Two-dimensional strain and atrial function: a study on patients after percutaneous closure of atrial septal defect

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Received 7 May 2008; accepted after revision 27 July 2008; online publish-ahead-of-print 26 August 2008

Aims
To assess the value of two-dimensional (2D) strain in assessing regional myocardial function along the atrial wall.

Methods and results
We studied 20 patients late after successful percutaneous atrial septal defect (ASD) closure. The analysis was performed for atrial longitudinal peak systolic strain on the interatrial septum, in correspondence of the device, and on the lateral wall of the left atrium. The speckle tracking indexes demonstrated almost the absence of any deformation on the Amplatzer ASD occluder, a bulky non-contractile element, passively moved by global heart motion. This study in a simple clinical model demonstrates that 2D strain is not influenced by global heart motion and tethering from adjacent segments and can also be used to study the regional atrial function. Moreover, both acquisition and post-processing times of 2D strain were very short, and the reproducibility was very good.

Conclusion
All these above-mentioned characteristics make the 2D strain a tool fully compatible with the clinical scanning, able to provide additional clinical information.

KEYWORDS
Two-dimensional strain; Strain rate; Atrial septal defect

Introduction
Although encouraging data have been obtained from the analysis of myocardial deformation properties of the atria using the tissue Doppler-based approach,¹ the analysis has major drawbacks: angle dependence, reproducibility, and a time-consuming acquisition and post-processing.²,³

Recently, a novel method for motion estimation based on two-dimensional tissue tracking strain (2D-S) echocardiography using time-domain processing has been developed, providing rapid assessment of regional myocardial strain (S) that is independent of both cardiac translation and angle dependency, with a very good reproducibility, unlike Doppler-based strain imaging.⁴,⁵

However, so far no study has been done to assess the ability of 2D-S in evaluating the regional function in the atrium. Thus, we studied atrial function in patients late after successful percutaneous atrial septal defect (ASD) closure, to assess the ability of 2D-S in discriminating the normal atrial deformation from the passive movement of an interatrial device.

Study population
We studied 20 consecutive patients (age 7 ± 2 years) > 1 year after successful percutaneous ASD closure using the Amplatzer ASD occluder (AGA Medical Corporation, Golden Valley, MN, USA).

All the studied patients were in sinus rhythm, and no one showed mitral annulus calcifications at the standard echocardiographic evaluation.

The studied subjects underwent a 2D-S evaluation of the left atrium.

2D-S study
Two-dimensional strain study uses gray scale (B-Mode) sector image and is based on frame-by-frame tracking of small rectangular image blocks with stable speckle pattern.⁴,⁵ A minimum frame rate of 40 Hz was required for reliable
operation of this programme and frame rates of 40–90 Hz were used for routine gray-scale imaging. Apical four-chamber view was obtained using the same ultrasound system and probe used for standard echocardiography; end-systole was chosen as the single frame for the endocardial to epicardial region of interest to include maximal wall thickness for strain calculation. The ‘Zoom/RES’ feature on the echocardiographic machine was used to improve the accuracy of atrial measurements. A circular region of interest was traced on the endocardial cavity interface of the apical four-chamber view at LA systole (minimum cavity area) by a point-and-click approach. Then, a second larger concentric circle was automatically generated near the epicardium with a default width of 15 mm. The region of interest then included the entire LA myocardial wall, and a click feature increased or decreased the width of the two circles for thicker or thinner walls, respectively. The tracking algorithm followed the endocardium from this one frame throughout the cardiac cycle. The image processing algorithm automatically subdivided the region of interest into blocks of ~20–40 pixels containing stable patterns of speckles.

