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IMAGING VIGNETTE

Left Atrial Strain Performance and its Application in Clinical Practice

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THERE IS INCREASING EVIDENCE OF THE IMPORTANCE OF LEFT ATRIAL (LA) FUNCTION INCREMENTAL TO atrial dilatation. The feasibility of LA function assessment has increased with the development of LA strain (1). Although the use of atrial strain is ready to spread beyond its research application, many clinicians are unfamiliar with the process of strain acquisition and continue to rely on other atrial parameters (e.g., LA volume, A-wave velocity). The purpose of this paper is to facilitate the acquisition of atrial strain for clinicians by illustrating its application with the most commonly used software.

Currently, most vendors use strain software that was originally developed for left ventricular strain. **Figures 1 to 4** show the steps to obtain this using machines with the most widely available software. In collaboration, we used the experience of more than 1,000 cases of LA strain analysis to develop a method of 8 steps that are common to all vendors: 1) image acquisition and/or selection; 2) electrocardiographic orientation "reference" (**Figure 5**); 3) detection and marking of fiducial landmarks; 4) detection and tracing of the endocardial border (**Figure 6**); 5) adjustment of regions of interest (**Figure 7**); 6) evaluating tracking quality; 7) excluding segments of inadequate and/or poor tracking; and 8) repeating in more than 1 view and then averaging to minimize error.

Atrial strain has now been evaluated in multiple conditions, especially heart failure and atrial fibrillation (2). In heart failure, LA strain has been used in the assessment and staging of diastolic dysfunction (**Figure 8**) and filling pressure (**Figure 9**). The assessment of atrial contractile function (**Figure 10**) may be pertinent to risk evaluation in atrial fibrillation.

