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EACVI CONSENSUS DOCUMENT

# Standardization of left atrial, right ventricular, and right atrial deformation imaging using two-dimensional speckle tracking echocardiography: a consensus document of the EACVI/ASE/Industry Task Force to standardize deformation imaging

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The EACVI/ASE/Industry Task Force to standardize deformation imaging prepared this consensus document to standardize definitions and techniques for using two-dimensional (2D) speckle tracking echocardiography (STE) to assess left atrial, right ventricular, and right atrial myocardial deformation. This document is intended for both the technical engineering community and the clinical community at large to provide guidance on selecting the functional parameters to measure and how to measure them using 2D STE.

This document aims to represent a significant step forward in the collaboration between the scientific societies and the industry since technical specifications of the software packages designed to post-process echocardiographic datasets have been agreed and shared before their actual development. Hopefully, this will lead to more clinically oriented software packages which will be better tailored to clinical needs and will allow industry to save time and resources in their development.

**Keywords** echocardiography • 2D speckle tracking • strain • strain rate • deformation imaging • right ventricle • left atrium • right atrium • free wall • reservoir function • conduit function • booster function

# Introduction

The European Association of Cardiovascular Imaging (EACVI)/American Society of Echocardiography (ASE)/Industry Task Force to standardize deformation imaging (the 'Task Force') has published a consensus document addressing standards for two-dimensional (2D) speckle tracking echocardiography (STE) of the left ventricle.[1] As with the prior consensus document, the primary aim of the current document is to standardize definitions and techniques for using 2D STE to assess left atrial (LA), right ventricular (RV), and right atrial (RA) function.

It is not intended to review the wide range of potential clinical applications of deformation imaging to assess LA, RV, and RA function. For the LA, applications have included (but not been limited to) patients with heart failure and both reduced and preserved ejection fraction, heart valve diseases, and atrial fibrillation.[2] For the RV, 2D speckle tracking has been used to stratify the prognosis and address management in patients with pulmonary arterial hypertension,[3] pulmonary embolism, acute coronary syndromes, left ventricular failure, arrhythmogenic cardiomyopathy, and congenital heart diseases.[4,5] 2D STE has been shown to be feasible for investigating RA function, and it has been studied as a prognostic marker in pulmonary hypertension.[6–10]

One of the challenges to widespread clinical application of these techniques has been the lack of both standardization of the parameters to be measured and specific software packages to use to obtain such measurements.[2,11] As such, a goal of the Task Force has been to provide standardization of LA, RV, and RA deformation imaging for both the technical engineering community (in order to foster the development of software packages specifically designed to measure myocardial deformation of LA, RV, and RA) and the clinical community at large (to provide recommendations about what parameters to use and how to measure them to assess myocardial deformation of LA, RV, and RA for both clinical and scientific purposes). This document represents the result of that effort. The reader is also referred to the prior consensus document addressing 2D speckle tracking of the left ventricle for more basic definitions regarding strain principles and calculations.[1]

# Standardization of LA myocardial deformation imaging

## Determining the region of interest/tracing the LA wall

Similar to the left ventricle, the complete myocardial region of interest (ROI) of the LA is defined by the endocardial border, which is the inner contour of the LA wall, and the epicardial border, which is the outer contour of the LA wall (or in the case of the atrial septum, the opposite edge of the septum). There are characteristics unique to the LA that may impact how the ROI is traced. For purposes of standardization, the Task Force recommends the following for tracing the LA: using the apical four-chamber, start the tracing at the endocardial border of the mitral annulus, and trace the LA endocardial border, extrapolating across the pulmonary veins, and/or LA appendage orifices, up to the opposite mitral annulus side. The apical two-chamber view can also be analysed to obtain a biplane calculation of the LA strain. Both apical views used should be optimized in terms of orientation, depth, and gain to avoid LA foreshortening and to visualize the entire LA throughout the cardiac cycle. Accordingly, dedicated four- and two-chamber views should be obtained to quantify LA strain.[12,13] The same views can be utilized for LA volume measurements.

If the tracking software requires the definition of an ROI, an adjustable ROI with a default width of 3 mm is recommended.[13,14] The ROI size and shape will be adjusted by the user in order to include the thickness of LA wall and to avoid including the pericardium. With software packages which use endocardial tracking only, the endocardial contour is delineated. As any tracking software requires a certain width of the wall to be tracked, such software tracks sub-endocardially. Given the thin walls of the LA, both approaches are likely to cover the same anatomical region. Consequently, a distinction between endocardial and mid-wall strain becomes meaningless for atrial analyses.

The LA delineation can be either user-defined or generated automatically. In the latter case, the user should be allowed to check it and, if needed, edit it manually. The use of a dedicated mode for atrial analysis is recommended.

Tracking results should be visually compared to the motion of the underlying atrial wall (particularly at the mitral ring and the atrial roof) in order to judge the accuracy of the atrial strain estimate. In case of large drop-outs in the visualization of the atrial wall (approximately one-third of the atrial contour) the analysis results should be rejected.

