the vectorial view, position the cursor on the desired tracking point: the graphs on the right correspond to the different parameters in the selected point.

The point selected appears in a different color. The same color is used on the graph.
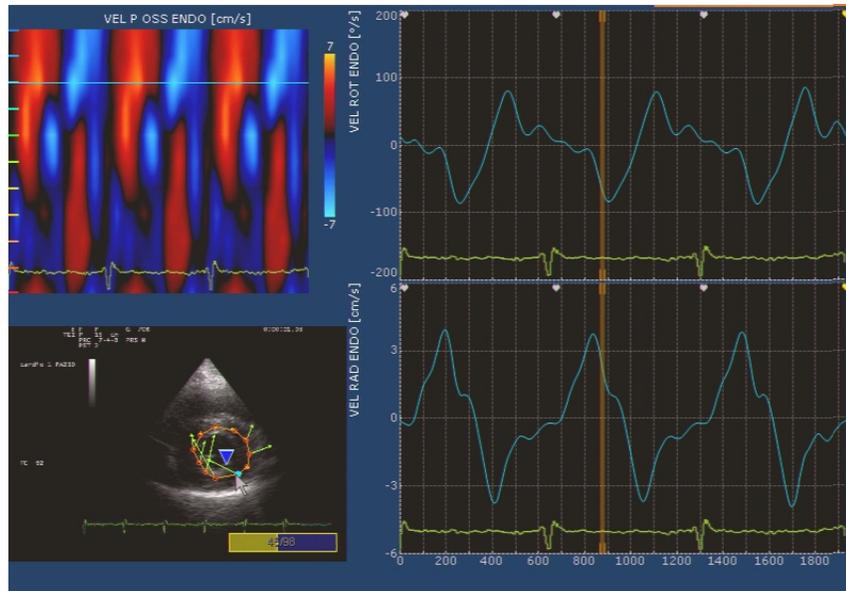
To select several points, position the cursor on the first point and press **ENTER** to fix it. Repeat this procedure for all desired points. The graphs will be updated accordingly. The **DELETE** key can be used to delete the points selected: the graphs of all tracking points will automatically be shown again.

Software Keys

The software keys are on two menu levels: the **NEXT/PREVIOUS** key scrolls the two levels.

ATTACH*	EXPORT	PLAY
CLEAR	FRAME	REVIEW
CYC TTP*	GRAPHS	SAVE*
DISPLAY	M-MODE	VECTORS
EXIT	MODIFY	

Only in RCA analysis

The **FRAME** key may be used to scroll through the single frames while the **PLAY** key shows the cycle in motion.

The **VECTORS** key shows the different type of velocities (refer to the first chapter for further information).

The **GRAPHS** key switches from one view to another: the user can display the velocities graphs, the Strain and Strain Rate graphs, the displacement and the view point velocity graphs.

The **DISPLAY** key shows the **time traces** of displacements, of velocities, of Strain and Strain Rate on the upper left side of the screen. When the cursor is placed on one of the markers on the left of the trace display, a horizontal line is shown over the trace, corresponding to one of the test points on the border. Press the **ENTER** key to fix the line: all graphs displayed on the right show the progress of the parameter selected with the **GRAPHS** key in the point selected by the line.

The **CR MMODE** option of the **REVIEW** key shows the time traces of the four parameters on the screen.

Trace presentation
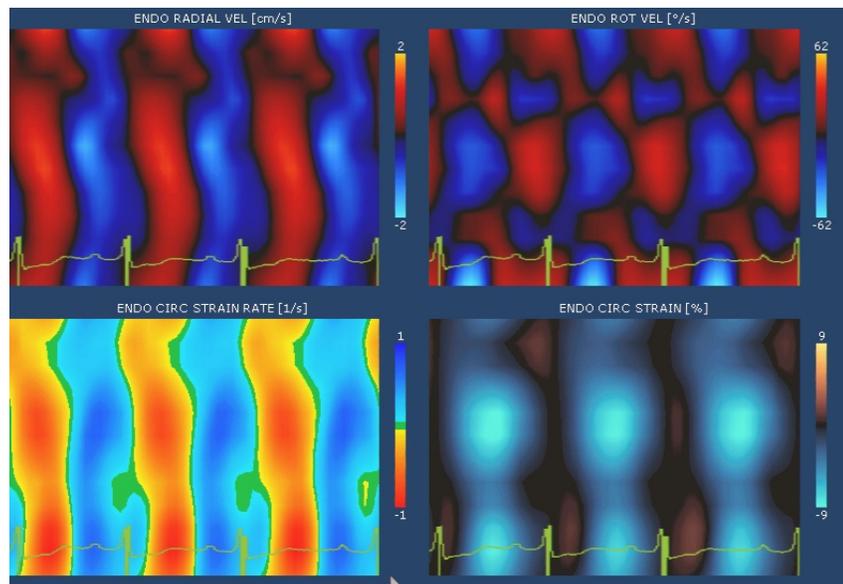
Positive velocities (shown in red) refer to movements towards the viewpoint, negative velocities (in blue) refers to movements away from it. Positive strain values (in brown) indicate elongation, negative strains (in blue) indicate shortening.