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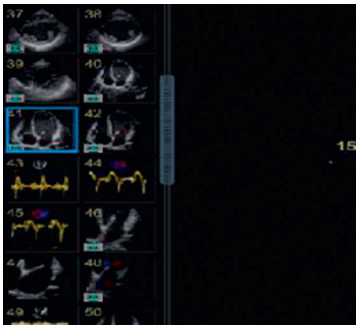
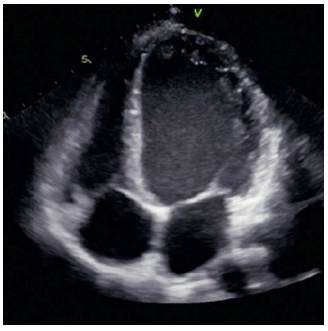
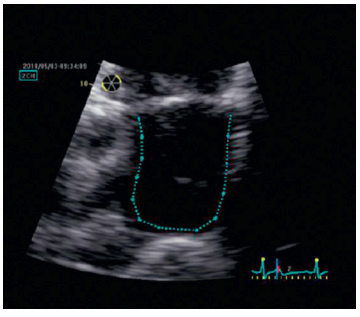
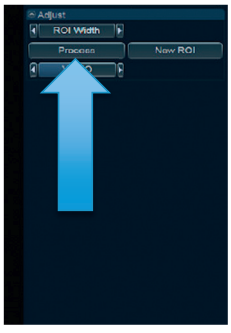
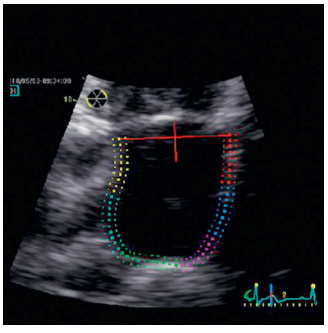
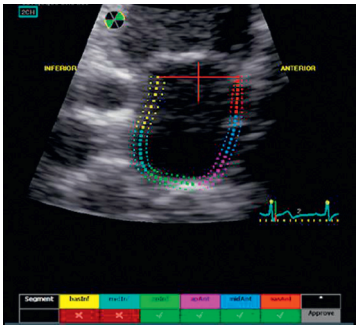
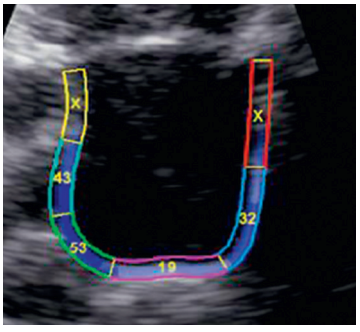
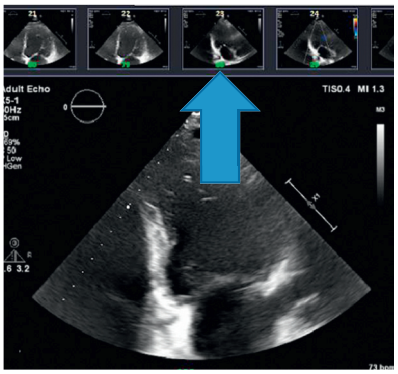
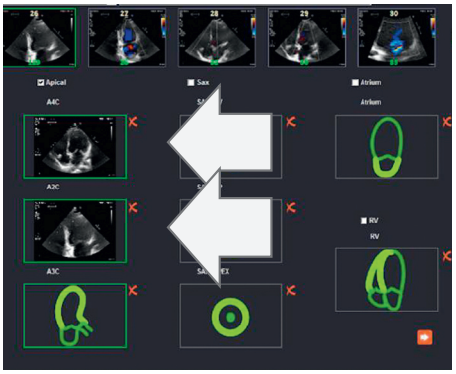
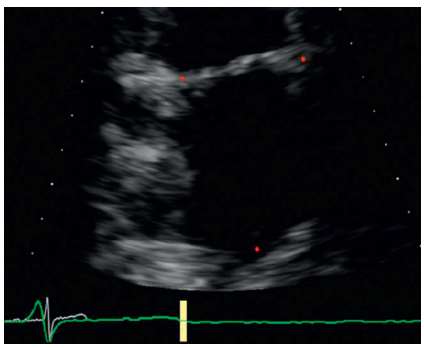
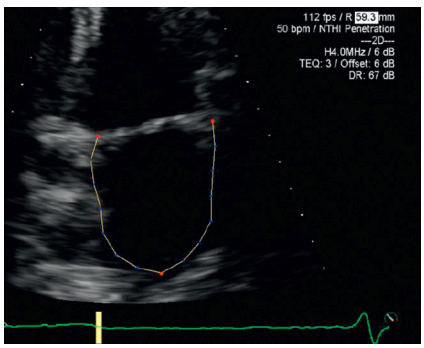
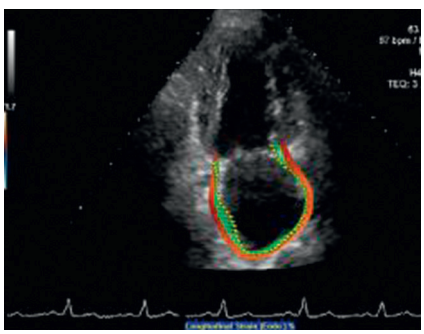
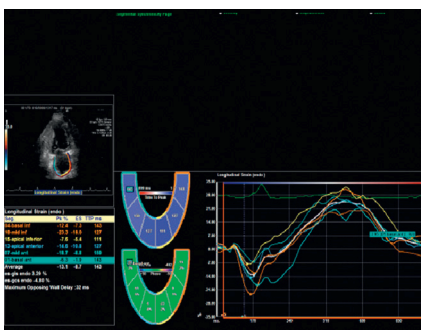
FIGURE 1 Steps of Performing Atrial Strain With ECHOPAC (GE Health Care, Milwaukee, Wisconsin)

Image selection/ acquisition. Left image shows available images to choose from (Choose the apical 4 chamber /or 2 chamber). Right image shows the chosen image. (Double click on the image you want to analyze)		
Detection of fiducial landmark and tracing endocardial border. Left image shows steps to perform LA strain. Right image shows manual endocardial tracking starting and finishing with the mitral valve insertion points		
Adjustment of ROI. Left image shows ROI adjustment icon, Click the ROI width to adjust ROI. Right image shows the thickness of the analyzed segment		
Evaluation of tracking quality and exclude poorly tracked segments. Left and right images show poorly tracked segments. The assessment of tracking quality involves visual assessment and adjustment of the linear contour Please see online video 2 to see examples of tracking		