**Task force recommendations**

LA strain should be measured using a non-foreshortened apical four-chamber view of the left atrium. Analysis software should offer an adjustable, 3-mm full wall or an endocardial contouring tool. The LA is contoured extrapolating across the pulmonary veins and LA appendage orifice. Once the ROI has been defined, the user should be always offered a moving display on which he/she can visually check the quality of tracking by comparing the underlying image loop with the superimposed tracking results, along with the actual curves derived from that tracking. A dedicated mode for atrial analysis should be used if available.

## Which strain parameters to use

Almost all studies using LA strain have used global longitudinal strain, defined as strain in the direction tangential to the endocardial atrial border in an apical view. A sub-division of the LA wall into segments is not recommended since the LA myocardium is thin and the echocardiographic images can usually not resolve sufficient detail for reliable local tracking. Further, varying interpolation across pulmonary vein orifices and the LA appendage make the definition of segments difficult. This Task Force, therefore, recommends to interpret LA strain as global strain derived from the length change of the entire LA contour in the image plane. For the same reason, the assessment of radial or transverse strain is not recommended.

**Task force recommendations**

LA myocardial deformation is assessed as global longitudinal strain.

## Image views

The recent consensus statement from the ASE and EACVI on chamber quantification recommended that LA volume should be computed using a biplane algorithm, which includes the apical four-chamber and two-chamber views.[12] Most publications on LA strain have used the same two views. Despite the fact that LA muscle bundles or strands running from superior to inferior have been identified only in the posterior wall of the left atrium (as imaged in the apical long-axis or four-chamber view),[14,15] the apical long-axis view can be difficult for LA strain analysis because the ascending aorta is difficult to separate from the LA wall and it may confound accurate LA strain measurements.

The use of a single apical view to assess the LA longitudinal strain is acceptable. It is supported by the results of a recent meta-analysis including 30 studies (2038 healthy subjects) that provided the normal reference values for LA strain during reservoir, conduit, and contraction phase.[16] As such, and also to increase feasibility, the Task Force recommends using the LA strain values obtained from an optimized (i.e. non-foreshortened) apical four-chamber view of the LA (*Figure 1*). Computation of the biplane LA strain which includes data obtained from both apical four- and two-chamber views may be an option.

**Task force recommendations**

LA global longitudinal strain should be calculated as the longitudinal strain obtained from a non-foreshortened apical four-chamber view. Biplane LA longitudinal strain (taking into account measurements obtained from both four- and two-chamber apical views) should be available as an option.

## Definition of end-diastole and onset of atrial contraction

For the definition of end-diastole, this Task Force refers to the earlier consensus statement.[1] Commonly, the nadir of the LA strain curve will coincide with mitral valve closure.[17] Current strain software packages usually provide an ECG trigger as time reference, which is frequently situated at the upslope of the R-wave. This time reference is only a surrogate for end-diastole and may be misleading in certain pathologies, such as bundle branch block. A simple and feasible approach may be to define end-diastole according to the nadir of the LA strain curve. In case of any uncertainty, the mitral valve flow profile should be consulted for comparison (*Figure 1*).

The onset of atrial contraction can be visualized as onset of the A-wave in the mitral inflow profile (*Figure 1*). Also, here the ECG can only provide limited guidance as this occurs after the beginning of the P-wave. If a horizontal strain curve in diastasis turns sharply into a downslope after the beginning of the P-wave in the ECG, the strain curve itself may be the most feasible guide for finding the correct measurement position. The frequently observed dip after the sharp downslope in the conduit phase at the beginning of diastasis should be avoided. In any case of uncertainty, the mitral inflow profile should be consulted for comparison.

**Task force recommendations**

End-diastole and onset of atrial contraction should be defined according to the mitral valve inflow profile. The R- and P-waves in the ECG can only be used as rough estimates. In an LA strain curve with typical morphology, the curve itself may provide sufficient information for finding the correct measurement positions.

## Definitions of the LA cycle

LA deformation is a cyclic process, which can be sub-divided into three phases:

a. Reservoir phase: Starts at the end of ventricular diastole (mitral valve closure) and continues until mitral valve opening. It encompasses the time of left ventricular isovolumic contraction, ejection, and isovolumic relaxation.
b. Conduit phase: Occurs from the time of mitral valve opening through diastasis until the onset of LA contraction in patients in sinus rhythm. In patients with atrial fibrillation it continues until the end of ventricular diastole (mitral valve closure).
c. Contraction phase: Occurs from the onset of LA contraction until end of ventricular diastole (mitral valve closure) in patients with sinus rhythm.

In the LA strain curve, these phases can be characterized with three measurements (*Figure 1*, red dots) and the LA strain of each phase can be calculated as the difference of two of these measurements. As the atrial wall lengthens during the reservoir phase, the strain in this phase should be reported as a positive value. The shortening of the LA wall during the other two phases suggests that they should be characterized by negative values.

