Aortic Valve Morphology Determines the Presentation and Surgical Approach to Acute Type A Aortic Dissection

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Background. Data on acute type A aortic dissection in patients with bicuspid aortic valve (BAV) syndrome are limited. This investigation evaluated the clinical details in patients with type A dissection stratified according to aortic valve morphology.

Methods. Between 1993 and 2013, 629 patients (median age 61 years [50; 73], 64% men) underwent surgical procedures for type A dissection. Forty-one patients with BAV were compared with 588 patients with tricuspid aortic valve (TAV).

Results. The BAV patients were younger (55 years [46; 67] vs 61 years [51; 73] years; \( p < 0.001 \)), presented more frequently with moderate or severe aortic insufficiency (51% vs 34%; \( p = 0.039 \)), cardiogenic shock (37 vs 21%; \( p = 0.029 \)), and had larger ascending aorta diameters (5.5 cm [5.1; 6.4] vs 4.8 cm [4.4; 5.5] cm; \( p < 0.001 \)). The BAV patients more frequently required aortic root replacement (81% vs 14%; \( p < 0.001 \)). Total arch replacement was performed in 5% of the BAV patients and 4% of the TAV patients. In-hospital mortality (14.6% vs 13.1%; \( p = 1.0 \)) and survival at 5, 10, and 15 years (56% ± 8%, 46% ± 10%, and 37% ± 11% vs 68% ± 2%, 49% ± 3%, and 36% ± 4%; log rank, \( p = 0.4 \)) were similar in the BAV and TAV patients. Twenty (3%) TAV and no BAV patients underwent proximal reoperations (\( p = 0.6 \)) at a median follow-up time of 4.1 years (range, 0.8 to 6.9 years).

Conclusions. BAV patients experience dissection at a younger age and at a greater ascending aortic diameter. Extensive aortic root repair in BAV patients is not associated with higher in-hospital mortality and prevents the need for later proximal redo operation.


Bicuspid aortic valve (BAV) syndrome is the most common congenital heart defect, affecting 0.5% to 2% of the population [1–3]. BAV is associated with cardiovascular malformations such as ascending aortic dilatation, aortic coarctation, patent ductus arteriosus, and atrial and ventricular septal defects. However, the most catastrophic adverse event in adult BAV patients is acute Stanford type A aortic dissection, which is associated with a high mortality of 8% to 13% even in high-volume centers [4–6]. The incidence of type A aortic dissection in patients with BAV syndrome at autopsy and in community cohort studies is eight to ten times higher than in patients with a trileaflet valve (TAV) [7–9].

There has been increasing awareness of BAV syndrome and its association with ascending aorta structural defects at the cellular level, such as decreased fibrillin, elastin fragmentation, and apoptosis [10, 11]. These intrinsic cellular defects in combination with a low morbidity and mortality in patients undergoing elective aortic root procedures has lowered the threshold for prophylactic replacement of the ascending aorta at 5 cm in these patients [12]. Despite the lower trigger for elective operation, 4% to 15% of patients who present with acute type A aortic dissection have BAV [13, 14]. Although recent studies have improved the understanding of the genetics, the pathobiology, and the course of BAV disease, clinical data on type A aortic dissection in BAV syndrome patients is limited. This investigation evaluated the clinical presentation, surgical management, and outcomes in patients with acute type A aortic dissection stratified according to aortic valve morphology.
Patients and Methods

Study Population
Between 1993 and 2013, among 629 patients (age 61 years [range, 60 to 73 years], 64% men) operated on for acute Stanford type A aortic dissection, 41 patients (7%) had BAV. The diagnosis of BAV was confirmed at operation. Acute aortic dissection was defined as a dissection operated on no later than 14 days after the onset of symptoms. Ascending aortic diameter was assessed before operation by transesophageal echocardiography and was available in 482 patients (77%).

The institutional review committee approved this retrospective study, and the need for informed consent was waived.

Patient Follow-Up
Surveillance follow-up data were obtained by contacting the general practitioners, the patients, and their family members or by the Social Security Death Index. Complete follow-up data were available for 534 of 546 hospital survivors (98%). Patients were followed up for a total of 2,812 patient-years, with a median follow-up time among survivors of 4.1 years (range, 0.8 to 6.9 years). Eighteen percent were followed up for 10 or more years.

