Speckle Tracking Echocardiography in Congenital Heart Disease – Transposition of Great Arteries

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Cross-point?
GUCH patients!

- Cardiology
  - Many patients
  - Big experience
  - Good cardiosurgery
  - Many innovations; technology

- Pediatric cardiology
  - Different CHD
  - Variable hemodynamics
  - Difficult cardiosurgery
  - Different thinking
What is TGA?

- Not uncommon - 8% of CHD.
- Potentially lethal without treatment
- Treatment is surgery!
- Two possible operations:
  - Atrial switch - Senning-Brom – 1964-1985 - Physiological correction;
  - Arterial switch - anatomic correction - 1980-..............
What is TGA?

- **TGA**
- **Senning**
- **Arterial switch**
Senning Operation

Diagram of heart with labeled parts:
- Baffle
- PVA
- SVA
- PA
- Ao
- RV
- LV

Diagram on the right shows blood flow with arrows.
Anatomic characteristics of the systemic RV

- Relatively small papillary muscles
- Hypokinetic part – infundibulum
- Systolic movement of septum towards LV
- Abnormal volume load
- Different coronary perfusion
- Different structure of the wall

Potentially dysfunctional
Long-term problems after Senning operation - pathophysiology

- Long-term volume overload
- Ischemia
- Fibrosis and remodeling of RV
RV Volume

Post Senning

Normal heart

Volume variation diagram

Volume variation diagram of the normal heart

Long-term problems after Senning operation

- Systemic venous or pulmonary venous obstruction
- RV- Dysfunction
- TR
- Arrhythmias
Diagnostic methods for RV

- Echocardiography
  - Conventional echo
  - TDI strain, strain rate
  - Speckle tracking strain and strain rate
  - 3D
- MRI – reference method
- Perfusion scintigraphy
Strain as a marker of deformation

Strain represents myocardial deformation and strain rate represents the rate at which this deformation takes place.
Two-dimensional (2D) strain is based on comparison of the image texture from frame to frame. The distortion of this pattern permits assessment of strain in the axis of movement rather than the axis of the ultrasound beam.
Key parts of the right ventricle

- inlet
- base
- equator
- apex

infundibulum
Table 2: Values of longitudinal and circumferential strain and SR in adults and children.

<table>
<thead>
<tr>
<th>Apical 4 Chambers segmental mean Systolic Strain %</th>
<th>Bas Sept</th>
<th>Mid Sept</th>
<th>Ap sept</th>
<th>Ap lat</th>
<th>Mid lat</th>
<th>Bas Lat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children</td>
<td>-20.6 ± 4.4</td>
<td>-20.9 ± 3.9</td>
<td>-25.4 ± 6.1</td>
<td>-19.8 ± 5.8</td>
<td>-23.3 ± 4.2</td>
<td>-22.9 ± 3.4</td>
</tr>
<tr>
<td>Adults</td>
<td>-15.8 ± 3.5</td>
<td>-17.7 ± 4.1</td>
<td>-24.0 ± 0.8</td>
<td>19.9 ± 4.82</td>
<td>-18.9 ± 4.9</td>
<td>-17.9 ± 5.2</td>
</tr>
<tr>
<td>P value</td>
<td>0.0002</td>
<td>0.0133</td>
<td>0.4664</td>
<td>0.4236</td>
<td>0.0052</td>
<td>0.0013</td>
</tr>
</tbody>
</table>

Table 3: Values of global longitudinal and circumferential Strain and SR in normal adults and children.

| Global Longitudinal Strain (all subjects) | -20.16 ± 3.37 | Global Longitudinal SR (all subjects) | -1.16 ± 0.22 |
| Global Longitudinal Strain Adults         | -19.05 ± 3.05 | Global Longitudinal SR Adults         | -1.07 ± 0.19 |
| Global Longitudinal Strain Children       | -22.18 ± 3.06 | Global Longitudinal SR Children       | -1.30 ± 0.20 |
| Global Circumferential Strain (all subjects) | -24.86 ± 6.76 | Global Circumferential SR (all subjects) | -1.78 ± 0.58 |
| Global Circumferential Strain Adults      | -24.93 ± 7.35 | Global Circumferential SR Adults      | -1.67 ± 0.55 |
| Global Circumferential Strain Children    | -25.60 ± 7.08 | Global Circumferential SR Children    | -1.95 ± 0.60 |
STE - validation in pediatric patients - RV

Table 2—Peak strain and strain rate in each segment ($x \pm s$)