This consensus document of the Task Force uses the following nomenclature for deformation parameters of the LA, defining LAS as LA longitudinal strain to distinguish it from left ventricular strain.

i. LASr = strain during reservoir phase, measured as difference of the strain value at mitral valve opening minus ventricular end-diastole (positive value).
ii. LAScd = strain during conduit phase, measured as difference of the strain value at the onset of atrial contraction minus mitral valve opening (negative value). In patients with atrial fibrillation, LAScd has the same value as LASr, but with a negative sign.
iii. LASct = strain during contraction phase, measured only in patients in sinus rhythm as difference of the strain value at ventricular end-diastole minus onset of atrial contraction (negative value).

In similarity to the above definitions, the peaks in the LA strain rate curve are defined:

i. pLASRr = (positive) peak strain rate during reservoir phase
ii. pLASRcd = (negative) peak strain rate during conduit phase
iii. pLASRct = (negative) peak strain rate during contraction phase

All parameters are based on Lagrangian strain unless otherwise specified.

### Task force recommendations

LA global longitudinal strain is reported separately for the reservoir, conduit, and contraction phase. All values are calculated as difference of two measurement points on the strain curve.

## Reference frame of zero strain

The task force recognizes that there are two distinct options with respect to which reference frame should be set to zero strain and that choosing one or the other option may affect LAS measurements[18]:

i. Zero strain reference set at left ventricular end-diastole (*Figure 1*, left panel).
ii. Zero strain reference set at the onset of LA contraction (*Figure 1*, right panel).

For a given length change, the resulting percentage strain value is determined by the baseline length it relates to. Therefore, all LA strain values which refer to the LV end-diastole as baseline are larger, since the LA wall is shortest at this point in time. LA strain values which refer to the onset of atrial contraction as baseline are smaller, as the LA wall is then somewhat longer (*Figure 1*).

LA strain values obtained with either approach can be converted into the other, if the respective LA contraction strain is known. Accordingly, to convert LA strain values obtained with the atrial contraction (ac) as zero reference into strain values measured using end-diastole (ed) as zero reference, each strain component has to be divided by one plus the contraction strain:

