Two-dimensional strain to assess regional left and right ventricular longitudinal function in 100 normal foetuses

Giovanni Di Salvo1*, Maria Giovanna Russo1, Dario Paladini2, Maria Felicetti3, Biagio Castaldi1, Antonio Tartaglione1, Laura di Pietto1, Concetta Ricci1, Carmela Morelli1, Giuseppe Pacileo1, and Raffaele Calabro`1

1Pediatric Cardiology Department, Second University of Naples, INBB Research Unit, Via Omodeo 45, Naples 80128, Italy; 2Prenatal Diagnosis Unit, Department of Gynecology and Obstetrics, University Federico II of Naples, Naples, Italy; and 3Department of Gynecology and Obstetrics, Second University of Naples, Naples, Italy

Received 6 January 2008; accepted after revision 2 March 2008; online publish-ahead-of-print 28 April 2008

Aims Previous reports have demonstrated that myocardial velocities are not sufficiently sensitive in foetal heart studies. Strain (S) imaging is a new non-invasive ultrasonic technique able to quantify regional myocardial deformation properties. Strain imaging has a superior sensitivity than myocardial velocity for non-invasive assessment of ventricular function. However, Doppler-derived strain imaging has been used to quantify myocardial deformation properties in the foetal heart with rather limited results, because of angle dependency, sensitivity to extracardial movement, the need for good-quality images, long and time-consuming post-processing and the low reproducibility of Doppler-derived strain.

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

However, no information on 2D-S in human foetuses has so far been provided.

Methods We studied 100 consecutive normal foetuses (gestation range: 20–32 weeks; no evidence of structural cardiovascular disease by 2D echo and Doppler study) using 2D-S imaging. Left ventricle (LV) and right ventricle (RV) peak myocardial negative strain values were obtained.

Results Strain data were obtained from all the studied subjects, the duration of post processing was 3 ± 2 min for each patient dataset. Peak longitudinal deformation parameters were homogeneous in all the three studied walls (strain: septum = −25 ± 5%; lateral wall = −25 ± 4%; RV free wall = −24 ± 4%; P = NS). There were significant correlations between gestational age and peak longitudinal strain (P < 0.001; R: −0.73). Inter and intra-observer variability for strain was good, <3 and <6%, respectively.

Conclusion This study demonstrated that 2D-S is a feasible and reproducible approach to assess regional ventricular function in the foetal heart, ready for the clinical application.

KEYWORDS
Strain rate imaging; Foetal heart; Echocardiography

Introduction
Quantitative assessment of foetal cardiac function has mainly been based on echocardiographic measures obtained by M-mode recordings of ventricular cavity size, cross-sectional calculation of cardiac volumes, and Doppler-derived indices of foetal haemodynamics. However, all these measurements are indirect markers of myocardial function.1

The use of colour Doppler myocardial imaging (CDMI) in assessing foetal heart function is still minimal,1 and some reports have demonstrated that myocardial velocities obtained from CDMI are not sufficiently sensitive in the foetal heart to evaluate regional myocardial function.2

Strain (S) imaging has a superior sensitivity over that of myocardial velocity for non-invasive assessment of ventricular function.3,4 However, Doppler-derived strain (S) imaging has been used to quantify myocardial deformation properties in the foetal heart with rather limited results, because of angle dependency, sensitivity to

* Corresponding author. Tel: +39 081 193 638 51; fax: +39 081 560 56 48. E-mail address: giodisal@yahoo.it

Published on behalf of the European Society of Cardiology. All rights reserved. © The Author 2008.
For permissions please email: journals.permissions@oxfordjournals.org.
extracardiac movements, the need for good-quality images, long and time-consuming post-processing, and the low reproducibility.\(^5\)

Recently, a novel method for motion estimation based on two-dimensional (2D) tissue tracking strain (2D-S) echocardiography using time-domain processing has been developed, providing rapid assessment of regional myocardial strain that is independent of both cardiac translation and angle dependency, with a very good reproducibility, unlike Doppler-based strain imaging.\(^6,7\)

However, no published studies on 2D-S in human foetuses have so far been provided.

**Methods**

One hundred consecutive foetuses with a gestational age ranging 20–32 weeks underwent a 2D echocardiography study.

The institutional committee on human research approved the study protocol and informed consent was obtained from each mother. All foetuses had normal morphological heart findings and were in normal sinus rhythm. Gestational age was calculated using biparietal diameter, head circumference, abdominal circumference, and/or femur length. The mothers were referred to our centre to perform foetal echocardiography because of family history of congenital heart disease.

The images were processed directly on the echocardiography with a commercially available software (AFI software, General Electric, Waukesha, WI, USA). The endocardial border of septal, lateral left ventricle (LV) walls, and right ventricle (RV) free wall was traced in an end-systolic frame. The outer border was adjusted to approximate the epicardial border. The software automatically selected six equidistant tissue-tracking regions of interest in the myocardium. Visual control of tracking quality was performed and optimized, if required, by adjusting the region of interest or manually correcting the contour to ensure adequate automatic tracking. The software automatically selected suitable stable acoustic objects for tracking, searched for them in the next frame using absolute differences algorithm, and provided a tracking score to measure the degree of decorrelation of the block-matching \(1 \text{ (excellent)} - 3 \text{ (poor)}\). An assumption was made that the natural acoustic markers change position from frame to frame in conjunction with motion of surrounding tissue.\(^6,7\)

The computer then provided a profile of longitudinal strain (%) with time.