The **RCA** (Regional Curves Analysis) option of the **REVIEW** key respectively show the volume and the segmental velocities graphs of the long axis views, and the areas and segmental velocities graphs of the short axis views.
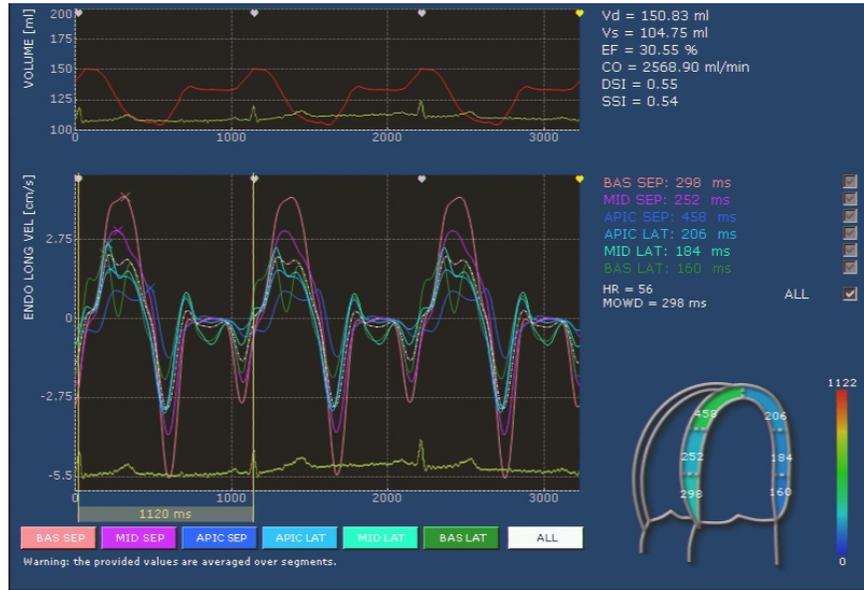
Short Axis View

The Area to Time graph of the ventricle is displayed on the upper part of the screen. The time interval corresponds to three cardiac cycles, as shown by the ECG trace. On the right side of the graph the following parameters are displayed:

Refer to the Appendixes for formulas and bibliographic references

Parameter	
Ad	Diastolic area
As	Systolic area
FAC	Fractional area change

Long Axis View

The Volume to Time graph of the ventricle (calculated using the modified Simpson method) is displayed on the upper part of the screen. The time interval corresponds to three cardiac cycles, as shown by the ECG trace. On the right side of the graph the following parameters are displayed:

Refer to the Appendixes for formulas and bibliographic references

Parameter	
Vd	Diastolic volume
Vs	Systolic volume
EF	Ejection fraction
CO	Cardiac output
DSI	Diastolic sphericity index
SSI	Systolic sphericity index

In both views parameters are automatically calculated basing on the average of the acquired heart cycles.

Segmental Velocities

The time graphs of the different parameters are shown in the lower part of the screen. The ventricle is divided in segments along the traced border (the border segmentation is based on ASE standard 1989).

Velocities, displacements, Strains and Strain Rates are calculated for each segment (the **GRAPHS** key switches among the different presentations). The average is calculated on the first heart cycle. The **CYC TTP** key changes the reference cycle: the listed parameters are consequently updated. Each segmental parameter is represented with a specific color: the color legenda is shown below the graphs, its options work also as buttons. Place the cursor on the segment button to display only the corresponding graph.

The **DISPLAY** key switches from the presentation of the parameter values (**VALUE**, **E** and **A** options) to the their Time to Peak presentations (**TTP**, **TTE** and **TTA** options). For the Peak and TTP presentations, all segments are pre-selected by default. In all other cases each segment has to be activated by placing the cursor on the corresponding button: once one or more segments have been activated, use the cursor to place the marker.