$$edLAS_{XX} = \mathrm{acLAS}_{XX}/(1 + (\mathrm{acLAS}_{ct}/100))$$

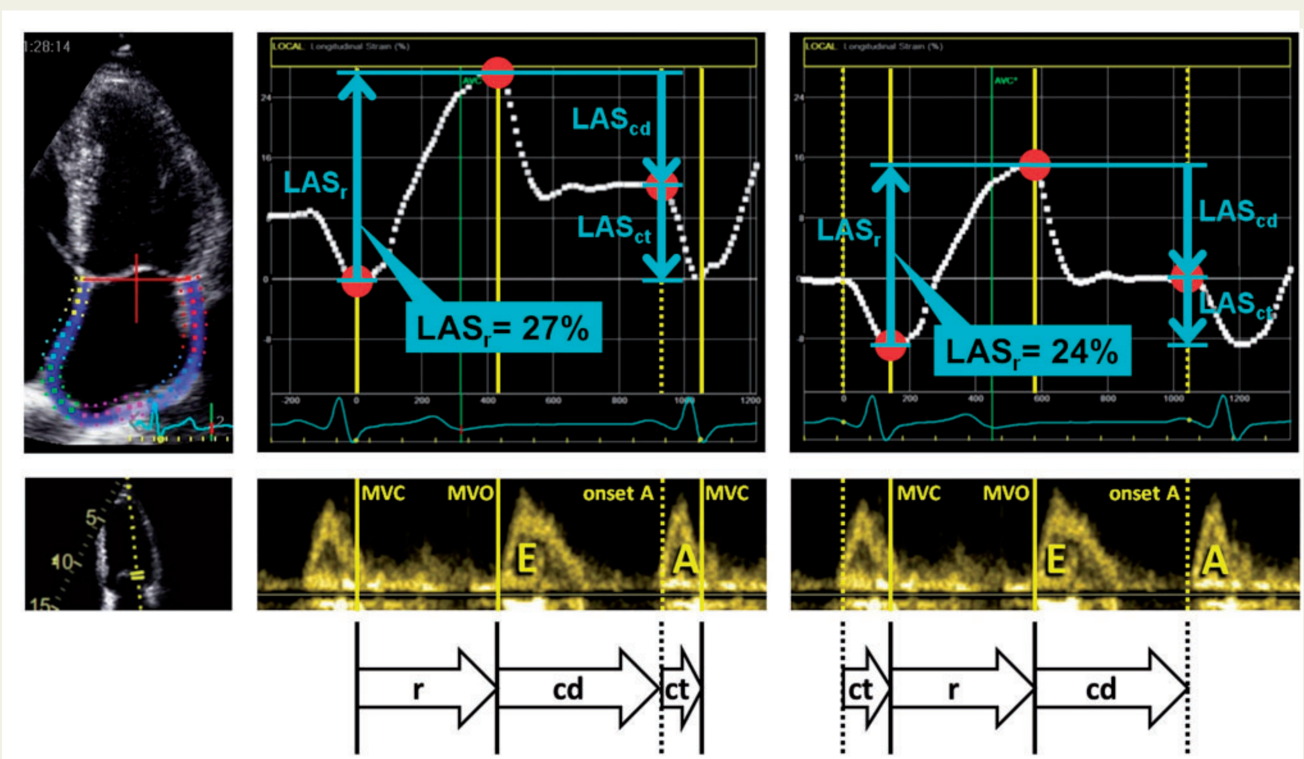


**Figure 1** Measurement of left atrial strain components. Left panel: with the zero strain reference at end-diastole (recommended), right panel: with zero strain reference at the onset of atrial contraction. In both cases, three measurement points (red dots) are needed to calculate the deformation during the three phases of the LA cycle: r, reservoir phase; cd, conduit phase; ct, contraction phase. The respective strains are LAS$_r$, calculated as difference between onset of filling and end-diastole; LAS$_{cd}$, calculated as difference between onset of atrial contraction and onset of filling; LAS$_{ct}$, calculated as difference between end-diastole and onset of atrial filling. Note that the entire strain curve changes its amplitude depending on the definition of the zero reference. MVO, mitral valve opening; MVC, mitral valve closure; E, A, E- and A-wave of the mitral inflow.

For the unlikely case that a conversion in the other direction is required, each strain component is divided by one minus the contraction strain:

$$acLAS_{XX} = edLAS_{XX}/(1\text{-}(edLAS_{ct}/100))$$

For both formulas: $edLAS_{XX}$, strain component with end-diastole as zero reference; $acLAS_{XX}$, same strain component with atrial contraction as zero reference; $acLAS_{ct}$, $edLAS_{ct}$, contraction strain with atrial contraction or end-diastole as zero reference, respectively. All values are entered in percentage.

The use of either end-diastole or onset of atrial contraction as zero reference point in previous studies has generated completely different normative values.[19–21] Advantages of using end-diastole (*Figure 1*, left panel) include the fact that measurements can be obtained in all patients (either in sinus rhythm or atrial fibrillation), and it facilitates the easy measurement of LA reservoir function which, with this zero reference, is equal to the positive peak systolic value of the LA strain curve. This is of clinical interest since LA reservoir function is the LA strain parameter, which has the largest body of evidence supporting its prognostic utility.[21,22] Using the onset of atrial contraction as reference (*Figure 1*, right panel) leads to a more physiological strain curve, with negative strain curves during LA contraction and allows, therefore, an easier measurement of the contractile phase, which has been reported to be more predictive of outcome in patients with new onset heart failure.[23–26] It must be considered, however, that the onset of atrial contraction cannot be used in patients with atrial fibrillation/flutter. Since there is no evidence demonstrating the superiority of one approach over the other, given the disadvantage of the lack of onset of atrial contraction in atrial fibrillation/flutter and given the common usage of the end-diastolic time reference for left ventricular strain measurements, for purposes of standardization, the Task Force recommends that the default baseline reference for LA strain curves should be end-diastole. Strain values obtained with a different time reference should be clearly marked as such and a conversion into end-diastole based values should be provided.

**Task force recommendations**

Ventricular end-diastole is recommended as the time reference to define the zero-baseline for LA strain curves. Strain values obtained with another baseline should be clearly marked as such and a conversion into end-diastole based values should be provided.

# Standardization of RV myocardial deformation imaging

## Determining the ROI/tracing the RV wall

Similar to the left ventricle,[1] the ROI of the RV is defined by the endocardial border, which is the inner contour of the myocardium, and the epicardial border, which is the outer contour of the myocardium (or in the case of the interventricular septum, the left ventricular endocardial contour of the septum). Each of these contours can be either manually traced by the user or generated automatically. If they are generated automatically, the user should be allowed to check and, eventually, manually edit them. Extreme care should be put in the definition of the ROI, since the inclusion of pericardium will result in underestimation of the measured strain. Endocardial strain measurements report the change in length of the endocardium during systole. Full wall myocardial strain refers to the average of measurements obtained over the whole myocardial thickness.

There are characteristics unique to the RV that may impact how the ROI is traced. For purposes of standardization, the Task Force recommends the following: use an RV-focused apical four-chamber view, which should be optimized in terms of orientation, depth, and gain to maximize the RV size and to visualize the RV apex throughout the cardiac cycle (*Figure 2*).[12] Select the frame in the cardiac cycle recommended by the software package vendor and start the tracing at the endocardial border at the lateral tricuspid annulus level, and trace the RV endocardial border to the medial tricuspid annulus level. Depending on the software used, the sole delineation of the RV free wall may be considered. For this, the delineation stops at the insertion of the RV free wall in the LV. It must be considered, however, that tracking is commonly more robust if the septum is included. Reliable measurements of RV strain require that all three segments of the RV free wall are adequately tracked.

Since the RV wall is thin, the Task Force recommends an adjustable ROI width with a default width of 5 mm.

