Stentless valve continence is affected by the implantation technique, annular symmetry and dilatation of the sinotubular junction. We tested in vitro how the Sorin Solo stentless pericardial valve adapts to a slightly dilated sinotubular junction. Stentless Sorin Solo aortic valves (25 mm) were sutured into a 32-mm Valsalva graft suspending the commissures into the expandable region of the graft. The neo-aortic root was pressurized and sinotubular junction size progressively decreased by wrapping the neocommissural ridge with Dacron rings. Direct endoscopic view and ultrasound imaging were used to observe geometry and morphology of leaflets, regurgitation, height and level of leaflets coaptation. Fresh porcine valves of the same annular size were used as controls. Solo valves had mild regurgitation at baseline, became continent at 32 mm sinotubular junction size and remained continent at any size of reduction, with optimal coaptation height and level. Porcine valves had severe regurgitation at baseline, became continent at 30 mm and showed mild insufficiency and reduction of the coaptation level at a sinotubular junction of 28 mm. The Solo valve prevents residual valve regurgitation for a wider range of sinotubular junction mismatch when compared with natural porcine valves. This extended tolerance to sinotubular junction mismatch suggests a safe use of stentless valves even in suboptimal geometry roots.

© 2008 Published by European Association for Cardio-Thoracic Surgery. All rights reserved.

Keywords: Aortic valve; Replacement; Heart valve; Stentless; Bioprosthesis; Echocardiography
These composite conduits were immersed in a saline bath at a constant temperature of 37 °C and mounted in the test circuit [13]. Briefly, a centrifugal pump driven was primed with saline and its arterial branch connected to a Y shaped cannula commonly used for port-access procedures. The Y cannula was modified by inverting the barbed tubing connection site with the Hemostasis valve, the side branch of the Y cannula was used for tubing connection, the Hemostasis valve was used to insert into the cannula a 5.0 mm 0° endoscope connected to a Teknocam 3000 P camera. The composite conduits were joined to the cannula by a properly designed connector. Aortic root grafts were instrumented by a pressure monitoring set for continuous pressure monitoring and perfused to reach a constant internal graft pressure of 100–110 mmHg. Saline recirculation through the circuit was ensured by the porosity of the graft and obtained by connecting to the basin the venous branch of the perfusion circuit. Flow was measured on the venous side by a Bioprobe TX40 [13].

To prevent skirt expansion, Dacron rings of decreasing size were then sequentially placed around the expandable portion of the graft at the level of the re-implanted commissures. Each valve prosthesis was tested at the initial STJ diameter (without ring) and then at a STJ diameter of 32, 30, 28, and 26 mm [13].

A qualitative appraisal of aortic leaflets coaptation in pressurized roots was made on images obtained by the endoscopic camera. Images of the coaptation profile of the valve were obtained at a pressure of 100 mmHg and transferred to a personal computer for off-line analysis.

Long and short axis views of the aortic root were acquired by a 5.2-MHz ultrasound probe connected to a Sonos 5500 HP machine. Diameter of the neo-STJ, coaptation height (defined as amount of leaflet coaptation) and coaptation level of aortic valve leaflets (defined as level of coaptation inside the aortic root) were measured. Amount of valve regurgitation was qualitatively assessed by direct vision of the regurgitant jet and classified semi-quantitatively as mild (+, jet diameter <2.0 mm), moderate (+ +, jet diameter 2–5 mm) and severe (+ ++, jet diameter >5 mm). Results were compared to six 25-mm aortic valves of isolated fresh porcine aortic roots reimplanted into a 32-mm Valsalva graft using the reimplantation technique [2]. Porcine valves had the same annular size of the Solo valves and the top of their commissures were sewn at exactly the same level in the skirt of the Valsalva graft. Of note, this control group had been previously used to properly establish the optimal STJ size in the reimplantation type of valve sparing procedure [13] and does not act as an ‘other stentless prosthesis’ comparison group, but as a ‘as close as possible to physiology’ reference. Both the Solo valves and the porcine valves had natively a 25-mm orifice diameter, and were sutured in the Dacron graft over a 25-mm sizer, to obtain a constant 25-mm size ‘aortic annulus’. The wider graft allowed us to establish the diastolic behavior of the valves in near normal conditions (when STJ is 4–6 mm wider than the annulus) and in progressively more ‘pathologic’ STJ mismatch conditions, on both sides of the spectrum.

3. Statistical analysis

Data entry was carried out directly at the time of experiments. Measures are reported as mean ± S.D. A double pathway of analysis was applied: first, to assess significance of differences in collected data at different SIJ sizes for each valve type, and second, to evaluate differences between the two valves at each fixed STJ size. In step one, separate analysis of variance (ANOVA) was applied. The analysis was performed with Bonferroni, Duncan and Tukey models, and showed significant differences (P < 0.05) in sinuses dimension and SIJ dimension, which were variables controlled by the physicians by changing the Dacron ring measure, as well as in coaptation height and coaptation level, which were variables observed in the experimental environment with no direct control from the physician. Obviously, no differences were found regarding annular ring dimension and tubular size. One-tail homoschedastic Student t-test was then performed to explore the difference between groups. In step two homoschedastic Student t-test was performed to explore the difference between observations. The significance values (P) for each set are presented in Tables 1 and 2. All statistical analyses were performed using SPSS Statistical Package 13.0.

4. Results

Effects of sequential wrapping manoeuvres on neo-root dimensions and leaflet geometry are reported in Tables 1 and 2, respectively. Progressive reduction of STJ size resulted in an increased height and slightly decreased level of aortic valve leaflet coaptation; optimal values were obtained at a STJ of 30 mm for porcine aortic valves and 32 mm for the Solo stentless valves. Further reduction of the STJ size resulted in progressive reduction of both coaptation height and level.