Two-dimensional longitudinal strains were assessed in standard 4 chamber view using a dedicated software (AFI), from the basal, mid, and apical segments of the RV free wall, the interventricular septum, and the LV lateral wall.

All data were acquired at a frame rate from 40 to 90 frames/s (GE Vivid Seven, Horten, Norway; 3.5 MHz). The mean acquisition time was 15–20 s.

Peak negative strain values obtained from three consecutive cardiac cycles (to be used for subsequent analysis) were recorded.

**Inter- and intra-observer variabilities**

Interobserver variability, expressed as coefficient of variation, was assessed by analysing 20 longitudinal regions in different randomly chosen subjects, by two independent investigators. For intra-observer variability, 10 longitudinal regions were analysed by one investigator two times within an interval of 4 weeks. The second round of intra-observer measures was blinded to results from initial measures.

**Statistics**

All the analyses were performed using a commercially available package (SPSS, Rel 11.0 2002. Chicago: SPSS inc.).

The data distribution was normal as assessed by Kolmogorov–Smirnov’s test.

Quantitative values are presented as mean ± 1 SD. Differences in the mean values between the left and right ventricles and interventricular septum were analysed by analysis of variance and Scheffe’s test. The relations of myocardial strain and SR studied parameters with age were assessed by linear regression analysis. The null hypothesis was rejected for a \(P\)-value < 0.05.

**Results**

All the foetuses were successfully studied by 2D-S.

All segments were evaluable and had a tracking score of 1 except for 10 segments with scores of 1.4.

Good quality strain curves were obtained from all the studied subjects (Figure 1); the duration of post processing was 3 ± 2 min for each patient dataset.

Peak negative strain values are listed in Table 1. Peak negative systolic deformation parameters were homogeneous in all the three studied walls (strain: septum = 18 ± 6%; lateral wall = 17 ± 7%; RV free wall = 19 ± 8%; \(P = \text{NS}\)).

There were significant correlations between gestational age and peak negative strain (Figure 2). Inter and intra-observer variability for strain was good, < 3% and < 6%, respectively.

**Discussion**

This is the first attempt to use 2D strain imaging to assess myocardial function of LV and RV in a large sample of normal foetuses.

This study demonstrated that 2D strain imaging is feasible in all the studied normal foetuses. This is in contrast to our previous experience using Doppler-derived myocardial strain that was feasible in some normal foetal heart (62%).\(^5\) Moreover, using Doppler-derived strain, we were able to assess only one segment for each studied wall.\(^5\) Moreover, Doppler strain required a continuous and time-consuming post-processing (≥ 30 min for single patient) always to keep the sample volume inside a very thin myocardial wall.\(^3\) This manual and tedious post-processing may be the cause for the higher variability recorded using the Doppler derived strain (up to 17%). Conversely, 2D-S is based on an automatic tracking system significantly reducing the post-processing time and greatly improving the reproducibility.\(^5,7\)

Comparing Doppler-derived strain values with those obtained using 2D-S, the latter have higher values. In our view, this discrepancy could be due to the angle dependency of the Doppler-derived strain (angle < 30° was tolerated in our previous study\(^9\)) and this may have significantly influenced the results. Indeed, it has been demonstrated that in the presence of 45° between the normal myocardium and the ultrasound beam, the strain despite the normal contractility is zero.\(^8\)

In agreement with previous reports,\(^9,10\) peak negative 2D-S values increase with the gestational age, showing a significant linear correlation (Figure 2).

**Conclusions**

This study demonstrated that 2D-S is a feasible and reproducible approach to assess both left and right regional ventricular function in the foetal heart ready for the clinical application.
Conflict of interest: none declared.

References


Table 1  Peak systolic values of 2D-S obtained in 100 normal foetuses

<table>
<thead>
<tr>
<th></th>
<th>Lateral wall (%)</th>
<th>Septal wall (%)</th>
<th>RV free wall (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basal segment</td>
<td>−25 ± 4</td>
<td>−25 ± 3</td>
<td>−24 ± 4</td>
</tr>
<tr>
<td>Mid segment</td>
<td>−25 ± 4</td>
<td>−25 ± 5</td>
<td>−25 ± 5</td>
</tr>
<tr>
<td>Apical segment</td>
<td>−26 ± 5</td>
<td>−26 ± 5</td>
<td>−25 ± 4</td>
</tr>
<tr>
<td>Average</td>
<td>−25 ± 4</td>
<td>−25 ± 5</td>
<td>−24 ± 4</td>
</tr>
</tbody>
</table>

Figure 1  Example of two-dimensional strain obtained from the basal, mid, and apical segments of the left ventricular lateral and septal walls.

Figure 2  Relationship between gestational age and average peak systolic strain value.