Left ventricular twist: comparison between two- and three-dimensional speckle-tracking echocardiography in healthy volunteers

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Aims

Left ventricular (LV) twist is the result of clockwise rotation of the base and counterclockwise rotation of the apex. The aims of this study were to investigate the feasibility of the three-dimensional speckle-tracking echocardiography (3DSTE) to assess LV twist values and compare the data measured by two-dimensional speckle-tracking echocardiography (2DSTE) in a group of healthy volunteers.

Methods and results

Fifty individuals were enrolled in the protocol. LV twist was defined as net difference between averaged 2DSTE apical (4 segments) and basal (6 segments) rotations. 3DSTE twist was obtained from the LV volumetric image and shown as the averaged global value of 16 segments. Time-to-peak by both techniques was also measured and compared. Significant differences between the two techniques were calculated using the paired Student t-test. P-values of <0.05 were considered significant. Reliable LV twist measurement was possible in 39 of 50 individuals (78%). 2DSTE twist mean peak value was $13.8 \pm 7.9$ with a mean time-to-peak of $388.3 \pm 152.3$ ms and global 3DSTE twist mean peak value was $10.2 \pm 7.6$ with a mean time-to-peak of $371.8 \pm 127.5$ ms. Peak LV twist values by 3DSTE was significantly smaller than by 2DSTE ($P < 0.01$) whereas time-to-peak results showed no significant difference.

Conclusion

3DSTE is feasible to assess LV twist deformation. Whereas further investigations using 3DSTE are needed to validate this promising technology, comparing 2DSTE and 3DSTE should be done with caution, as values for peak LV twist differ.

Keywords

Echocardiography • Speckle tracking • Rotation • Twist

Introduction

Left ventricular (LV) twist deformation is due to the complex helical myocardial fibre architecture. This wringing motion of the heart is the result of the clockwise rotation of the base and the counterclockwise rotation of the apex and plays an important role in ventricular performance. Several invasive and non-invasive techniques have been used to describe and quantify this cardiac motion. Recently developed, two-dimensional speckle-tracking echocardiography (2DSTE) has proved to be a simple non-invasive technique to quantify the LV twist mechanism. A novel technique based on three-dimensional speckle-tracking echocardiography (3DSTE) has been developed to reduce some of the shortcomings of 2DSTE. The aims of this study were to investigate the feasibility of 3DSTE to assess LV twist values and compare the data measured by 2DSTE in a group of healthy volunteers.

Methods

Study population

This prospective study was approved by the Ethics Committee of the Teaching and Research Institute of the Hospital Sírio-Libanês (São Paulo, Brazil). Written informed consent was obtained from all participants before enrolment. Fifty subjects (24 female, aged $32 \pm 9$ years)
were enrolled in the protocol. All subjects had normal physical examination, electrocardiogram, and conventional thoracic echocardiogram.

