**Left Ventricle Mechanics Evaluation By Four-Dimensional Speckle Tracking in Children With Uncorrected Patent Ductus Arteriosus**

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**Abstract:** Children suffering from patent ductus arteriosus (PDA) are at high cardiovascular risk in childhood and adulthood. Although there were many studies on left ventricle (LV) function in PDA children, not study was reported using Four dimensional (4D) echocardiographic speckle tracking (ST) analysis in uncorrected rather than post ligation patients. This work aimed at evaluating LV mechanics of the global longitudinal strain (GLS), the global circumferential strain (GCS) and global radial strain (GRS) in children with uncorrected PDA in comparison with a healthy control people. Sixty-two people (25 with PDA and 37 normal) were involved. Their mean age was 11.52±2.5 months (54% male), and 11.1±2.07 (41% male). All participants were subjected to the clinical evaluation and echocardiographic examination. LV function was also assessed by two dimensional (2D) ejection fraction (EF), fractional shortening (FS) and 4D echocardiography speckle tracking (STE). Longitudinal and circumferential Myocardial deformation in those with PDA were documented less than in the healthy children while 4D radial strain, 2D EF and FS were higher in PDA patients. For PDA and control groups, GLS was −17.404±1.06 versus −20.66±1.6 (P: 0.000) respectively and the GCS was−17.87±0.62 for PDA patients in contrast to −21.36±1.57 (P: 0.000) for the control groups. The GRS of PDA was +46.5±6.3 while the normal group was +38.26±3.01 (P: 0.000). 2D EF 74.47±3.6 was for the patients with PDA while 72.7±2.9 (P: 0.04) was for the normal ones. The PDA and control groups were 2D FS 37.49±1.7 versus 36.38±1.8 (P: 0.02). A new technique by 4D derived ST showed that children with uncorrected PDA were subjected to early subclinical LV mechanical insults despite the apparently normal or augmented LV systolic function which necessitates early intervention to avoid these consequences.
**Keywords:** Four-dimensional echocardiography, speckle tracking, Left ventricle mechanics, Patent ductus Arteriosus.

**Introduction**
The pulmonary artery and the proximal descending aorta are connected by the ductus Botalli which is a fetal circulation shunt \(^{(1)}\). PDA is one of the wide spread congenital heart defect. In every 10,000 live births, it happens in 8 for every term infants. \(^{(2, 3)}\)
PDA shunt causes pulmonary overload and leads to volume overload and remodeling of the left ventricle (LV). Congestive heart failure reported in patients with larger shunts \(^{(4)}\). The good image quality, and the ability of reference information contributed to best suiting child age group for (4D) (4D STE). \(^{(5,6)}\) This study aimed to assess LV GLS, GRS and GCS in children with uncorrected PDA compared with normal ones.

**Methods**
Informed consents to involve the targeted children were obtained before the study began. All measures were taken to meet the guidelines of the institution.

**Study Population**
Patients whose mean ages are 11.52 ± 2.5 months with a known case of PDA attending the echocardiography unit for follow up were included in the study. Detailed clinical and laboratory measures were followed to exclude other conditions that might affect the accuracy of the results. In addition, echocardiography was performed blindly by an experienced echocardiographer at Al- Furat teaching hospital.

**Echocardiographic Measures**
The Diameter of PDA was calculated by the use of the parasternal views of short axis color-Doppler and modified high ones to find the narrowest point. EF was assessed in the two groups by traditional 2D echocardiography using the M-mode method. The 4D full volume was acquired in an apical 4 chamber view. In addition, the chosen multi-slice technique software automatically exhibited the apical 2, 3, 4-chamber with the LV short-axis views. \(^{(7)}\) We stored the image after obtaining a multi-beat in order to increase the frame rate. The stored data were digitally analyzed using Vivid E9 with 4V probe. Following the identification of the points at apex and base line during systole and diastole, the software automatically identified the border of LV. The LV cavity includes the papillary muscles. Following the automatic LV border traces at the end of diastole and the end systole, sometimes, manual adjustment for the LV border was needed. There were automatic LV divisions into many sections and the program provided 4D ST analysis to obtain a specific curves for the GLS, GCS and GRS as in figure 1:
**Statistical Methods**

The data are described as follows: the mean ± SD throughout the analysis. The variables of PDA patients are compared with that of the normal controls by the use of the unpaired t test. The SPSS version 18 was utilized to conduct the statistical analysis and showed that a statistical significant of a P value <0.05.