Subsequent frames were then analysed automatically by searching for the new location of each of the blocks with correlation criteria and the sum of the absolute differences. The location shift of these acoustic markers from frame to frame, which represents tissue movement, provides the spatial and temporal data used to calculate velocity vectors. Temporal alterations in this stable speckle patterns are identified as moving further apart or closer together, and a series of regional strain vectors are calculated as changes in length/initial length. Accordingly, for atrial longitudinal strain myocardial shortening was represented with a negative value, colour-coded as red; myocardial lengthening was represented with a positive value, colour-coded as blue; and then these were superimposed to conventional 2D images. The tracking processing and conversion to Lagrangian strains were performed offline in a dedicated software (EchoPAC PC 2D strain—BT 0.5.2—GE Healthcare).

The software then automatically divided the image into six standard segments and provided an automated tracking score, similar to statistical standard deviation, as feedback of the stability of the regional speckle tracking, ranging from 1.0 to 3.0 in arbitrary units. A tracking score value of

<table>
<thead>
<tr>
<th>Table 1. General characteristics of the studied population</th>
<th>Patients (n = 20)</th>
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<tbody>
<tr>
<td>Age (years)</td>
<td>7 ± 2</td>
</tr>
<tr>
<td>Sex</td>
<td>4M/6F</td>
</tr>
<tr>
<td>Heart rate (bpm)</td>
<td>83 ± 9</td>
</tr>
<tr>
<td>BSA (m²)</td>
<td>0.9 ± 0.1</td>
</tr>
<tr>
<td>NYHA class (%)</td>
<td>1 (100%)</td>
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NYHA, New York Heart Association.

Figure 1 Comparison of myocardial maximal 2D strain assessed on the interatrial device (yellow) and on the lateral left atrial wall (blue). The maximal deformation (Strain) of the normal lateral atrial wall was 76% while on the device the deformation was almost zero. AVO, aortic valve opening; AVC, aortic valve closure.
1.5 was determined as acceptable as previously described. The analysis was performed from the four-chamber apical view for the mid-segments of LA septum and LA lateral wall. Continuous care was taken to keep the sample volume out of the pulmonary veins and of oval fossa. For each atrial wall, we measured the strain maximal positive value.

Statistics
For continuous variables, the unpaired Student’s t-test was performed. The relationship between continuous variables was studied by linear regression analysis.
Values are presented as mean ± 1 SD. A P-value of <0.05 was considered statistically significant.

Results
General characteristics of our studied sample are presented in Table 1.

Two-dimensional strain evaluation of the left atrium was feasible in all the studied subjects (in all cases, the tracking score was ≤1.5).

The acquisition time was few seconds and the post-processing time was 1–3 min.
The inter- and intra-observer variability was very good, 5 and 3%, respectively.

Using 2D-S, almost no deformation was detectable on the interatrial device (S = 2 ± 3%), significantly discriminating the normal lateral wall (S = 68 ± 6%, P < 0.0001) (Figure 1).

There was a significant correlation between peak atrial strain of the lateral left atrial wall and left atrial volume (P = 0.0008; R = 0.47).

To avoid any influence related to the 2D gain setting in the evaluation of atrial myocardial deformation properties, we repeated the analysis on the same clips with high and low gain levels, and the results were identical (Figure 2).
Discussion
Two-dimensional strain has been developed to overcome the limitations of tissue Doppler-derived strain. So far no study has been performed to assess its ability in evaluating atrial regional function.

This study, in a simple clinical model, clearly demonstrated that 2D strain can assess regional atrial function. Indeed, analysing the Amplatz ASD occluder, a bulky non-contractile element, passively moved by global heart motion, 2D strain demonstrated almost the absence of any deformation. Conversely, on the normal lateral atrial wall a significant higher deformation was detectable.

This study demonstrates that 2D strain is not influenced by global heart motion and tethering from adjacent segments, and can also be used to study the regional atrial function. Moreover, both acquisition and post-processing times were very short, and the reproducibility was very good. All these characteristics make the 2D strain a tool fully compatible with the clinical scanning, able to provide additional clinical information.

Conclusions
This study demonstrated for the first time in a simply clinical model the ability of 2D strain in assessing regional atrial function.

References