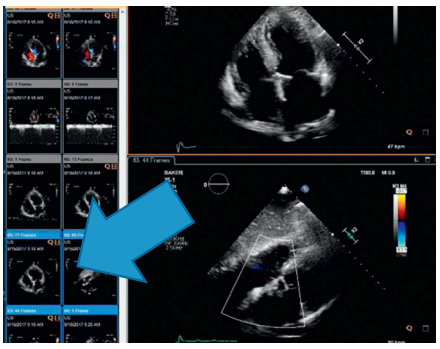
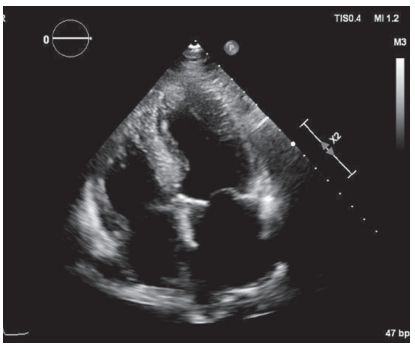
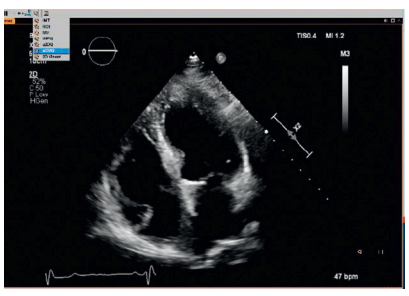
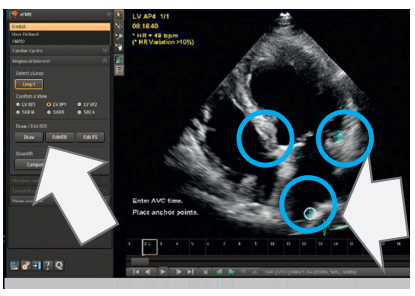
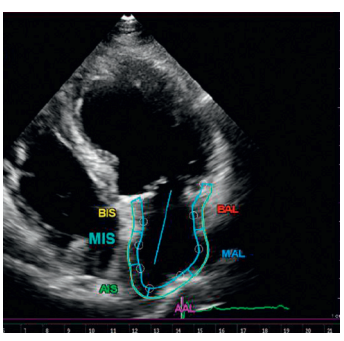
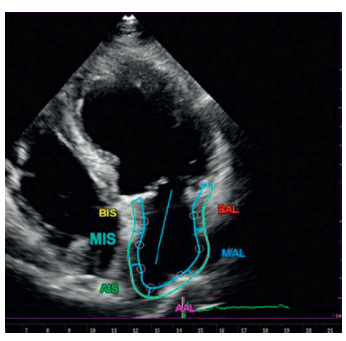
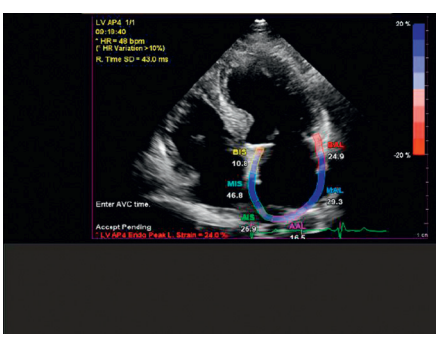
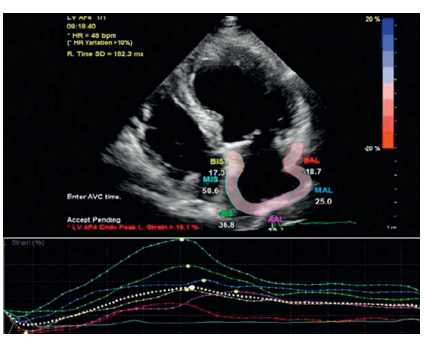
Videos 1 and 2 illustrate the steps and tracking. LA = left atrial; ROI = region of interest.

FIGURE 2 Steps of Performing Atrial Strain With TOMTEC (Siemens, Malvern, Pennsylvania)

Image selection/ Acquisition. Left image shows available images to choose from. Right image shows selected images. Drag the image you want to analyze in the provided boxes for the apical 4 chamber and 2 chamber accordingly. (Note we use the boxes provided for LV strain)		
Detection of fiducial landmark and endocardial border. Left image shows the fiducial landmarks, click both mitral annuluses and then right click roof of LA. Right image shows automatic completion of endocardial border tracking		
Evaluation of tracking quality and exclude poorly tracked segments. Left image shows tracking. Right image shows LA strain graph. The assessment of tracking quality involves visual assessment and adjustment of the linear contour Please see online video 3 to see an examples of tracking		