Aortic regurgitation data are displayed in Table 3. Regurgitation was always present at baseline, which represents the highest mismatch grade, but was severe for porcine valves and mild for Solo stentless valves (P < 0.001). In the porcine model, its amount significantly decreased when the STJ was fixed at 32 mm and disappeared at a STJ of 30 mm. An eccentric mild aortic regurgitation was observed at 28 mm STJ. This was somehow expected as 30 mm represents the closest approximation to the natural proportion between annulus and STJ.

In the Solo stentless valve, central aortic regurgitation already disappeared at a STJ of 32 mm and no regurgitation was present for a STJ of 30 and 28 mm. An eccentric mild aortic regurgitation was observed only when the STJ was reduced to 26 mm.

In the porcine model, at baseline a significant aortic regurgitation was associated with marked tethering and outward bending of the aortic leaflets. At 32 mm, aortic leaflets tethering was still present and associated with mild aortic regurgitation. Tethering, bending and regurgitation disappeared when the STJ was reduced to 30 mm (Fig. 1a), confirming once again that this proportion, near to the native one, is the one that gets the valve working optimally.

In the Solo stentless model at baseline, a mild aortic regurgitation was associated with modest tethering and
was slightly changed by marked reduction of the STJ or even 26 mm from 16.5 mm to 8.2 mm;

Changes in leaflet geometry by progressively decreasing the diameter of the STJ

Changes in aortic root geometry by progressively decreasing the diameter of the STJ

rotational

No statistical differences between Solo stentless and porcine aortic valve group were present (all $P>0.05$).

### Table 2
Changes in leaflet geometry by progressively decreasing the diameter of the STJ

<table>
<thead>
<tr>
<th>Wrapping ring size</th>
<th>None</th>
<th>32 mm</th>
<th>30 mm</th>
<th>28 mm</th>
<th>26 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solo stentless valve</td>
<td>CH (mm)</td>
<td>8.4 ± 0.6*</td>
<td>9.9 ± 0.3</td>
<td>9.9 ± 0.2</td>
<td>7.6 ± 0.7</td>
</tr>
<tr>
<td></td>
<td>CL (mm)</td>
<td>13.9 ± 0.9*</td>
<td>13.3 ± 2.1*</td>
<td>13.9 ± 0.89*</td>
<td>13.3 ± 0.7*</td>
</tr>
<tr>
<td>Porcine aortic valve</td>
<td>CH (mm)</td>
<td>7.6 ± 0.6*</td>
<td>9.5 ± 0.6</td>
<td>10.6 ± 0.6</td>
<td>7.7 ± 0.4</td>
</tr>
<tr>
<td></td>
<td>CL (mm)</td>
<td>18.6 ± 0.2*</td>
<td>18.6 ± 0.5*</td>
<td>16.5 ± 0.4*</td>
<td>8.2 ± 1.3*</td>
</tr>
</tbody>
</table>

### Table 3
Degree of aortic regurgitation (mean) by progressively decreasing the diameter of the STJ

<table>
<thead>
<tr>
<th>Wrapping ring size</th>
<th>None</th>
<th>32 mm</th>
<th>30 mm</th>
<th>28 mm</th>
<th>26 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solo stentless valve</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>Porcine aortic valve</td>
<td>++</td>
<td>+</td>
<td>–</td>
<td>+</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

5. Discussion

STJ dilatation often due to ascending aortic aneurysm is one of the main causes of aortic valve regurgitation and can be simply treated by reducing the STJ at normal size using a Dacron conduit [14]. Correct matching between annulus and STJ is crucial for maximal leaflet coaptation and for assuring a competent aortic valve. As stentless aortic valve prostheses are very similar by design to a natural aortic valve the same rules applies. Mismatch between annulus and STJ diameter is a contraindication for prosthetic stentless valve implantation: a dilated STJ, by pulling apart the prosthetic valve commissures, decreases the amount of leaflet coaptation and causes leaflets tethering and central valve regurgitation. On the other hand, an excessive reduction of the STJ diameter is the cause of leaflet prolapse with consequent reduction in the level of leaflet coaptation and in the height of leaflet coaptation.

The Sorin Solo stentless valve is a biological whole pericardial valve suitable to be implanted in a supra-annular position with a fast and simple single suture-line implant technique [15]. For its peculiar design, the Solo valve could tolerate some degree of mismatch between the annulus and the STJ and permit good adaptability to anatomic variations. The results of the present study confirms that, at least in in-vitro settings, this stentless aortic valve tolerates a far higher dimension mismatch, both on the upper and lower end, than a natural porcine valve.

Moreover, a marked reduction in the STJ diameter produced a different effect on the leaflet of the stentless valve if compared with porcine valve. While in the porcine valve, a marked reduction of the STJ caused a mild reduction in the coaptation height but a marked reduction in the...
coaptation level inside the root, in the Solo valve both effects were less evident. This extended tolerance to STJ mismatch suggests a potential for minimizing surgical human errors.

A possible limitation of the present study is its specific focus only on the diastolic behavior of the valve leaflets. It is possible that a pulsatile flow simulator or an in-vivo setup could yield a different result. However, the diastolic properties of a prosthetic aortic valve are usually not influenced by flow pulsatility.

The performance of other commercially available stentless valves in the same experimental setting is currently planned to assess whether the observed advantages of the Solo valve over a native porcine valve are shared with other valvular grafts.

References