**Echocardiographic protocol**

The echocardiographic studies were performed using commercially available equipment (Artida™; Toshiba Medical Systems, Tokyo, Japan). Images were digitally stored with a continuous single lead electrocardiogram. Two-dimensional echocardiography was performed using a 1–5 MHz phased-array transducer. After a comprehensive study including ejection fraction analysis by Simpson’s rule, additional images were obtained to track the movement of stable acoustic markers, recognized as echocardiographic speckles. From the parasternal short-axis views of the base and apex of the left ventricle, at a frame rate of 50 ± 2 frames/s, three points of the endocardium (at 4, 8, and 12 o’clock positions) were marked manually. The software automatically tracks the endocardial and epicardial contours on the subsequent frames regarding the whole myocardial regions of interest, providing information shown in colour overlays superimposed on grey-scale images in basal and apical short axes and also generates curves for quantification of the 2DSTE rotational movement (Figure 1). 2DSTE mean peak values of LV twist were estimated as the net difference between average peak degree of rotation at the six basal segments and at the four apical segments. Three-dimensional echocardiography was then performed using a 1–4 MHz matrix phased-array transducer. After an apical acquisition of the heart, by triggered volume mode, at a volume rate of 20 ± 1 volumes/s, the entire LV volumetric image was obtained. From the apical four- and the orthogonal two-chambers, three points of the endocardium (two at the edges of the mitral valve and one at the apex) were marked manually. The software automatically tracks the endocardial and epicardial contours in the subsequent volumes in three different orthogonal planes, performed on the whole LV myocardium, providing information shown in colour overlays superimposed on grey-scale images in three short-axis slices from apex to base and apical four-chamber and two-chamber and also generate the curves for quantification of the 3DSTE peak values of global LV twist (Figure 2). For both methods, the studied myocardial segments were considered acceptable for analysis when presenting uniform patterns of colour overlays superimposed on grey-scale images and uniform patterns of curves allowing reading twist movements. Exclusion of the study was done based on visual assessment, when abnormal curves were believed to be artefactual. Time-to-peak LV twist was defined as the time to reach peak values measured from the QRS onset. The average time-to-peak basal and apical rotations by 2DT and the average global time-to-peak LV twist by 3DT were measured.

**Statistical analysis**

Quantitative variables are expressed as mean ± SD. Peak LV twist values acquired by both 2DSTE and 3DSTE techniques were compared by the Student’s t-test. To assess inter-observer variability, 10 echocardiographic studies were randomly selected from the examinations performed. The 2DSTE and 3DSTE twist values were analysed by two different observers, blinded to the results of the previous measurements, and compared by an intra-class correlation coefficient. Significance was defined as \( P < 0.05 \).

**Results**

Values of LV ejection fraction by conventional thoracic echocardiography varied from 0.60 to 0.72 (mean 0.66 ± 3.6).

**Feasibility of three-dimensional speckle-tracking echocardiography**

From the 50 individuals studied, reliable data with allowing reading twist movements by 3DSTE were possible in 39 cases (78%).

**Comparison between left ventricular peak twist obtained by two-dimensional speckle-tracking echocardiography and three-dimensional speckle-tracking echocardiography**

2DSTE peak twist mean value was 13.4 ± 8.2°. 3DSTE global peak twist mean value was 10.2 ± 7.6°. LV twist by 3DSTE was significantly smaller than by 2DSTE (\( P < 0.05 \); Table 1).

**Figure 1** Rotation values detected by two-dimensional speckle-tracking echocardiography from basal (left) and apical (right) segments of the left ventricle and also shown in colour overlays superimposed on the grey-scale images. Left ventricular twist was defined as the net difference between average apical and basal rotations values.
Comparison between LV time-to-peak twist obtained by 2DSTE and 3DSTE. 2DSTE showed average time-to-peak LV twist values of $388.3 \pm 152.3$ ms. 3DSTE showed global time-to-peak LV twist values of $371.8 \pm 127.5$ ms. Time-to-peak twist by 3DSTE was similar to the values observed by 2DSTE ($P=NS$; Table 1).

### Table 1  Left ventricular mean values of peak basal and apical rotations, peak twist and time-to-peak by two-dimensional speckle-tracking echocardiography, mean values of peak twist and time-to-peak by three-dimensional speckle-tracking echocardiography

<table>
<thead>
<tr>
<th></th>
<th>2DSTE</th>
<th>3DSTE</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak basal rotation</td>
<td>$\pm 5.4$</td>
<td>$\pm 3.5$</td>
<td></td>
</tr>
<tr>
<td>Peak apical rotation</td>
<td>$\pm 8.2$</td>
<td>$\pm 7.6$</td>
<td>$&lt;0.05$</td>
</tr>
<tr>
<td>Peak LV twist</td>
<td>$13.4 \pm 1.2$</td>
<td>$10.2 \pm 7.6$</td>
<td></td>
</tr>
<tr>
<td>Time-to-peak (ms)</td>
<td>$388.3 \pm 152.3$</td>
<td>$371.8 \pm 127.5$</td>
<td>NS</td>
</tr>
</tbody>
</table>

2DSTE, two-dimensional speckle-tracking echocardiography; 3DSTE, three-dimensional speckle-tracking echocardiography; $^\circ$, degree; ms, millisecond.