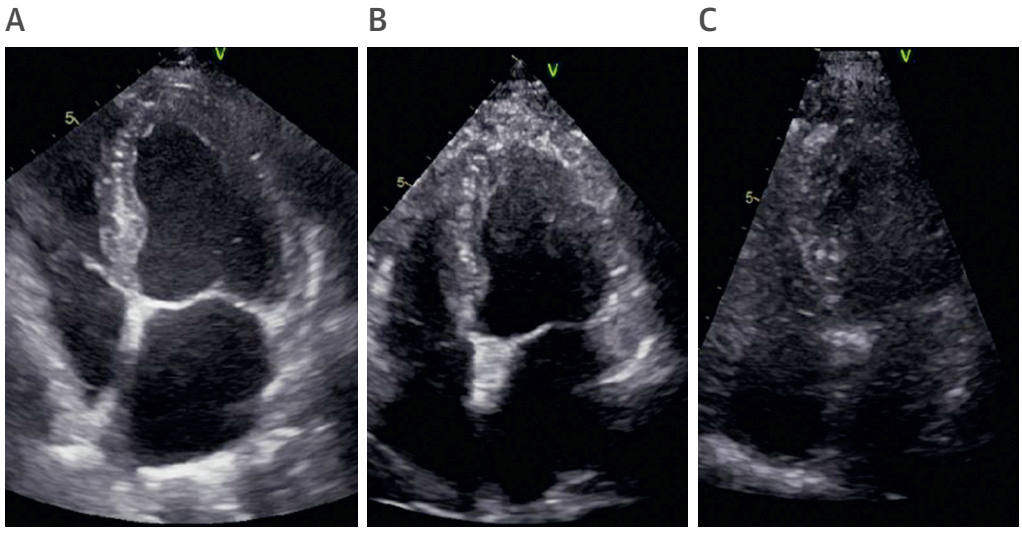
Video 3 illustrates tracking. LV = left ventricular; other abbreviation as in **Figure 1**.

FIGURE 3 Steps of Performing Atrial Strain With QLAB (Philips, Andover, Massachusetts)

Image selection/ acquisition. Left image shows available images to choose from (Choose the apical 4 chamber /or 2 chamber). Right image shows the chosen image. (Double click on the image you want to analyze)		
Detection of fiducial landmark and endocardial border. Left image – clicking CMQ allows a semi-automated tracing by marking three fiducial landmarks. Right image click "draw" then click both mitral annuluses and then click the roof of LA		
Adjustment of ROI. Left image shows ROI Thickness. Right image shows the thickness analyzed segment after adjustment. For adjustment simply click on the outer line to decrease or increase thickness		
Evaluation of tracking quality and exclude poorly tracked segments. Left image shows tracking. Right image shows LA strain graph. The assessment of tracking quality involves visual assessment and adjustment of the linear contour. Please see video 4.		

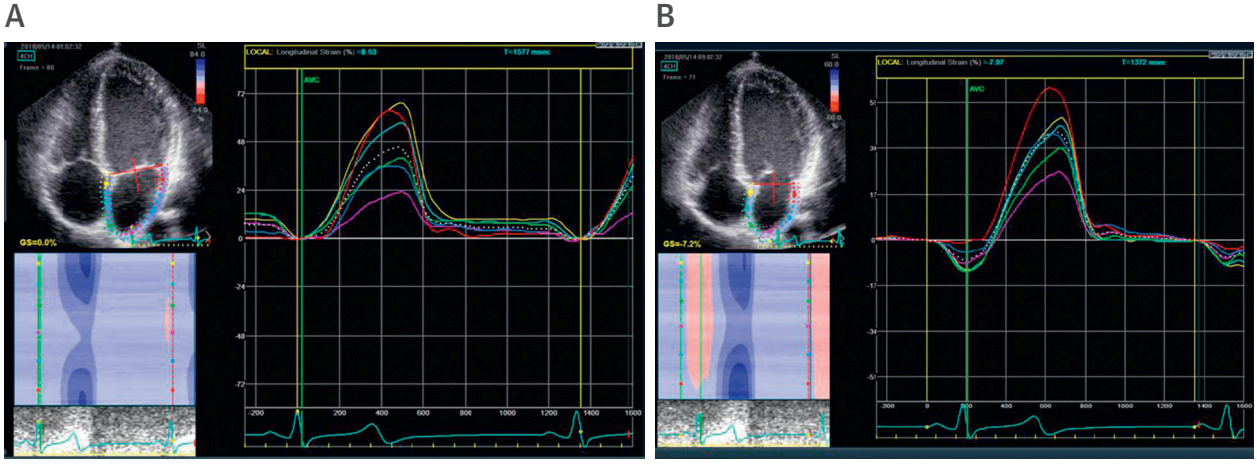
Video 4 illustrates tracking. CMQ = cardiac motion quantification; LA = left atrium/atrial; other abbreviations as in Figure 1.

