Creating a bicuspid valve from the aortic wall:
a new surgical approach on aortic valve disease (in vitro study)

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Abstract
We described a new technique (called ‘bicuspidization’), which is performed by using autogenous material, without replacement of the aortic valves for the surgical treatment of aortic stenosis and/or insufficiency and tested it in in vitro sheep model. Different stress conditions were simulated by applying three different flow patterns (hemodynamic challenge tests) successively by using a centrifugal pump. It was demonstrated that the competency of the new bicuspid valves was excellent (zero insufficiency). There was a 10–11 mmHg-increase on trans-valvular gradient comparing the normal hearts. The autogenous bicuspid valve has not blocked the way of the coronary flow in the closed position. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Aortic valve stenosis; Aortic valve insufficiency; Bicuspid valve; Bicuspidization technique

1. Introduction
We described and tested a surgical technique called ‘bicuspidization’ which is an alternative for mechanical or bioprosthetic valve replacements and homograft usage for aortic valve (AV) insufficiency and/or stenosis.

2. Materials and methods
Eight adult sheep hearts were used. First, the opening gradient of the AV was determined by applying the test protocol to normal hearts (Group-A). Then bicuspid AV was created from the aortic wall of the same hearts (Group-B) and by repeating the tests, the opening gradients and competency of the new valves were investigated.

2.1. Preparation of the heart for hemodynamic challenge tests
After cannulating of left ventricle (through the left atrium and mitral valve) and ascending aorta, the heart was fixed to an adjustable experiment apparatus at natural position. The cannulas were connected to a centrifugal pump console. The pressures on both sides of AV and the right and left coronary arteries were monitored.

After performing the tests to the native hearts (Group-A), the cannulas were removed and bicuspidization technique was applied to these hearts (Group-B). Then the same tests were repeated.

2.2. Bicuspidization technique
Ascending aorta was transected at a height above the sinotubular junction which equals the aortic diameter. Native AV was excised and the main coronary arteries were detached from the aortic sinuses. The defects were closed with dacron patches.

From the free opposing margins of aorta, two crescentic pieces, in which their deepest points were one-fifth of the internal aortic diameter, were extracted and completely removed (Fig. 1). To prevent the dissection of the native aortic wall layers that will function as a bicuspid valve, a continuous suture line was fashioned at the distal end of the aortic stump with 6/0 polypropylene suture.

A low-porosity woven Dacron tube graft (20% larger than the external aortic diameter) was selected. Separated pledgeted-2/0 polyester sutures were passed from the inside to outside of the left ventricular outflow tract (with pledgets...
facing the ventricular side) at the level of the aortic annulus, and inside to outside of this graft. Then graft was placed on to the proximal aortic stump and sutures were tied. Right and left coronary buttons were reimplanted to the graft. Then, two commissures were formed by using pledgets. The fixation sutures (4/0 polypropylene) were placed between Dacron graft and both commissures to suspend the new AV in a symmetrical fashion and to keep them at a fixed tension (Fig. 2).

The other end of the graft was anastomosed end-to-end to the distal ascending aorta.

2.3. Hemodynamic challenge test

Three different flows (each represents a different stress condition for the AV) were applied sequentially by using a centrifugal pump:

- **Condition-1: Antegrade, pulsatile flow.** The maximal systolic gradient of the valves were determined with the pulsatile pressure.
- **Condition-2: Antegrade, non-pulsatile flow.** The gradient which opens the valves during the continuous flow was detected.
- **Condition-3: Retrograde, pulsatile flow.** Competence of the valve was tested.

### 3. Results

The mean values of the pressure measurements are summarized in Table 1.

In the normal sheep hearts (Group-A), during antegrade pulsatile flow, the pressure values at the proximal of both coronary arteries are found to be 0 mmHg at systole (closed position), and 65 mmHg at diastole (opened position). Sheep AV were observed to open with a 15-mmHg peak pressure gradient during pulsatile pressure and 10-mmHg pressure gradient during constant pressure. This gradient is increased 10 mmHg (25 mmHg) and 11 mmHg (21 mmHg) during pulsatile and continuous flows, respectively, in Group-B.

The effective valve function was shown from the pressure changes. The bicuspid valve did not cause regurgitation during retrograde flow according to pressure values.

By using a thoracoscopic probe, inserted into the aortic

<table>
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<th>Table 1</th>
<th>Pressure measurements (mmHg)</th>
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<td>Group A</td>
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<td></td>
<td>I&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>P1&lt;sup&gt;d&lt;/sup&gt;</td>
<td>139/39</td>
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<td>P2&lt;sup&gt;d&lt;/sup&gt;</td>
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<td>P3&lt;sup&gt;d&lt;/sup&gt;</td>
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- **a** Step I: A pulsatile pressure of 60/min (maximum about 140 mmHg) from the ventricle side.
- **b** Step II: A continuous pressure (maximum about 140 mmHg) from the ventricle side.
- **c** Step III: A pulsatile pressure of 60/min (maximum about 90 mmHg) from the aortic side.
- **d** Pressures: P1, left ventricle; P2, ascending aorta; P3, left coronary artery.
graft, valve motions were observed during antegrade and retrograde flow and full coaptation was confirmed visually.

4. Discussion

Although simple and uncomplicated in appearance, the closure mechanism of the AV is more delicate than other valves. Thus, AV reconstruction techniques are scarce in number and are usually palliative [1–4].

In this study, we reconstruct a new valve out of the aortic wall itself by the surgical technique. Although this new valve system works slightly similar, its configuration and shape, thickness, localization (more distally localized than the native valves), leaflet number (bicuspid) and histological nature are different from the native valves. With all these differences, the system showed a reasonable performance in our in vitro model.

Recently, we described a different surgical technique (‘flap-valve’ method) [5] for isolated AV regurgitation. This technique is based on the idea that uses the vessel wall itself (otogenous tissue) as a flap, while the AV are preserving. We also described a similar technique (‘flap-valvul’ method) [6] for chronic venous insufficiency.

However, the bicuspidization, is the first method in literature with an autogenous valve system reconstructed from aorta.

The new bicuspid valve is a living tissue (not fixed by any agent) and has vasavasorum. We believe this ensures even more advantageous results than biological valve replacements.

It is not possible to predict long-term results of this new valve system in terms of altered geometry of the sinuses, hemodynamic performance and calcification. Obviously, an animal study would clarify these issues. Because, the system showed a reasonable function in the first step of our project, we will proceed to the second step to demonstrate long-term results in in vivo environment.

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