### Interobserver variability

Measurements of LV twist by 2DSTE and 3DSTE by two independent observers showed an intra-class correlation of $0.95$, 95% CI $(0.77 \text{ a } 0.99)$ and $0.94$, 95% CI $(0.41 \text{ a } 0.99)$, respectively.

### Discussion

LV twist is regarded as one of the most complex and important ventricular movement as it is related to both systolic and diastolic mechanisms. The twist deformation of the left ventricle is the result of the movement of two orthogonally oriented muscular bands of a helical myocardial structure with consequent clockwise rotation of the base and counterclockwise rotation of the apex. Only more recently has it become possible to demonstrate this deformation in the clinical setting using tagged magnetic resonance imaging.

Echocardiographic speckle tracking is a technique based on a frame-by-frame tracking of speckle patterns created by interference of the ultrasound beam within the myocardial tissue. 2DSTE is based on B-mode imaging and is therefore not dependent on the angle and translation of the ventricle and shows good temporal resolution. 2DSTE has been well validated in studies of cardiac twist by sonomicrometry and tagged magnetic resonance imaging.
resonance imaging. 11,15–19 3DSTE has already been validated for LV rotation 20 as well as for longitudinal, radial, and circumferential strain 3,21 but not for twist movement. The study described herein is a pilot and to our best knowledge is the first to compare LV twist deformation measured by 2DSTE and 3DSTE in a group of healthy young adults. Our results showed good feasibility by the 3DSTE technique (78%). From the 11 failed cases, 8 were due to speckle-tracking limitations and 3 were due to poor cardiac image definition. Previous published papers dealing with speckle-tracking techniques have shown feasibility varying from 35 to 93%. 3,19,22 The inter-observer variability was very poor cardiac image definition. Previous published papers dealing with speckle-tracking limitations and 3 were due to good feasibility by the 3DSTE technique (78%). From the 11 failed cases, 8 were due to speckle-tracking limitations and 3 were due to different from previous publications, the inter-observer variability was slightly lower and less spread among patients for the 2DSTE compared with the 3DSTE measurements. Our findings, however, are corroborated by others. The values of peak LV twist we found using 2DSTE are in agreement with previous study. 19 We observed peak LV twist values by 3DSTE significantly smaller than by 2DSTE.

Although, at this point 3DSTE produces less than ideal quality of images, it has the advantage of measuring three-dimensional wall motion through a greater number of myocardial segments. Therefore, it would be expected that the total twist displacement measured by 3DSTE may significantly differ from 2DSTE. Previous publication has postulated that the relatively low level of inter-technique agreement between the two techniques is because 3DSTE is not limited to one imaging plane and, as a result, can better describe the complex three-dimensional motion of the ventricular wall.

Limitations
Current image quality obtained by 3DSTE technology is <2DSTE. The low volume rate is a significant limitation of the 3DSTE as this technique may be affected by relatively low temporal and spatial image resolutions. These considerable differences in frame rate and volume rate might have affected the results when comparing both techniques. However, there was no significant difference in time-to-peak strain between the two techniques, suggesting that the difference in frame rate is not a main cause of the observed discordance between 3DSTE and 2DSTE. Because LV twist has not yet been validated, we still does not have an independent reference technique.

Conclusions
This novel method, based on 3DSTE technique, is feasible to assess LV twist deformation, potentially bringing new insights into this complex ventricular motion. Whereas further investigations applying 3DSTE are needed to validate this promising technology, caution should be taken when comparing 2DSTE and 3DSTE values of LV twist.

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Conflict of interest: none declared.

References