Surgical Approach
In all patients, previously described standardized integrated surgical management was applied [15]. Briefly, this approach included direct admission to the operating room, immediate operative repair, replacement of the entire ascending aorta, resuspension of the aortic valve with Teflon felt “neomedia” root repair or, in case of root aneurysm, dissection tear extending to the sinus segment or structural BAV abnormalities (eg, large fenestrations, cusp elongation), replacement of the sinus of Valsalva, and finally open replacement of the aortic arch (aggressive hemiarch replacement with excision of most of the dissected aortic arch) and the use of hypothermic arrest with reinforcement of the residual arch tissue with Teflon felt “neomedia.”

Statistical Analysis
Continuous data are presented as median (first quartile; third quartile); categoric variables are given as counts and percentages. For comparison of continuous variables, the Student’s t test was applied when equal distribution was present as tested by the Kolmogorov-Smirnov test. For unequally distributed variables, the Mann-Whitney rank sum test was used. Categoric variables were compared with the χ² test. In case of small group sizes (n <5), Fisher’s exact test was used. Survival was analyzed by the Kaplan-Meier method and log rank calculations.

Results

Clinical Presentation
Patients with BAV were an average of 6 years younger (55 [46; 67] vs 61 [51; 73] years; p = 0.030) (Fig 1) and were in a similar gender distribution (63% vs 64% males; p = 0.9) as TAV patients. The BAV patients had a lower incidence of hypertension (56% vs 81%; p < 0.001). The incidence of all other cardiovascular risk factors did not differ between the two groups (Table 1). Three BAV patients underwent aortic valve replacement 23, 8, and 4 years before type A dissection. Two BAV patients underwent coronary artery bypass procedures 8 and 3 years before type A dissection. In the TAV group, 11 patients underwent prior aortic valve replacement, 26 underwent coronary artery bypass grafting, 10 underwent both valve and bypass procedures, and 4 underwent other cardiac surgical interventions.

The BAV patients had a higher incidence of moderate or severe aortic valve insufficiency (51% vs 34%; p = 0.039) than did the TAV patients. Nine (22%), 5 (12%), and 2 (5%) of 41 BAV patients had mild, moderate, or severe aortic valve calcification. The incidence of cardiac tamponade was higher among BAV patients, but this difference did not reach statistical significance (34% vs 24%; p = 0.2). The BAV patients had a higher incidence of cardiogenic shock (37% vs 21%; p = 0.029). The organ malperfusion pattern was similar in both groups.

Aortic dissection extended beyond the aortic arch with equal frequency in BAV and TAV patients (dissection DeBakey type I: 66% vs 70%; p = 0.7). The diameter of the dissected aorta was significantly larger in BAV patients (5.5 cm [5.1; 6.4] vs 4.8 cm [4.4; 5.5]; p < 0.001) (Fig 2).

Proximal and Distal Aortic Repair
The BAV patients had a sixfold increased requirement of aortic root replacement (81% vs 14%; p < 0.001). The reasons for aortic root replacement included aortic root aneurysm in 27 patients, severe dissection involving coronary arteries in 8 patients, dissection entry extending to the root in 2 patients, and aortic valve degenerative changes in 14 patients. Aortic root preservation and valve resuspension was performed in 17% of the BAV patients and 83% of the TAV patients (p < 0.001). In both groups, 95% of the patients underwent a distal hemiarch replacement. Total arch replacement was performed in
5% (2 of 41) of the BAV patients and 4% (25 of 588) of the TAV patients.

Cardiopulmonary bypass times and aortic cross-clamp times were on average 50 and 71 minutes longer (both \(p < 0.001\)) in the BAV patients, and the hypothermic circulatory arrest time did not differ between the two groups (Table 2).