FIGURE 4 Image Quality



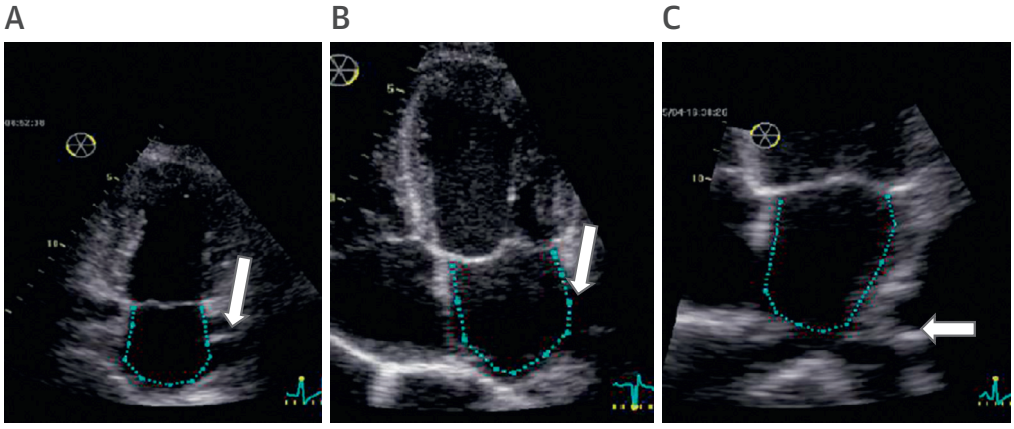
(A) The image is considered adequate for LA strain measurement. The part of intra-atrial septum and entry of right lower pulmonary vein might not track well, but **(B)** global longitudinal strain is still measurable. **(C)** The quality of image 3 is too poor to analyze (Videos 5, 6, and 7). Note: Acquire and/or select images of dedicated apical 4 and 2 chambers that have a visible endocardial border throughout the cycle to assess tracking quality. Optimize gain, depth and avoid foreshortening. Atrial strain can still be measured when 1 or 2 segments are not visible due to artifacts. Abbreviation as in Figure 1.

FIGURE 5 Gating the Strain Image



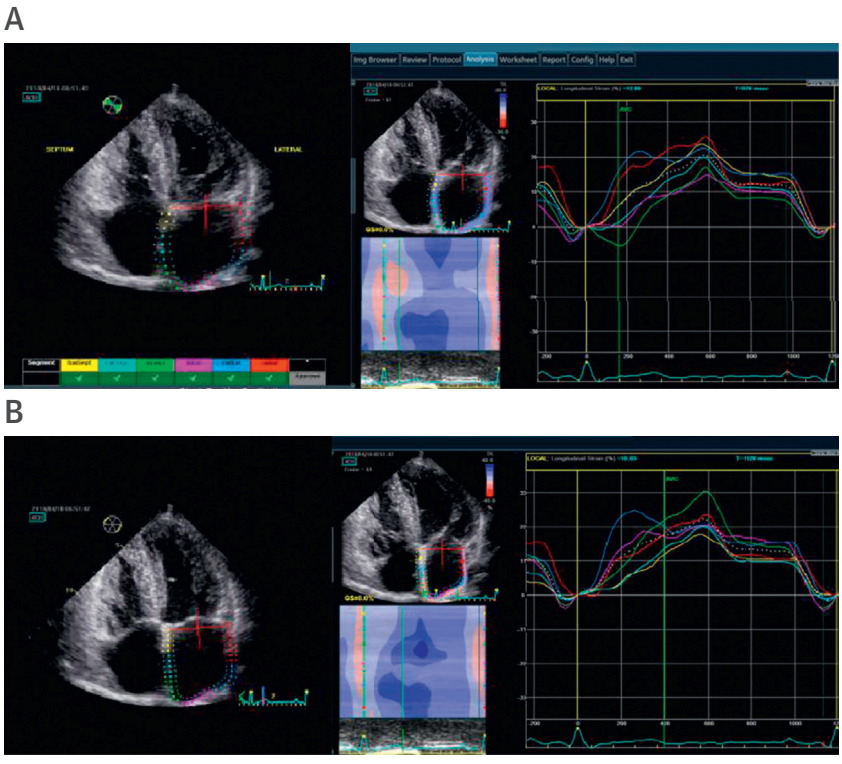
(A) Atrial strain using R-R gating. **(B)** Atrial strain using P-P gating. Note: Most vendors measure the atrial strain reference frame of zero strain from R-R by default. However, some vendors offer changing the electrocardiographic orientation to P-P; in addition, LA strain from either approach can be converted into the other. We recommend using R-R for the purposes of diastolic assessment and P-P in case of atrial contractile function assessment.