**Task force recommendations**

A RV focused four-chamber apical view should be used. The analysis software should offer an adjustable ROI with a default width of 5 mm or an endocardial contouring tool. The ROI should include both the RV free wall and interventricular septum. Once the ROI has been delineated, the user should always be offered a moving display, where s/he is able to visually check tracking quality by comparing the underlying image loop with the superimposed tracking results, along with the actual curves derived from that tracking. Software packages should explicitly state the method (i.e. endocardial or full wall) used to measure the longitudinal strain. A dedicated mode for RV analysis should be used, if available.

## What strain parameters to use

Almost all studies using RV strain have used longitudinal strain, defined as strain in the direction tangential to the RV endocardial border in the apical view. As for the left ventricle, RV global longitudinal strain can be calculated using the entire ROI while computing the deformation, or by averaging values of equal segment lengths. Transverse strain (assessing the radial strain component) is not very accurate in the thin-walled RV, and as such, the Task Force does not recommend using this parameter to assess RV deformation at this time. However, since the RV adapts differently to different loading conditions, both radial and longitudinal displacement of the RV should be made available.

Although the RV wall is thin, differences between endocardial and mid-/full-wall strain measurements can be expected. Accordingly, it should be clearly stated in a report which strain parameter was obtained.

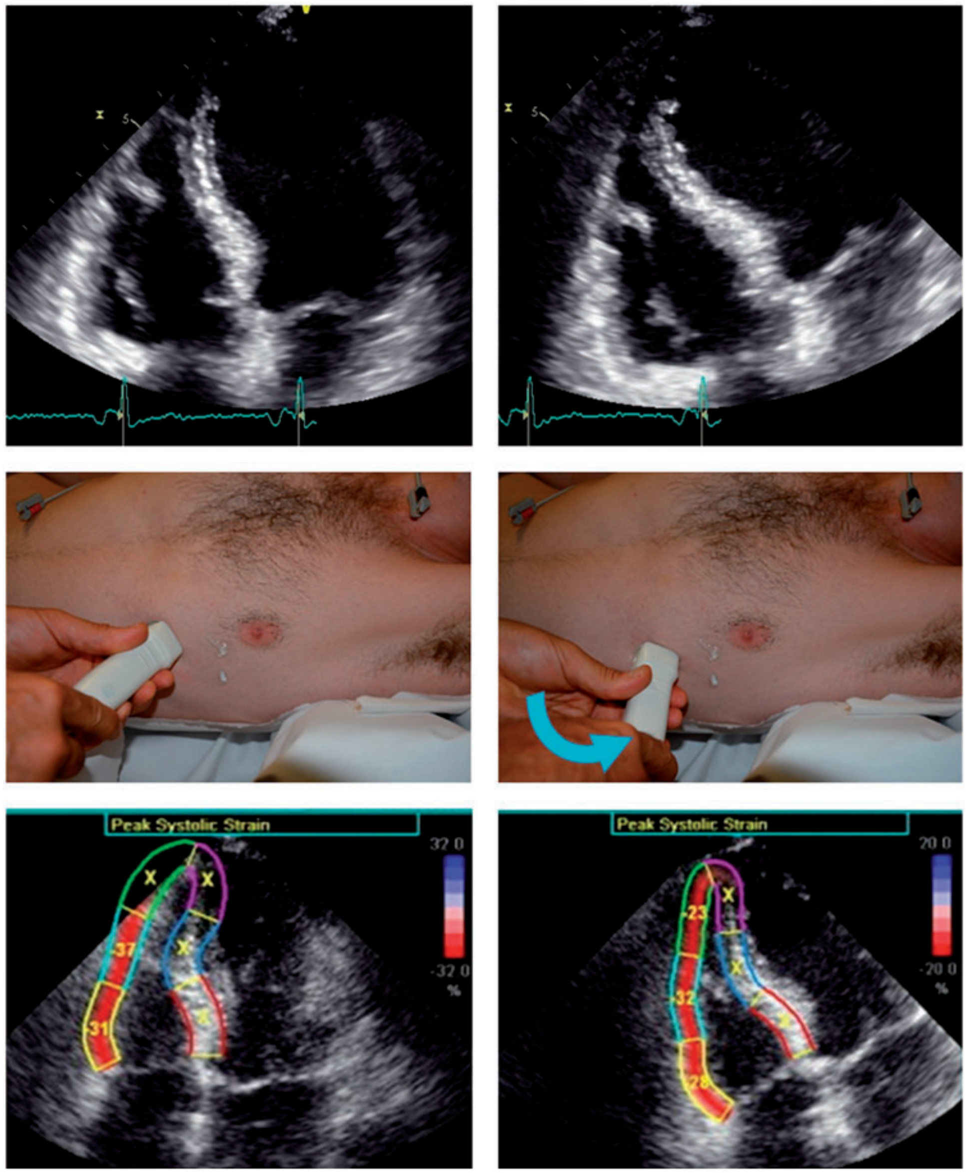


**Figure 2** Correct image orientation of the conventional (upper left panel) and right ventricular (upper right panel) apical four-chamber views. Probe positions to acquire the conventional apical four-chamber view (mid-left panel) and the right ventricular focused apical four-chamber view (mid-right panel). Differences in right ventricular free wall longitudinal strain between the conventional (lower left panel) and the right ventricular focused (lower right panel) four-chamber apical views. Note that, using the conventional four-chamber view, the right ventricular apex cannot be tracked (out of the scan sector), whereas it is easily tracked by using the right ventricular focused view.