**Immediate and Long-Term Outcomes**

In-hospital mortality did not differ between the BAV and TAV patients (14.6% vs 13.1%; \(p = 1.0\)). The perioperative stroke rates were 5% in both groups. Overall survival was similar in the BAV patients (75% ± 7%, 56% ± 8%, and 46% ± 10% at 1, 5, and 10 years) and the TAV patients (83% ± 2%, 68% ± 2%, and 49% ± 3% at 1, 5, and 10 years; log rank, \(p = 0.4\)) (Fig 3). All BAV patients who underwent aortic valve resuspension presented with a competent aortic valve (no moderate or severe regurgitation) at follow-up (range, 1 to 18 years). No BAV patients and 20 (3%, \(p = 0.6\)) TAV patients underwent reoperation on the aortic root; 3 (7%) BAV patients and 49 (8%, \(p = 1.0\)) TAV patients underwent distal reoperation (aortic arch or descending aorta) reoperation during the follow-up.

**Comment**

*Patients With BAV Experience Dissection at a Younger Age*

Aortic dissection can occur at any age; however, the highest incidence of type A dissection is during the seventh and eighth decades [16]. The International Registry
for Acute Aortic dissection investigators suggested that younger patients (<40 years old) who experienced type A or B aortic dissection more often had a BAV than did older patients (>40 years old; 9% vs 1%; p < 0.01) [17]. In a recent report from Shanghai on a relatively young type A dissection population including 30 BAV and 258 TAV patients, the average age of BAV patients was 46 years and of the TAV patients was 51 years (p = 0.033) [18].

Our results confirmed this observation and showed that BAV patients who experienced acute type A dissection were on average 6 years younger than were patients with TAV. Furthermore, among 41 BAV patients, only 1 was older than 80 years.

The male predominance (3:1) in BAV syndrome has been observed in autopsy studies and in the latest Genetically Triggered Thoracic Aortic Aneurysms and Cardiovascular Conditions (GenTAC) gender study [1, 19]. Our findings support and extend these observations by demonstrating a male predominance (>60%) in BAV patients with acute Stanford type A aortic dissection.

BAV Patients Experience Dissection at a Greater Ascending Aortic Diameter

The majority of patients with acute type A aortic dissection present with aortic diameters under the threshold diameter (<5.5 cm) for elective ascending replacement [14, 20]. However, criteria other than size of the aorta for timing of prophylactic operations are still not available. Little is known about the ascending diameter in BAV patients who experience acute type A dissection. Pape and colleagues [14] observed in the International Registry of Acute Aortic Dissection (IRAD) (16 BAV patients) larger diameters in BAV patients than diameters measured in patients with TAV (p < 0.05). Similar findings were demonstrated by Wang and colleagues [18]. Our findings showed significantly larger diameters in BAV patients (5.5 cm vs 4.8 cm; p < 0.001).

This aortic size difference leads to several possible hypotheses. We report on diameter of the dissected aorta. It is conceivable that the dissection process itself leads to changes in the aortic diameter. Given that BAV disease is associated with a congenital or genetic disorder of the proximal aorta, acute diameter increase evolved by the dissection process may differ between TAV and BAV.

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Table 2. Surgical Procedures for Type A Aortic Dissection Details and Outcomes

<table>
<thead>
<tr>
<th>Variable</th>
<th>All (n = 629)</th>
<th>BAV (n = 41)</th>
<th>TAV (n = 588)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal repair</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aortic valve resuspension</td>
<td>493 (78.4)</td>
<td>7 (17.1)</td>
<td>486 (82.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CVG</td>
<td>115 (18.3)</td>
<td>33 (80.5)</td>
<td>82 (13.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>V-SARR</td>
<td>6 (1.0)</td>
<td>0</td>
<td>6 (1.0)</td>
<td>0.856</td>
</tr>
<tr>
<td>Wheat procedure</td>
<td>13 (2.1)</td>
<td>1 (2.4)</td>
<td>12 (2.0)</td>
<td>0.693</td>
</tr>
<tr>
<td>Distal repair</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemiarch replacement</td>
<td>598 (95.1)</td>
<td>39 (95.1)</td>
<td>558 (94.9)</td>
<td>0.698</td>
</tr>
<tr>
<td>Total arch replacement</td>
<td>27 (4.3)</td>
<td>2 (4.9)</td>
<td>25 (4.3)</td>
<td>0.836</td>
</tr>
<tr>
<td>CPB time (min)</td>
<td>212 (185; 252)</td>
<td>251 (209; 292)</td>
<td>211 (185; 252)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CX time (min)</td>
<td>143 (118; 175)</td>
<td>213 (154; 239)</td>
<td>142 (117; 169)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>HCA time (min)</td>
<td>34 (26; 44)</td>
<td>36 (30; 50)</td>
<td>34 (26; 44)</td>
<td>0.710</td>
</tr>
<tr>
<td>Stroke: new onset</td>
<td>32 (5.1)</td>
<td>4 (4.9)</td>
<td>30 (5.1)</td>
<td>0.945</td>
</tr>
<tr>
<td>In-hospital mortality</td>
<td>83 (13.2)</td>
<td>6 (14.6)</td>
<td>77 (13.1)</td>
<td>0.966</td>
</tr>
</tbody>
</table>