The obtained values/times are listed on the right side of the screen and displayed in the graph, using number and chromatic identification.

The time necessary to reach the peak is calculated for each parameter. The user can then move the indicated peak:

Procedure

- Select one segmental velocity

- Place the cursor on the graph and move the vertical line to the desired peak.

- Press **ENTER** to confirm.

- The new maximum is indicated by a dot and the correlated time to peak is calculated again.

The system automatically calculates also the following parameters:

In long axis	
MOWD	Maximum difference between times to peak of opposite walls
FC	Heart Rate

In short axis	
FC	Heart Rate
MEAN	Times mean value
STAND DEV	Standard deviation

One or more segments can be excluded from the computation of values/times and of other parameters. Place the cursor on the "ALL" field and press the **ENTER** key: the included cells, displayed on the right side of the times list, are enabled. To exclude one parameter, disable the corresponding cell.

The **ATTACH** key encloses the RCA graphs page, the view under exam, the calculated parameters and any comment to the report.

The **SAVE** key saves the segmental values/times of the displayed parameter on the report: the saved data can be reviewed by selecting the **REPORT** option of the **REVIEW** key.

Second Menu Level

An anatomic M-Mode trace can be performed on the cardiac cycle so that anatomical references may be used alongside the Strain and Strain rate analysis.

Procedure

- Press **NEXT** to view the second menu level.

- Press the **M-MODE** key to activate the cursor.

- Position the cursor on the first point and press **ENTER** to confirm.

- Position the second point and press **ENTER** again to confirm. Press **UNDO** to end the procedure.

The system shows the M-Mode trace in the top left-hand corner.
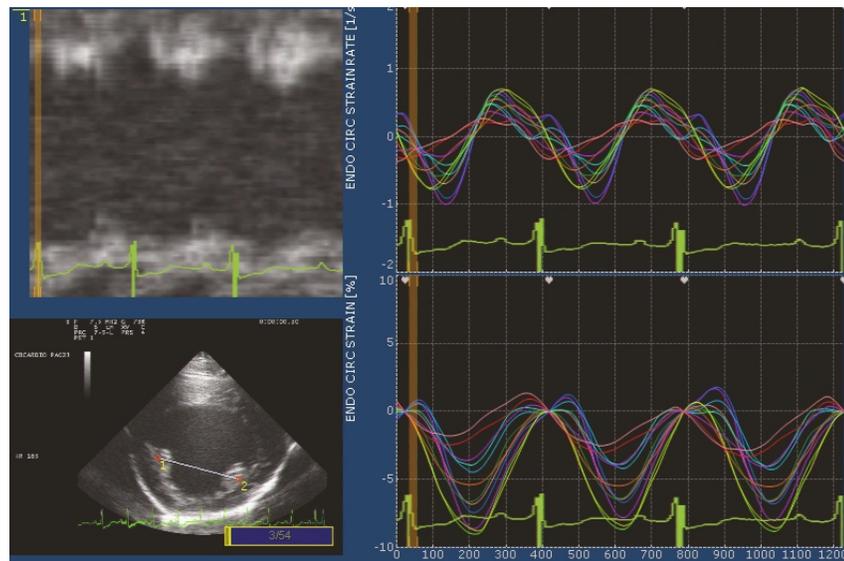
Press **M-MODE** again to return to the standard view.

The **IMAGE** key saves the picture shown on the screen; the **CLIP** key is disabled (on **MyLab25 Gold** and **MyLab30 Gold** models the **CLIP IMAGE** key saves both the displayed image and the clip). By pressing the keys for remote control of the printers, the picture on the screen may be printed.

Ending the Strain Analysis

The scan may be ended at any time by pressing the **EXIT** key: the system returns to the exam or archive menu.

Chapter

5

5 - Exporting Data

The **EXPORT** key is on the second level of software keys available for Strain and Strain Rate analysis.

Second level software keys

<div style="text-align:center">

EXPORT

FRAME

M-MODE

PLAY

</div>

All numeric values of the parameters are saved to an external drive, included in a specific folder, in text format with field separators (CSV, Comma Separated Value format) defined as follows:

- A comma (,) as a list separator.

- A full-stop (.) as a decimal separator.

- No symbol for grouping numbers.

The folder is identified by the name and surname entered on the Start Exam page and contains as many files as the calculated parameters .

Data Import Settings

In order to correctly import the files, the aforementioned settings must be applied to the target application.

Note

Different settings could cause errors in the data importing procedure.

