Blood Flow Patterns In The Ascending Aorta After TAVI And Surgical Aortic Valve Replacement: A Study Using 4D Flow MRI

R. F. Trauzeddel 1, U. Lübe 2, A. Barker 3,4, C. Gelsinger 1, C. Butter 2, M. Markl 3,4, J. Schulz-Menger 1, F. von Knobelsdorff 1

1 Working Group on Cardiovascular Magnetic Resonance, Experimental and Clinical Research Center, a joint cooperation between the Charité Medical Faculty and the Max-Delbrück Center for Molecular Medicine, and HELIOS Klinikum Berlin Buch, Department of Cardiology and Nephrology, Berlin, Germany
2 Department of Radiology, FARB School of Medicine, Northwestern University, Chicago, Il, USA
3 Department of Biomedical Engineering, McCormick School of Engineering, Northwestern University, Chicago, Il, USA

PURPOSE

- Transcatheter aortic valve implantation (TAVI) is a new method for treating patients with severe aortic stenosis with high risk for or rejected from conventional heart surgery
- Studies demonstrated at least non-inferiority regarding clinical outcome and echocardiographically derived pressure gradients
- There is insufficient information regarding the comparison of ascending aortic hemodynamics in the form of blood flow patterns and parameters like wall shear stresses and oscillating shear indexes after TAVI, stented bioprostheses and healthy controls
- Using time-resolved three-dimensional flow sensitive CMR (4D Flow) after both interventions promises new insights regarding their respective hemodynamics

STUDY AIMS

We applied 4D Flow in patients after TAVI and stented bioprostheses as well as healthy controls to examine if any differences were evident regarding vortices and helices as well as wall shear stresses (WSS) and blood flow distribution

METHODS

- Study sample: n=17 with TAVI (all Edwards Sapien prostheses), n=12 with stented bioprostheses and n=9 healthy controls (Table 1)
- 1.5T MRI scanner ( Magnetom Avanto, Siemens, Germany)
- SSFP cine imaging to assess cardiac function and dimensions as well as prosthetic orifice area
- Acquisition of 4D Flow: Sagittal oblique volume covering the thoracic aorta, prospective ECG gating, respiratory navigator. Acquisition parameters: echo time = 2.3 ms, repetition time = 4.8 ms, bandwidth = 440 Hz/pixel, acceleration mode GRAPPA with factor 2 to 5, 24 reference lines, flip angle q = 9°, temporal resolution = 38.4 ms, field of view = 400 x 375 mm, matrix = 192 x 158, voxel size = 2.1 x 2.4 x 2.2 mm³, phase encoding direction = anterior-posterior, number of slices = 26, slice thickness = 2.2 mm, velocity encoding = 2.5 m/s
- Reading of 4D Flow: Helix and vortex strengths were graded in 0=none, 1=mild, 2=moderate, 3=severe. Peak WSS during systole (WSSpeak) was calculated for 8 segments along the aortic circumference. The distribution of the blood flow as an indication of flow eccentricity is shown.
- Postprocessing was done using tools based on Matlab and Ensight as well as SPSS 20 and Prism 5
- Continuos data are represented as mean ± standard deviation, ordinal data as percentages
- Kruskal-Wallis-Test and Mann-Whitney-U-Test for statistical analysis

RESULTS

Figure 1. Examples of the blood flow in the ascending aorta using pathlines during peak systole in TAVI (left), a stented bioprosthesis (middle) and Control (right). (OA, orifice area; EF, ejection fraction; EDV, enddiastolic volume; AoD, aortic diameter)

Figure 2. Vorticity and helicity. The prevalences are shown. There was a significant difference concerning the helicity between stented bioprostheses and TAVI.

Figure 3. Segmental distribution of WSSpeak along the circumference of the aortic wall at the midpoint of the aorta and comparison between the three groups. * indicates p<0.05, ** indicates p<0.01. (RA, right-anterior; R, right; RP, right-posterior; P, posterior; LP, left-posterior; L, left; LA, left-anterior; A, anterior)

Table 1. Patients' characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>TAVI Bioprostheses</th>
<th>Controls</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age [years]</td>
<td>77 ± 7</td>
<td>77 ± 4</td>
<td>59 ± 16</td>
</tr>
<tr>
<td>Labeled valve size</td>
<td>25.8 ± 2.2</td>
<td>23.2 ± 2.2</td>
<td>0.012</td>
</tr>
<tr>
<td>Orifice area [mm²]</td>
<td>1.9 ± 0.2</td>
<td>1.5 ± 0.4</td>
<td>4.0 ± 0.8</td>
</tr>
<tr>
<td>Aortic diameter [mm]</td>
<td>34.8 ± 3.1</td>
<td>38.5 ± 4.4</td>
<td>30.7 ± 4.9</td>
</tr>
<tr>
<td>LV ejection fraction [%]</td>
<td>57.2 ± 10.1</td>
<td>56.0 ± 10.9</td>
<td>65.9 ± 6.1</td>
</tr>
<tr>
<td>Stroke volume [ml]</td>
<td>87.9 ± 33.1</td>
<td>84.9 ± 32.3</td>
<td>91.4 ± 28.2</td>
</tr>
<tr>
<td>Enddiastolic volume [ml]</td>
<td>157.0 ± 63.3</td>
<td>149.9 ± 61.8</td>
<td>139.8 ± 41.4</td>
</tr>
<tr>
<td>Enddiastolic volume index [ml/m²]</td>
<td>0.9 ± 0.4</td>
<td>0.9 ± 0.4</td>
<td>0.8 ± 0.2</td>
</tr>
<tr>
<td>Left ventricular mass [g]</td>
<td>175.7 ± 59.3</td>
<td>165.2 ± 55.1</td>
<td>129.2 ± 25.3</td>
</tr>
<tr>
<td>Left ventricular mass index [g/m²]</td>
<td>1.1 ± 0.3</td>
<td>1.0 ± 0.4</td>
<td>0.7 ± 0.1</td>
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CONCLUSIONS

- Stented bioprosthesis and TAVI differed significantly from each other concerning the helices in the ascending aorta but not regarding the vortices
- There were no statistical differences concerning the wall shear stresses. Both prostheses types revealed a similar eccentricity of flow
- Both prostheses types differed significantly from native aortic valves concerning blood flow patterns and parameters
- Larger samples with matched controls and with longitudinal follow-up are needed

Conflict of Interest: None

European Students' Conference – Berlin 2014

res-felix.trauzeddel@charite.de; http://cmr-berlin.org