**Task force recommendations**

RV myocardial deformation will be assessed as longitudinal strain as well as radial and longitudinal displacement. Within the report, a clear statement if strain was measured either using an endocardial or a mid-/full-wall approach should be annotated.

## Views and segmentation

Most published studies have used the conventional apical four-chamber view to measure RV myocardial deformation. However, the conventional apical four-chamber view (i.e., focused on the left ventricle) results in considerable variability in how the right heart is imaged and the view orientation may vary widely with relatively minor rotations in transducer position.[11,27] The RV-focused apical four-chamber view is obtained with a more lateral transducer position than the one used for conventional apical four-chamber view (*Figure 2*), keeping the left ventricular apex at the centre of the scanning sector, while displaying the largest basal RV diameter. This is the most reproducible apical view of the RV, allowing assessment of the RV insertion point by avoiding RV foreshortening.[27]

When computing RV global longitudinal strain, inclusion, or exclusion of the interventricular septum provides significantly different

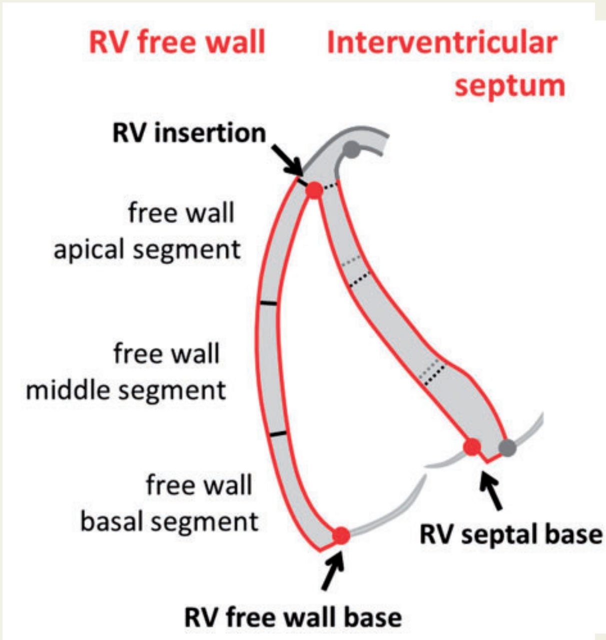


**Figure 3** Segmentation of the RV. The RV FW between the FW base and the insertion point of the FW into the LV is divided in a basal, mid, and apical segment which have equal length at end-diastole. The interventricular septum can be segmented likewise (black dashed lines). It has to be noted, however, that such septal segments are not compatible with the septal segments from a standard LV segmentation (grey dots and grey dashed lines) and results can therefore not be used interchangeably.

results as the interventricular septum has lower absolute strain values compared to RV free wall in normal hearts.[11] Although the ventricular septum contributes importantly to RV systolic performance, it is mainly a constituent part of the left ventricle, and the majority of studies showing the prognostic value of longitudinal strain measured RV free wall myocardial deformation only. Accordingly, it is the recommendation of the Task Force for purposes of standardization to report free wall RV longitudinal strain as a default parameter, but to allow the computation of four-chamber RV longitudinal strain (i.e. including the ventricular septum) as an option. The method used to calculate the RV longitudinal strain should be clearly identified in the result screen and mentioned in the report.

Regional myocardial dysfunction of the RV occurs not only in patients with ischaemic heart disease or arrhythmogenic cardiomyopathy, but also in patients with acute or chronic RV overload. Accordingly, assessment of regional longitudinal strain may have both diagnostic and prognostic value. To measure regional longitudinal strain, the myocardium of the RV free wall between the free wall base and the insertion point of the RV into the LV is divided in 3 segments of equal length at ventricular end-diastole which are named basal, mid, and apical (*Figure 3*). If tracking software provides segmental strain data for the interventricular septum, it must be considered that the septal segmentation derived from an RV and LV approach are not compatible and that therefore results cannot be used interchangeably (*Figure 3*).

#### Task force recommendations

RV longitudinal strain should be measured using the RV focused apical four-chamber view to improve reproducibility. By default, RV longitudinal strain should be reported as the RV free wall deformation, but an option is left to the user to also report the four-chamber RV longitudinal strain (i.e. including the ventricular septum into the computation). To obtain regional longitudinal strain the RV free wall is divided into three segments of equal end-diastolic length (i.e. basal, mid, and apical). Septal segmental strain should be measured as part of an LV assessment.