FIGURE 6 Tracing Borders



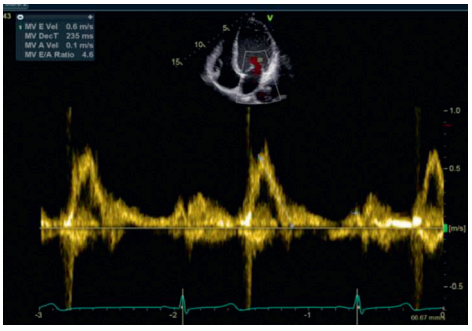
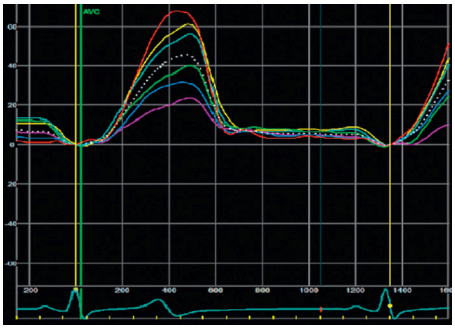
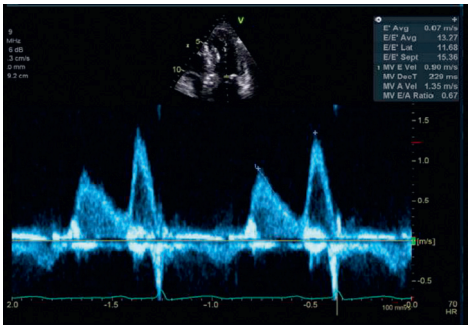
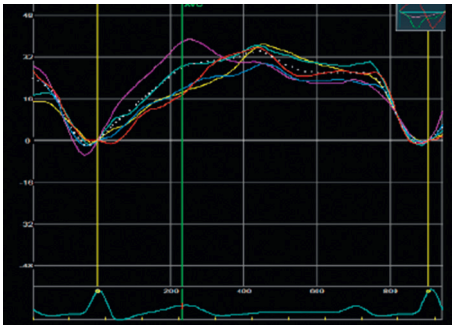
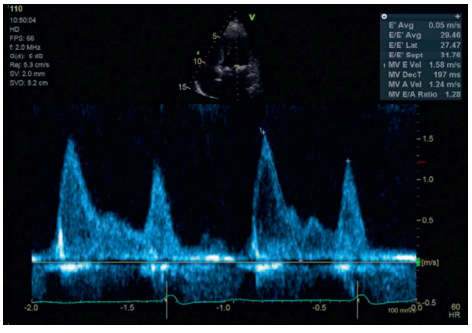
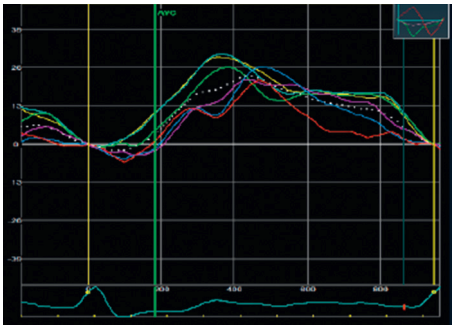
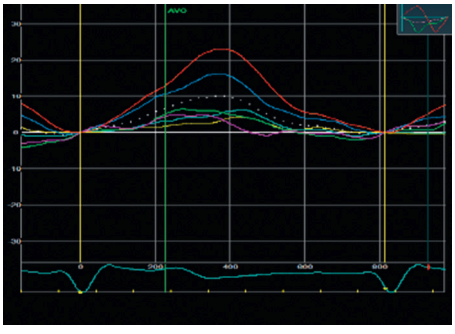
(A) Apical 2-chamber view with **arrow** pointing to left atrial appendage (LAA). **(B)** Apical 4-chamber view with **arrow** pointing to right lower pulmonary vein. **(C)** Apical 4 chamber view with **arrow** pointing to the left lower pulmonary vein. Note: Trace the LA endocardial border, extrapolating across the pulmonary veins, and/or LAA orifices, up to the opposite mitral annulus side. In the semiautomated software, only choose the mitral annulus and roof of the LA in apical 4- and 2-chamber views. Abbreviation as in Figure 1.