**Results**

**Demographic Features**

Sixty-three children, twenty-six of whom were patients with a known case of PDA attending cardiology unit in Al-Furat teaching hospital/Iraq for follow up and 37 healthy control children were examined.

There were no statistical differences in age nor in body surface area (BSA):

**Table 1 Study Population Demographic Features**

<table>
<thead>
<tr>
<th></th>
<th>PDA group (n=26)</th>
<th>Control group (n=37)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, months</td>
<td>11.52±2.5</td>
<td>11.1±2.07</td>
<td>0.4</td>
</tr>
<tr>
<td>BSA</td>
<td>0.39 ± 0.03</td>
<td>0.42±0.06</td>
<td>0.09</td>
</tr>
</tbody>
</table>

The mean duct size of the patient was 3.4 ± 0.7 mm. 2D EF and 2D FS were significantly higher in the PDA group. The PDA patients had statistically lower GLS and GCS but higher radial strain when compared with the normal control group as can be seen in table 2.
**Table 2 Echocardiographic Parameters Among The Study Groups**

<table>
<thead>
<tr>
<th></th>
<th>PDA group (n=26)</th>
<th>Control group (n=37)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>4D global longitudinal strain</td>
<td>-17.40±1.06</td>
<td>-20.66±1.6</td>
<td>0.000</td>
</tr>
<tr>
<td>4D global circumferential strain</td>
<td>-17.87±0.62</td>
<td>-21.36±1.57</td>
<td>0.000</td>
</tr>
<tr>
<td>4D global radial strain</td>
<td>+46.5±6.3</td>
<td>+38.26±3.01</td>
<td>0.0001</td>
</tr>
<tr>
<td>2D EF</td>
<td>74.47±3.6</td>
<td>72.7±2.9</td>
<td>0.04</td>
</tr>
<tr>
<td>2D FS</td>
<td>37.49±1.7</td>
<td>36.38±1.8</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Duct size negatively correlated with GLS (figure 2A) and GCS (figure 2B), while no relationship was documented with GRS (see figures 2C).

*Figure 2A Correlation of duct size (mm) with global longitudinal strain % (GLS)*
Discussion
STE derived GLS, GRS and GCS are more superior to the velocities of the tissue and other traditional 2D measures as the later are influenced by loading condition.\(^{(8)}\)

The deformation technique is attractive in the assessment of the ventricular function in the diseases of the congenital heart. This method is no affected by ventricular geometry and,
therefore, can be valuable to assess the ventricles regardless of their morphology. On the contrary to conventional echocardiographic measures which mainly depended on the calculation of radial function, the new method of 4D ST can be used to quantify the motion and deformation of LV in a variety of longitudinal, radial, and circumferential directions.\(^9\)

Our results showed that 2D assessment of LV function by EF and FS is higher in PDA group, perhaps because they depend on the loading condition making these parameters of little reliance. In contrast, the load independent speckle tracking measures revealed a significant decrease of GLS and GCS. The GRS was higher in PDA patients because of a status of volume overload and Frank-Starling’s Law.\(^10\) Our results agreed with that of Mohammad et al and Bussmann et al, who suggested that a PDA could increase the radial deformation measures, signifying that the increased LV preload from a PDA shunt can boost intrinsic contractility in the radial but not circumferential level.\(^11\) Most researchers studied the LV function by traditional 2D measures and / or the speckle tracking derived strain in post ligation rather than pre-ligation alone. However, many others, used the 2D ST rather than the more advanced 4D ST.\(^12,13,14\)

**Conclusion**

A new technique by 4D derived ST, showed that children with uncorrected PDA are subjected to early subclinical LV mechanical insults despite the apparently normal or augmented LV systolic function which necessitates early intervention to avoid these consequences.

**Limitation**

It is difficult to obtain a full volume 4D image in this age group as many cases were cancelled because of the stitching artifact which cannot be avoided by holding the breath as in case of adult age group.

**References**


14- Tilahun, B., & Tefera, E. (2013). Transient left ventricular systolic dysfunction following surgical closure of large patent ductus arteriosus among children and adolescents operated at the cardiac centre, Ethiopia. *Journal of cardiothoracic surgery, 8*(1), 139.