Categoric values are n (%), continuous values are median (first interquartile; third interquartile). CPB = cardiopulmonary bypass; CVG = composite valved graft; CX = cross-clamp; HCA = hypothermic circulatory arrest; V-SARR = valve-sparing aortic root replacement.

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Fig 3. Kaplan-Meier analysis of survival in patients with bicuspid (BAV) and tricuspid (TAV) aortic valve who underwent operations for acute type A aortic dissection.
patients. Another possibility is that BAV patients have baseline structural abnormalities of the aorta \cite{11, 21} predisposing the proximal aorta for dilation and dissection. However, the turbulent blood flow and uneven stress distribution \cite{22} that are present for the entire life in BAV patients might play paradoxically a protective preconditioning role against aortic dissection. Therefore, more BAV patients experience acute dissection, but the aorta dissects at a greater diameter. A larger ascending diameter might be an argument against prophylactic intervention in BAV patients with diameters less than 5.5 cm. However, owing to the currently lower trigger for elective ascending aorta replacement in BAV patients versus TAV patients, the observed diameters of dissected aortas may differ between patients with different valve morphology, and therefore a definitive conclusion on aortic size cannot be made.

**Aortic Root Replacement Is Required in the Vast Majority of BAV Patients**

Distal aortic repair in BAV and TAV patients did not differ in our cohort, and 95% of all patients underwent aggressive hemiarch replacement. Aortic valve morphology, however, was significantly associated with the method used for proximal aortic repair. Our policy is to preserve the sinus segment whenever possible (intimal dissection tear does not extend to the aortic root, and aortic root diameter is <4.5 cm). Most patients with dissections have normal aortic root architecture that has been acutely devastated by the dissection process. Aortic valve resuspension with sinus segment repair and the application of Teflon felt “neomedia” or a Wheat procedure were performed in 85% of TAV patients and in fewer than 20% of BAV patients. Aortic root replacement was necessary in BAV patients, usually because of root aneurysm frequently accompanied by severe dissection propagating to the aortic annulus involving one or both coronary arteries. Patients whose sinus segment and BAV could be preserved showed at the last follow-up visit robust reconstruction results with no moderate or severe aortic valve insufficiency and no need for proximal reintervention. Of note, extension of the proximal aortic repair to include an aortic root replacement in BAV patients did not negatively affect in-hospital survival.

The David operation is an alternative in patients with an entry tear extending toward the aortic annulus; however, it requires longer cardiac arrest and cardiopulmonary bypass times, which may negatively influence the outcome, especially in patients with malperfusion syndrome. Therefore, we avoid valve-sparing root replacement in the setting of acute type A aortic dissection.

**Immediate and Long-Term Outcomes Do Not Differ Between BAV and TAV Patients**

Our data revealed 14.6% and 13.1% in-hospital mortality rates in BAV and TAV patients, respectively. These results compare superiorly with the recently reported mortality of 23.6% in the IRAD \cite{23} and 16.9% in the GERAADA (German Registry of Acute Aortic Dissection Type A) registries \cite{24} and are similar to the results in single tertiary high-volume centers \cite{25, 26}.

