AORTIC ROOT ANEURYSMS: THE BIOMECHANICAL ADVANTAGE OF THE SLEEVE TECHNIQUE OVER THE DAVID PROCEDURE

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Introduction

Aortic root (AR) aneurysms can lead to secondary aortic valve regurgitation with a worldwide incidence of 19% [1]. When valvular tissue is not jeopardized, preserving the native aortic valve (AV), through a valve-sparing surgery, is preferable. Although the excellent long-term results of gold standard techniques, i.e. David (reimplantation) and Yacoub (remodeling) techniques, they are still technically demanding. Recently, the simpler Sleeve technique has been proposed with encouraging early-term outcomes [2]: the entire AR unit is preserved “wearing” a bulb-shaped graft around it, so the coronary arteries re-implantation is not required. In this work, exploiting finite element (FE) models, we assessed for the first time the AR biomechanics following the Sleeve procedure, using the most recent version of the traditional David technique as term of comparison.

Methods

Long-axis 2D Cardiac Magnetic Resonance (CMR) was performed on 2 patients affected by a predominant sinotubular junction (STJ) dilatation (about 65% respect to the annulus). A paradigmatic aneurysmatic AR model was used which accounts for realistic AR asymmetry and curvature. The two sparing techniques were then simulated wearing the native AR with the graft for the Sleeve procedure and re-suspending the native AV within the graft model for the David technique (Fig. 1).

![Figure 1: 3D geometrical model of aneurysmatic AR and graft in the two sparing procedures.](image1)

Both human aorta and prosthesis material were considered non-linear and anisotropic. A comparative analysis between Sleeve and David technique was therefore carried out. In both cases, after graft implantation, the repaired AR biomechanics was simulated applying physiological time-dependent pressure loads throughout a cardiac cycle (ABAQUS Explicit, SIMULIA, Dassault Systèmes, USA). Connector elements were adopted to connect native tissues with the graft, in order to reliably mimic the technique-specific surgical stitches used in the procedure.

Results

AV kinematics, in both the sparing models, well matched with physiological data [3] (Table 1).

<table>
<thead>
<tr>
<th></th>
<th>David</th>
<th>Sleeve</th>
<th>In vivo [2]</th>
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<tbody>
<tr>
<td>RVOT [ms]</td>
<td>47</td>
<td>52</td>
<td>57.5 ± 11.1</td>
</tr>
<tr>
<td>RVCT [ms]</td>
<td>35</td>
<td>43</td>
<td>39.5 ± 5.0</td>
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Table 1: Leaflet kinematics. RVOT=Rapid Valve Opening Time, RVCT= Rapid Valve Closing Time.

As compared to the David model, the Sleeve technique induced lower maximum stresses on the aortic valve belly (-13.8%, -6.7%, -12.5% on the right, non-coronary and left leaflet, respectively), at the diastolic peak (Fig. 2-a). Indeed, during diastole the stress patterns averaged over the leaflets were 35% lower in the Sleeve model (Fig. 2-b). Moreover, due to the direct interaction between the AV and the prosthesis, near the commissural attachment the David procedure induced higher local stresses with an average of 369 kPa (+75% compared to the Sleeve one).

![Figure 2: AV mechanical stress on the leaflets (a) and stress time-course averaged on the three leaflets (b).](image2)

Discussion

Our study confirmed that both techniques are prone to restoring a normal valve functionality. Nonetheless, from a biomechanical standpoint, the Sleeve technique better preserved the leaflet-sinus unit with respect to traditional David procedure. If corroborated by long-term clinical outcomes, the obtained results suggested that using the Sleeve technique could successfully simplify the surgical repair of AR aneurysms and reduce the intraoperative complications.

References

1. R. Bekerjadian, Circulation 112:125-34, 2005