<table>
<thead>
<tr>
<th>Group</th>
<th>NO.</th>
<th>Right ventricular free wall</th>
<th></th>
<th>Septum</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>BS</td>
<td>MS</td>
<td>AS</td>
<td>BS</td>
</tr>
<tr>
<td>Ss(%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>31</td>
<td>$-24.47 \pm 1.41$</td>
<td>$-23.36 \pm 1.84$</td>
<td>$-23.89 \pm 1.29$</td>
<td>$-24.14 \pm 1.21$</td>
</tr>
<tr>
<td>2</td>
<td>32</td>
<td>$-23.95 \pm 1.59$</td>
<td>$-24.22 \pm 1.38$</td>
<td>$-23.67 \pm 2.00$</td>
<td>$-24.31 \pm 1.24$</td>
</tr>
<tr>
<td>3</td>
<td>29</td>
<td>$-24.36 \pm 1.40$</td>
<td>$-24.15 \pm 2.12$</td>
<td>$-24.18 \pm 1.74$</td>
<td>$-24.55 \pm 1.40$</td>
</tr>
<tr>
<td>4</td>
<td>31</td>
<td>$-23.92 \pm 3.22$</td>
<td>$-24.23 \pm 1.49$</td>
<td>$-24.49 \pm 0.82$</td>
<td>$-23.88 \pm 1.20$</td>
</tr>
<tr>
<td>5</td>
<td>28</td>
<td>$-24.70 \pm 2.06$</td>
<td>$-24.47 \pm 2.01$</td>
<td>$-24.58 \pm 1.73$</td>
<td>$-24.32 \pm 1.86$</td>
</tr>
<tr>
<td>SRs(s$^{-1}$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>31</td>
<td>$-2.55 \pm 0.35$</td>
<td>$-2.49 \pm 0.51$</td>
<td>$-2.58 \pm 0.81$</td>
<td>$-2.59 \pm 0.30$</td>
</tr>
<tr>
<td>2</td>
<td>32</td>
<td>$-2.64 \pm 0.57$</td>
<td>$-2.57 \pm 1.32$</td>
<td>$-2.58 \pm 0.54$</td>
<td>$-2.67 \pm 0.54$</td>
</tr>
<tr>
<td>3</td>
<td>29</td>
<td>$-2.58 \pm 0.85$</td>
<td>$-2.61 \pm 0.32$</td>
<td>$-2.63 \pm 0.44$</td>
<td>$-2.64 \pm 0.74$</td>
</tr>
<tr>
<td>4</td>
<td>31</td>
<td>$-2.60 \pm 1.26$</td>
<td>$-2.56 \pm 0.74$</td>
<td>$-2.65 \pm 1.35$</td>
<td>$-2.70 \pm 1.06$</td>
</tr>
<tr>
<td>5</td>
<td>28</td>
<td>$-2.71 \pm 0.59$</td>
<td>$-2.61 \pm 0.30$</td>
<td>$-2.66 \pm 0.20$</td>
<td>$-2.68 \pm 0.26$</td>
</tr>
<tr>
<td>SRd(s$^{-1}$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>31</td>
<td>$2.08 \pm 0.47$</td>
<td>$2.18 \pm 0.57$</td>
<td>$1.98 \pm 0.13$</td>
<td>$2.18 \pm 0.33$</td>
</tr>
<tr>
<td>2</td>
<td>32</td>
<td>$2.11 \pm 0.95$</td>
<td>$2.00 \pm 0.89$</td>
<td>$2.19 \pm 0.40$</td>
<td>$2.15 \pm 0.40$</td>
</tr>
<tr>
<td>3</td>
<td>29</td>
<td>$2.15 \pm 0.48$</td>
<td>$2.09 \pm 0.55$</td>
<td>$2.02 \pm 0.35$</td>
<td>$2.11 \pm 0.39$</td>
</tr>
<tr>
<td>4</td>
<td>31</td>
<td>$2.09 \pm 0.82$</td>
<td>$2.11 \pm 1.27$</td>
<td>$2.20 \pm 1.06$</td>
<td>$2.14 \pm 0.44$</td>
</tr>
<tr>
<td>5</td>
<td>28</td>
<td>$2.16 \pm 0.70$</td>
<td>$2.18 \pm 0.32$</td>
<td>$2.07 \pm 0.86$</td>
<td>$2.15 \pm 0.75$</td>
</tr>
</tbody>
</table>
Regional right and left ventricular function after the Senning operation: an ultrasonic study of strain rate and strain

Benedicte Eyskens,1 Frank Weidemann,2 Miroslaw Kowalski,2 Jan Bogaert,3 Steven Dymarkowski,3 Bart Bijnens,2 Marc Gewillig,1 George Sutherland,2 Luc Mertens1

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Right Ventricular Function with Standard and Speckle-Tracking Echocardiography and Clinical Events in Adults with D-Transposition of the Great Arteries Post Atrial Switch

Andreas P. Kalogeropoulos, MD, Anjan Deka, MD, William Border, MBChB, MPH, Maria A. Pernetz, RDCS, Vasiliki V. Georgiopoulou, MD, Jawad Kiani, MD, Michael McConnell, MD, Stamatios Lerakis, MD, Javed Butler, MD, MPH, Randolph P. Martin, MD, and Wendy M. Book, MD, Atlanta, Georgia

2012; in Press
Table 2  Echocardiographic parameters and association with clinical events