Appendix A - Bibliographic References

Bibliographic References

- J.D'hooge A.Heimdal.., <u>Regional Strain and Strain Rate Measurements by Cardiac Ultrasound: Principles, Implementation and Limitations,</u> *Eurpean J Echocardiography,* 2000, 1, pp. 154-170.

- C.Pislaru, T.P.Abraham..., <u>Strain and Strain Rate Echocardiography,</u> *Current Opinion in Cardiology*, 2002, 17, pp. 443-454.

- Mani A. Vannan, G.Pedrizzetti.., <u>Effect of Cardiac Resynchronization Therapy on Longitudinal and Circumferential left Ventricular Mechanics by Velocity Vector Imaging: Description and Initial Clinical Application of a Novel method Using high-Frame Rate B-Mode Echocardiographic Images</u>, *Echocardiography: J of CV Ultrasound Allied Tech.*, Vol.22, N.10, 2005.

- G.Buckberg, <u>Basic Science Review: The Helix and the Heart</u>, *J Thoracic Cardiovascular Surgery*, Vol.124, N.5, Nov.2002

- B.Cappelli, MR.Concetta, G.Galanti… "<u>Two-Dimensional Tracking and TDI are Consistent Methods for Evaluating Myocardial Longitudinal Peak Strain in Left and Right Ventricle Basal Segments in Athlets</u>", *Cardiovascular Ultrasound,* February 2007, 5:7

- B.Cappelli, G.Galanti.. "<u>Supernormal Functional Riserve of Apical Segments in Elite Soccer Players: an Ultrasound Speckle Tracking Handgrip Stress Study</u>", *Cardiovascular Ultrasound*, April 2008, 6:14

- CM.Bertini, I.Corazza… "<u>Ventricular Dyssynchrony at Echo: Detection by Two-Dimensional Tracking and Tissue Doppler Imaging in Candidates to Biventricular Pacing</u>", *Computers in Cardiology* 2008, Vol. 35:113−116 - ISSN 0276−6574

- C.Bussadori, M.Carminati.. "<u>A new 2D-based method for myocardial velocity strain and strain rate quantification in a normal adult and</u>

paediatric population: assessment of reference values", *Cardiovascular Ultrasound*, February 2009, 7:8

Appendix

B

Appendix B - Formulas and Bibliographic References

Modified VS Simpson Volume Formula	Measure Unit	Derived Parameters
Vd and $Vs = (\pi/4) * (h/64) * \Sigma_{1-64} D^2_h$ h: Long axis D_h: Diameter V: Volume	ml	-
R.M.Lang, M.Bierig.. "A report from the America Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification", *J Am Soc Echocradiogr*, 00, 18:1440-1463		

Ejection Fratcion Formula	Measure Unit	Derived Parameters
EF = 100*(Vd-Vs)/Vd Vd: Diastolic volume Vs: Systolic volume	-	-
J.Oh, J Seward... "The echo manual – Second edition", Lippincott Williams & Wilkins		

Cardiac Output Formula	Measure Unit	Derived Parameters
CO = (Vd-Vs) * bpm Vd: Diastolic volume Vs: Systolic volume Bpm: Heart rate	ml/min	-
J.Oh, J Seward... "The echo manual – Second edition", Lippincott Williams & Wilkins		

Fractional Area Change Formula	Measure Unit	Derived Parameters
FAC = 100 * (Ad-As)/Ad	ml/min	-
Ad: Diastolic rea		
As: Systolic area		
J.Oh, J Seward... "The echo manual – Second edition", Lippincott Williams & Wilkins		

Sphericity Index Formula	Measure Unit	Derived Parameters
$LVSI = V/(\pi/6 * L^3)$	-	-
V: Volume		
L: Ventricle length in long axis		
T Kono, HN Sabbah... "Left Ventricle shape as a determinant of functional mitral regurgitation in patients with severe heart failure secondary to either coronary artery disease or idiopathic dilated cardiomyopathy", *Am J Card*, 1991, Aug 1, 68(4):355-359 HFJMannaerts, JA Van der Heide… "Early detection of left ventricular remodelling after myocardial infarction, assessed by transthoracic 3D echocardiography", *Eur Heart J*, 2004, 25:680-687		

MOWD (Maximal Opposite Wall Difference) Bibliographic Reference
Yu C-M, J Gorcsan III... "Usefulness of Tissue Doppler Velocity and Strain Dyssinchrony for Predicting Left Ventricular Reverse Remodelling Response after Cardiac Resynchronization Therapy", *Am J Card*, 2007, 100:1263-1270