With the presented approach, perioperative mortality did not differ between the BAV and TAV patients, even though patients with BAV presented more frequently in cardiogenic shock, which is highly associated with perioperative mortality. Long-term survival was similar in both groups. No BAV patient required aortic root reintervention during the follow-up. The rates of distal reintervention were not influenced by the aortic valve morphology. These findings support the postulate that BAV syndrome is a pathologic condition of the proximal aorta \cite{27}, and replacement of this aortic segment seems to be a definitive treatment of BAV syndrome aortopathy. In this series, after surgical repair of the proximal aorta in patients with BAV type A dissection, we did not observe any additional risks in terms of greater late aortic event rates in comparison with patients with normal trileaflet valves.

This was a retrospective study with all its limitations. The number of patients who died at home or on the way to the hospital remains unknown. Detailed BAV morphology was not retrievable in more than 50% of all operating reports; therefore, the pathophysiologic implications of different BAV configurations could not be analyzed. Finally, demonstrated aortic diameters are the diameters of already dissected aortas, which are known to differ from predissection diameters.

In conclusion, aortic valve morphology determines the clinical presentation and surgical approach to acute Stanford type A aortic dissection. BAV patients experience dissection at a younger age and at greater ascending aortic diameters. Patients with BAV need aortic root replacement six times more frequently, which is not associated with higher in-hospital mortality and prevents the need for later proximal redo operation.

**References**


DISCUSSION

DR JOSHUA BAKER (Boston, MA): Excellent presentation. My question for you would be when you and Dr Desai looked through all these patients, does this change the way that you approach type A dissections that come in? Are you more likely now to do a valve-sparing root replacement in a patient with bicuspid aortic valve or a root replacement?

DR RYLSKI: In bicuspid aortic valve patients, we aim to preserve the valve. When we see that it is a functionally normal valve, the root is not dilated (less than 4.5 cm), and there is no dissection tear that extends towards the annulus, we try to spare the valve. But as you have seen, aortic root replacement was still necessary in almost 80% of patients, and it was usually due to a dysfunctional valve and root dilatation.

DR EDWARD CHEN (Atlanta, GA): I have a question, and it may be difficult to answer. Obviously, the bicuspid valve patients had a large aortic diameter at the time of operation. How many of those patients were actually being followed up, particularly those who had had previous cardiac operations? And the second question is, based on this information, do you have any thoughts in terms of size criteria differences you may apply going forward in terms of elective intervention?

DR RYLSKI: The questions regarding the diameter of the ascending aorta are always very interesting. Indeed, we observed significantly larger ascending aortas in bicuspid aortic valve patients. However, we should keep in mind that the diameter of the dissected aorta differs when compared with the nondissected aorta in the same patient. We recently published an article presenting a diameter increase of 25% in tricuspid aortic valve patients caused by dissection. We do not know what happens in bicuspid valve patients. We suppose that it may be similar. It is difficult to say what we can do with these data. I think that we should keep on following the recommendations; however, we still do not know how to identify those patients who are at risk for dissection.

DR DESAI: Just to echo those comments and maybe provide a little bit more background on our approach, typically, as we mentioned, we like to perform a root-sparing operation, basically, where we repair the neomedia and spare the root and the valve. In the bicuspid patients, because the aortas are larger, we have typically done root replacement. We are probably more interested in doing root reimplantations in those patients as well, as we have gained more experience of doing those in acute dissections. I think that the message that Tirone David gave at Tech-Con this week is an important one and a sobering one, that
although there has been a push to operate on bicuspid valves at smaller diameters, we still don’t really have a lot of data to say that it is unsafe to wait until above 5 cm to operate on those patients, and I think these data would suggest that bicuspid valves can have larger aortas and not dissect until later.

DR CHEN: The patients that had previous cardiac operations in the bicuspid group: do you know what operations they had? Were they aortic valve replacements?

DR RYLSKI: There were 5 patients with previous cardiac operations in the bicuspid aortic valve group. Three of them had aortic valve replacement and 2 of them had coronary artery bypass grafting before a type A dissection.

DR CHEN: And those with the valves, were they mechanical or tissue, and what did you do with those? I know it’s very fine detail, but I am just curious about it.

DR RYLSKI: As far as I can remember, 1 patient had aortic valve stenosis and 2 patients had aortic valve insufficiency. We tried to figure out what was the diameter of the ascending aorta at the time of the initial operation, but those patients were not operated on at our hospital. So we did not get that information.