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>HR (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RV fractional area change (%)</td>
<td>22.9 ± 7.5</td>
<td>1.08 (1.00–1.17)</td>
<td>.047</td>
</tr>
<tr>
<td>RV diameter (base) (mm)</td>
<td>45.6 ± 5.6</td>
<td>1.11 (0.99–1.23)</td>
<td>.072</td>
</tr>
<tr>
<td>RV wall thickness (mm)</td>
<td>10.0 ± 1.8</td>
<td>1.17 (0.86–1.58)</td>
<td>.32</td>
</tr>
<tr>
<td>RV area at diastole (cm²)</td>
<td>41.4 ± 7.9</td>
<td>1.03 (0.96–1.10)</td>
<td>.37</td>
</tr>
<tr>
<td>RV area at diastole (cm²/m²)</td>
<td>21.8 ± 3.7</td>
<td>0.93 (0.80–1.09)</td>
<td>.36</td>
</tr>
<tr>
<td>Tricuspid s’ velocity (cm/sec)*</td>
<td>5.1 ± 1.8</td>
<td>1.16 (0.83–1.63)</td>
<td>.39</td>
</tr>
<tr>
<td>Tricuspid e’ velocity (cm/sec)*</td>
<td>5.4 ± 2.3</td>
<td>1.04 (0.83–1.30)</td>
<td>.76</td>
</tr>
<tr>
<td>RV isovolumic velocity (cm/sec)*</td>
<td>4.0 ± 1.6</td>
<td>1.12 (0.78–1.61)</td>
<td>.53</td>
</tr>
<tr>
<td>RV isovolumic acceleration (m/sec²)*</td>
<td>1.33 ± 0.68</td>
<td>1.33 (0.48–3.68)</td>
<td>.58</td>
</tr>
<tr>
<td>RV MPI†</td>
<td>0.63 ± 0.13</td>
<td>1.01 (0.97–1.06)</td>
<td>.51</td>
</tr>
<tr>
<td>TAPSE (mm)*</td>
<td>9.8 ± 2.8</td>
<td>1.00 (0.81–1.23)</td>
<td>.97</td>
</tr>
<tr>
<td>Tricuspid regurgitation severity‡</td>
<td>1.5 ± 1.3</td>
<td>0.94 (0.56–1.59)</td>
<td>.82</td>
</tr>
<tr>
<td>Left (subpulmonic) ventricular ejection fraction (%)*</td>
<td>61.6 ± 9.0</td>
<td>1.00 (0.95–1.06)</td>
<td>.93</td>
</tr>
<tr>
<td><strong>Deformation based</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RV global strain (%)</td>
<td>-12.5 ± 3.0</td>
<td>1.35 (1.14–1.58)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>RV global systolic SR (sec⁻¹)†</td>
<td>-0.59 ± 0.14</td>
<td>1.06 (1.02–1.11)</td>
<td>.006</td>
</tr>
<tr>
<td>RV global early diastolic SR (sec⁻¹)§</td>
<td>0.68 ± 0.22</td>
<td>1.04 (1.00–1.07)</td>
<td>.031</td>
</tr>
<tr>
<td>RV global late diastolic SR (sec⁻¹)§</td>
<td>0.32 ± 0.17</td>
<td>1.02 (0.98–1.06)</td>
<td>.42</td>
</tr>
</tbody>
</table>
Speckle tracking derived strain – clinical applications

Supports decision making in:

- Heart failure therapy
- Further investigation (Cath., MRI)
- Re-operation:
  - tricuspid valve repair
  - conversion to arterial switch
Conclusion

- Patients after Senning op. have significantly reduced RV strain, and it correlates with MRI derived EF.
- RV Strain $< -10\%$ correlates with adverse outcome in patients after Senning OP.
Arterial switch operation
Arterial switch – late complications

- RV outflow tract obstruction
- LV outflow tract obstruction
- Ao regurgitation
- Epicardial coronary artery stenosis
- Perfusion defects
- Wall motion abnormalities
- Dysrhythmia
40% of arterial switch patients have scyntigraphy perfusion defects, undetected by angiography. All of them have regional wall motion abnormality due to microcirculatory disturbances.
Abnormal microcirculation

- Progressive intimal proliferation due to coronary translocation
- Denervation of coronary arteries in the operation
- Frequently abnormally high origin of the coronary arteries
- Reduced coronary flow reserve
Late myocardial ischemia after Arterial switch operation is asymptomatic because of coronary intraoperative denervation!
Coronary circulation- evaluation

- Perfusion scintigraphy
- MRI
- Heart catheterization
- Echocardiography - STE?
STE strain and strain rate after arterial switch – our study ...

- 09.2011 – ongoing
- 58 arterial switch patients
  - 1-18 years old
- 17 healthy controls
- STE – offline analyze by Siemens-Syngo US Workplace VVI
P<0.05
Longitudinal strain of LV

-25.00
-20.00
-15.00
-10.00
-5.00
0.00

arterial switch
controls

P<0.05
Considerations

- Strain adds information regarding systolic function of LV and RV in patients after arterial switch.
- Microcirculatory coronary abnormalities result in regional wall dyskinesia.
- Potential clinical applications of STE strain in patients with congenital heart disease have to be further evaluated.