FIGURE 7 Defining the ROI



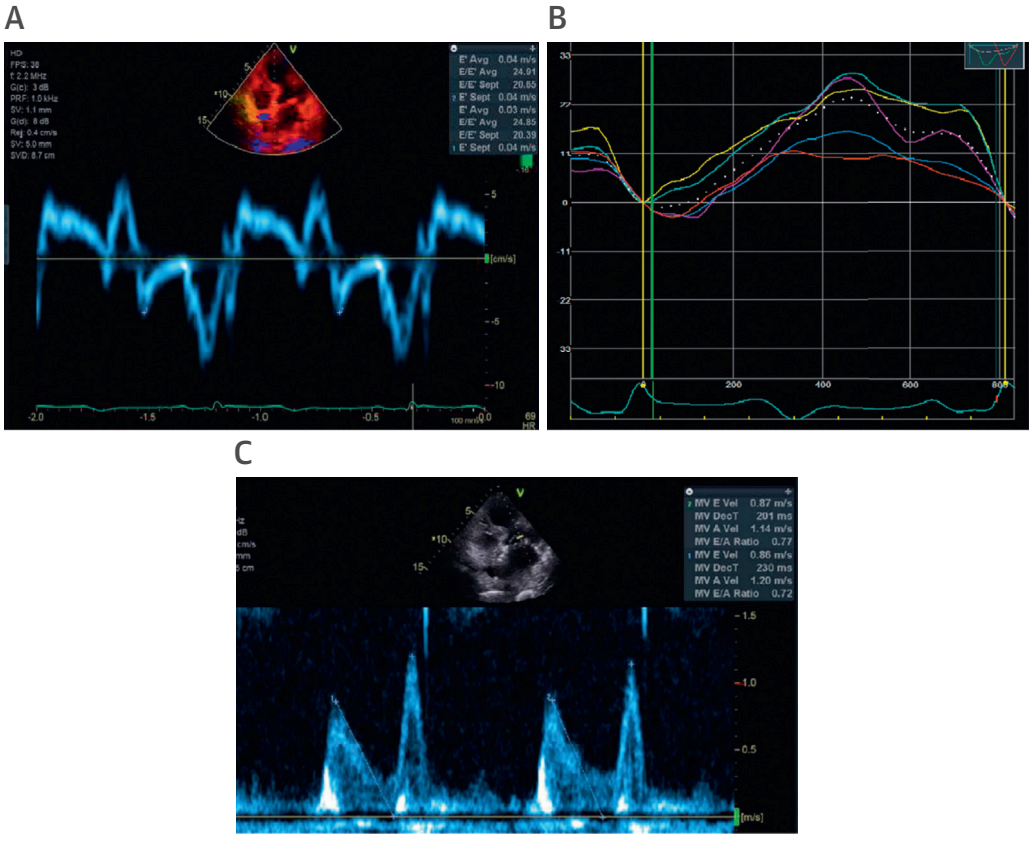
Same patient shown in the other figures. **(A)** Thick ROI as provided by software without adjustment (reservoir strain 21% and contractile strain 12%). **(B)** ROI after adjustment (reservoir strain 25% and atrial contraction 15%. ROI of the LA is defined by the endocardial border (inner contour of the LA wall), and the epicardial border (outer contour of the LA wall, or in the case of the atrial septum, the opposite edge of the septum). A default width of 3 mm is recommended. LA strain can be underestimated if ROI is not adjusted. Abbreviations as in Figure 1.