## Nomenclature

This consensus document of the Task Force uses the following nomenclature for the deformation parameters of the RV:

i. RVFWSL = right ventricular free-wall longitudinal strain
ii. RVFWSRL = right ventricular free-wall longitudinal strain rate
iii. RV4CSL = right ventricular four-chamber strain (including the ventricular septum)
iv. RV4CSRL = right ventricular four-chamber strain rate (including the ventricular septum)
v. Basal RVFWSL = longitudinal strain of the basal segment of RV free wall
vi. Mid RVFWSL = longitudinal strain of the mid segment of RV free wall
vii. Apical RVFWSL = longitudinal strain of the apical segment of RV free wall
viii. Basal RVFWDL = longitudinal displacement of the basal segment of RV free wall
ix. Mid RVFWDL = longitudinal displacement of the mid segment of RV free wall
x. Apical RVFWDL = longitudinal displacement of the apical segment of RV free wall
xi. Basal RVFWDR = radial displacement of the basal segment of RV free wall
xii. Mid RVFWDR = radial displacement of the mid segment of RV free wall
xiii. Apical RVFWDR = radial displacement of the apical segment of RV free wall

## Timing of measurement

Similar to what has been recommended for the left ventricle, clinically relevant strain values along the strain curves can be:

- End-systolic strain: the value at end-systole (the way end-systole is defined by the different software packages should be specified);
- Peak systolic strain: the peak value during systole;
- Positive peak systolic strain: a local myocardial stretching, sometimes occurring to a minor extent in early systole, or as a relevant deformation in regional dysfunction; and
- Peak strain: the peak value during the entire heart cycle. The peak strain may coincide with the systolic or end-systolic peak, or may appear after pulmonary valve closure. In the latter case, it should be described as 'post-systolic strain'.

At present, only the peak systolic values of RV myocardial deformation and displacement have been studied. Accordingly, the Task Force recommends to use only peak systolic values of RV myocardial deformation parameters. End-diastole should be defined by tricuspid valve closure and end-systole by pulmonary valve closure obtained from the respective Doppler tracings of the valves. For end-diastole, the ECG trigger at the R-wave may be used as surrogate, considering that it can be misleading in certain pathology (e.g. bundle branch blocks).

#### Task force recommendations

Peak systolic values of RV myocardial deformation parameters should be reported routinely, with other parameters specified explicitly. Doppler tracings of the tricuspid and pulmonary valves should be used to determine the timing of end-diastole and end-systole.

# Standardization of RA myocardial deformation imaging

## Determining the ROI/tracing the RA wall

For purposes of standardization, the Task Force recommends the following for tracing the right atrium (RA) ROI: using the RV-focused apical four-chamber view, start the tracing at the tricuspid valve annulus, along the endocardial border of the RA lateral wall, RA roof, RA septal wall, and ending at the opposite tricuspid annulus. The RV-focused apical four-chamber view should be optimized in terms of orientation, depth, and gain to maximize RA area, avoid RA foreshortening and to visualize the entire RA throughout the cardiac cycle. Therefore, a dedicated view should be obtained to quantify both RA volumes and strain.[9]

## Nomenclature

This consensus document of the Task Force uses a nomenclature for deformation parameters of the RA which is equivalent with that of the LA:

i. RASr = strain during reservoir phase
ii. RAScd = strain during conduit phase
iii. RASct = strain during contraction phase
iv. pRASRr = (positive) peak strain rate during reservoir phase
v. pRASRcd = (negative) peak strain rate during conduit phase
vi. pRASRct = (negative) peak strain rate during contraction phase

All parameters are based on Lagrangian strain and all using longitudinal deformation unless otherwise specified. All considerations made for the LA regarding the placement of the ROI, the strain

