Reduced systolic flow efficacy in left ventricular dyssynchrony evident by blood speckle imaging


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Introduction: Intraventricular vortices facilitate efficient blood flow in a healthy heart. Changes in the blood flow pattern can cause energy loss and inefficient filling or ejection. Thus, changes, or reduction in vorticity may therefore be of importance for cardiac function. Blood speckle imaging (BSI) is a novel blood flow visualization tool based on echocardiography, partially overcoming the angle dependency of conventional colour Doppler. BSI tracks speckles generated by the moving blood cells, similar to myocardial speckle tracking, but requires a very high frame rate limiting penetration. Dyssynchrony in left bundle branch block (LBBB) affects the systolic functions but there is limited insight into how LBBB alters the blood flow vorticity.

Purpose: We investigated the effect of dyssynchrony on blood flow hemodynamics using blood speckle imaging.

Methods: In eight anesthetized canine mongrels, left ventricular flow was visualized using BSI. A qualitative visual assessment of vortices during the cardiac cycle, together with a quantitative assessment based on kinetic energy loss and vorticity were made. Regional myocardial function parameters were measured by sonomicrometry. Peak septal flash strain in isovolumetric contraction (IVC) was measured by sonomicrometry (figure) as an indicator of dyssynchrony. Assessments were made at baseline, under right ventricular free wall pacing (RV pacing) mimicking LBBB, after induced LBBB by ablation and under cardiac resynchronization therapy (CRT).

Results: During IVC at baseline all animals had a central ventricular vortex. However during RV pacing and LBBB it was distorted in various patterns. RV pacing significantly reduced the number of vortices in systole and disrupted the central vortex in IVC (1.0±0.0 vs 0.4±0.0, p=0.01). Energy loss (EL) in systole increased (40.2±12.5 vs 55.3±23.3 mW/m, p<0.05). Septal end systolic strain was significantly reduced (-8.8±5.1 vs -1.9±7.3 %, p<0.01) and septal flash strain was significantly increased (1.0±1.4 vs 7.7±3.6 and 6.6±3.8 [ER1] [ER2] %, p<0.01) in RV pacing and LBBB. CRT caused a realignment of the central vortex (0.8±0.5 vs 0.3±0.5, p=0.03). The change in energy loss was not significant, but numerically reduced (55.4±38.8 vs 76.4±48.9 mW/m, p=0.06). See table and figure 1.

Conclusions: The main systolic vortex in IVC was disrupted during septal flash by RV pacing and LBBB, altering the flow pattern compared to baseline. The resultant unstructured flow pattern had increased energy loss in systole, indicating a less efficient pattern and less preservation of energy. It should be further explored if this is of importance to understand the reduced LV function and LV remodelling during dyssynchrony.

Figure 1

Figure 1: Illustrative example of the isovolumetric contraction phase of the cardiac cycle with respective electrocardiography (ECG) septal and lateral myocardial strain curves. * p<0.05 vs. baseline [ER1] [ER2] vs. Cardiac Resynchronization Therapy (CRT), LBBB = left bundle branch block (LBBB), RV pacing = right ventricular free wall pacing.
<table>
<thead>
<tr>
<th></th>
<th>N = 8</th>
<th>Baseline</th>
<th>RV pacing</th>
<th>LBBB</th>
<th>CRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central vortex IVC</td>
<td>1.0±0.0</td>
<td>0.4±0.5*</td>
<td>0.3±0.5</td>
<td>0.8±0.5*</td>
<td></td>
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<tr>
<td>Septal flash strain (%)</td>
<td>1.0±1.4</td>
<td>7.7±3.6*</td>
<td>6.0±3.8</td>
<td>1.7±2.4</td>
<td></td>
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<tr>
<td>End systolic strain, septum (%)</td>
<td>-8.8±5.1</td>
<td>-1.9±7.3*</td>
<td>-2.4±3.7</td>
<td>-7.3±6.0*</td>
<td></td>
</tr>
<tr>
<td>Energy loss systole (mW/m)</td>
<td>40.2±12.5</td>
<td>55.3±23.3*</td>
<td>76.4±48.9</td>
<td>55.4±38.8</td>
<td></td>
</tr>
<tr>
<td>Vorticity systole (1/s)</td>
<td>29.9±6.5</td>
<td>30.4±8.4</td>
<td>32.2±12.8</td>
<td>33.0±12.2</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Values are mean ± SD. Students t-test was used to compare mean values. * p<0.05 vs. baseline † p<0.05 vs. left bundle branch block (LBBB). IVS = isovolumetric contraction. mW/m = milliwatt/meter.