FIGURE 8 Gradation of Atrial Reservoir Strain at Each Stage of Diastolic Dysfunction

a. Normal (reservoir strain 45%)		
b. Delayed relaxation (reservoir strain 33%)		
Grade II diastolic dysfunction (Pseudonormal) (reservoir strain 24%)		
Grade III diastolic dysfunction (restrictive) (reservoir strain 10%)		

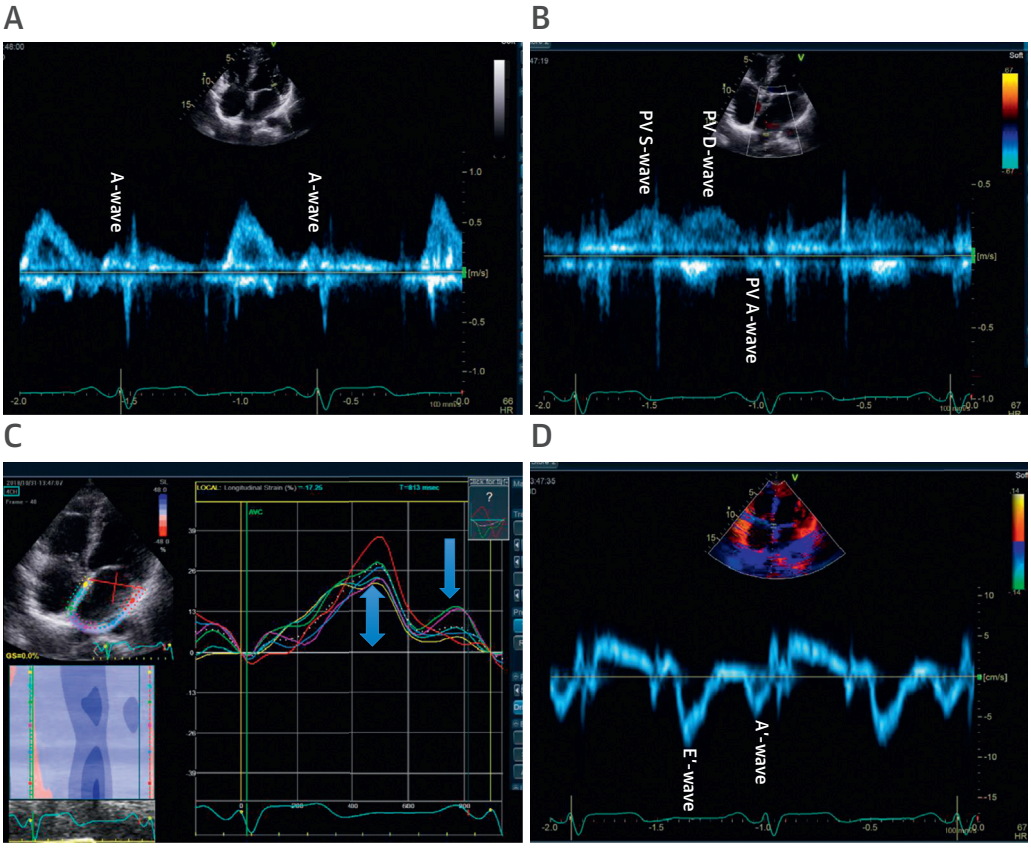
At each stage, there is a progressive decrement of reservoir strain.

FIGURE 9 Use of LA Strain for Estimation of Increased LV Filling Pressure



(A) Tissue Doppler. **(B)** Atrial strain. **(C)** Mitral inflow. There is an inverse relation between E/e′ and atrial strain. Filling pressure estimated by tissue Doppler is increased (E/e′: 24). Total LA strain (reservoir strain) of 22% is decreased. Abbreviations as in Figures 1 and 2.

FIGURE 10 Application for Assessment of Atrial Function



Different modes to assess atrial stunning in a patient 10 min post-cardioversion for atrial fibrillation. **(A)** Pulsed wave Doppler of mitral valve inflow, showing a small A-wave. **(B)** Pulmonary venous Doppler, showing a decrease in the pulmonary vein S-wave (PVS) and in the AR wave. **(C)** Atrial strain curve, showing decrease in reservoir strain (28%; expected range 35% to 40%), and a small LA booster pump (8%; expected range 16% to 19%). **(D)** Tissue Doppler and mitral valve annular velocity, showing small a′.

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KEY WORDS atrial function, atrial strain, global longitudinal strain

APPENDIX For supplemental videos, please see the online version of this paper.