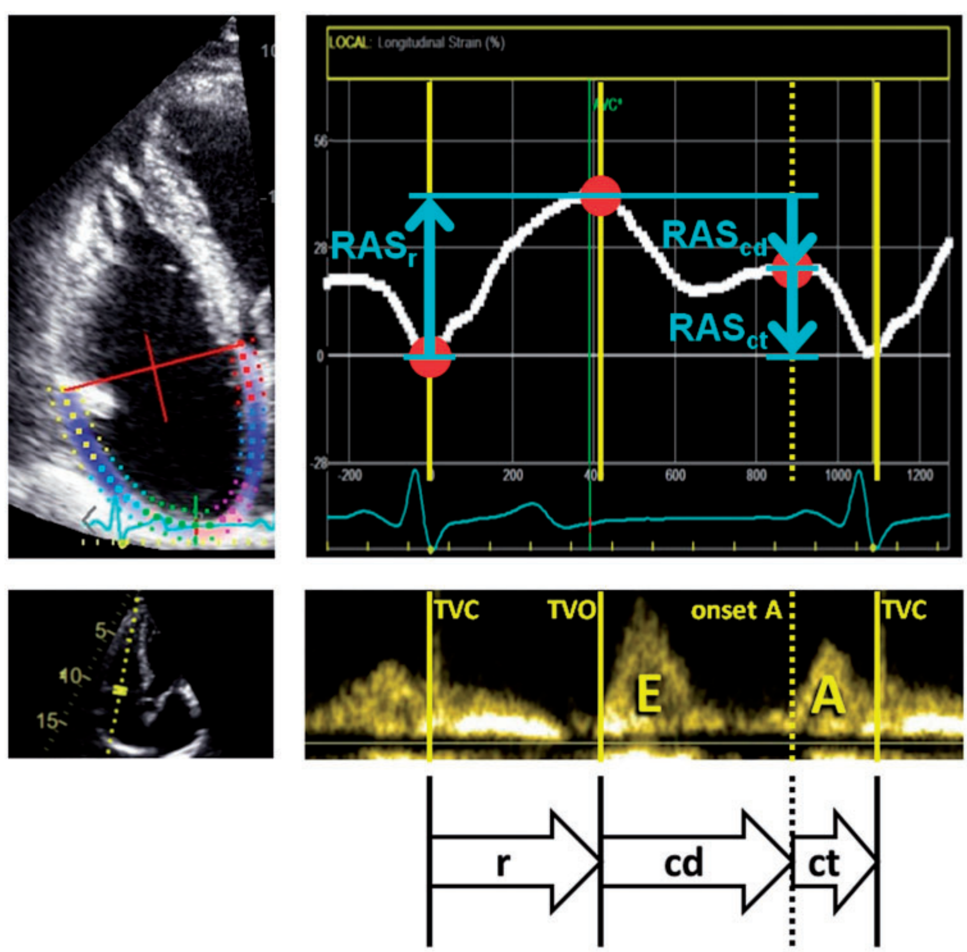


**Figure 4** Measurement of right atrial strain components. The explanations from Figure 1 apply respectively. TVO, tricuspid valve opening; TVC, tricuspid valve closure; E, A, E- and A-wave of the tricuspid valve inflow.

parameters to be measured, the timing definitions, and the algorithm to convert strain values measured with end-diastole as the zero-strain reference to strain apply respectively to the RA. See *Figure 4* for an example.

# Tracking—technical details

As described in the prior consensus document addressing left ventricular deformation,[1] the following recommendations are also applicable to the assessment of LA and RV deformation:

a. Reporting Lagrangian strain preferentially over Eulerian (natural) strain unless otherwise specified, and specifying which is reported.
b. If baseline drift correction is applied, it should be specified, and an option to turn it on or off should be provided.
c. Acquisition frame rates should be optimized for speckle tracking to provide the highest frame rate per cardiac cycle without significantly decreasing spatial resolution. This optimal frame rate range must be specified by the vendor.
d. Software packages should explicitly state what is being measured and the spatial extent (in pixels or millimeters) over which the data is sampled for a given ROI.
e. In patients with atrial fibrillation, measurements obtained from at least three consecutive cardiac cycles should be averaged.

# Unanswered questions

Traces of LA deformation obtained by speckle tracking are largely a mirror image of the deformation in the left ventricle, since the LA and the left ventricle share the mitral annulus. When the LA is filling, the left ventricle is emptying, and vice versa. Measurements of strain in the LA are largely explained by measurements in the left ventricle.[23,28] LA reservoir strain has been reported to correlate with left ventricular filling pressure,[29] and in smaller studies peak LA strain correlated with pulmonary capillary wedge pressure and with LV end-diastolic pressure.[30,31] Measuring LA strain during reservoir and conduit phases is probably useful in patients with heart failure when they are in atrial fibrillation. In subjects in sinus rhythm, it is likely that LA strain during booster pump function is more informative, since it correlates strongly and inversely with serum concentrations of brain natriuretic peptide.[25] We recommend that investigators, who are studying the diagnostic or prognostic value of LA strain measured by speckle tracking, assess if the measurements provide new information after taking into account variations in left ventricular function. LA function during atrial contraction deserves further study as a potential non-invasive indicator of left ventricular end-diastolic compliance.

The Task Force recommends that RV regional strain should be measured by segmenting the RV free wall visualized in the RV-focused apical four-chamber view in three equally-spaced segments. This recommendation mimicks the segmentation of left ventricular apical views despite the fact that the structure of the two ventricles is definitely different. From the anatomical point of view, the RV free wall in the RV-focused apical four-chamber view could be divided into components from the RV smooth inlet and trabeculated body which can respond differently to loading. It is likely that a two-segment model could be more appropriate, functionally. However, all the studies about normal values[11] and those reporting the clinical value of RV longitudinal strain in different cardiac conditions[4,5,32,33] have applied the three-segment model. Moreover, there is no anatomical landmark to allow a clear separation between the two parts of the RV. All these considerations have motivated the Task Force to maintain the three-segment model, but further research is needed to find the most appropriate segmentation model to study the RV.

# Conclusions

The present document has been developed by the EACVI/ASE/Industry Task Force to Standardize Deformation Imaging to provide standardization of LA, RV, and RA deformation imaging using 2D STE for both the technical engineering community and the clinical community at large. This document represents a significant step forward in the collaboration between the scientific societies and the industry since technical specifications of the software packages designed to post-process echocardiographic data sets have been agreed and shared before their actual development. Hopefully, this lead to more clinically oriented software packages which are better tailored to clinical needs and will allow industry to save time and resources in their development.

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