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Functional Aortic Root Parameters and Expression of Aortopathy in Bicuspid Versus Tricuspid Aortic Valve Stenosis

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ABSTRACT

BACKGROUND The correlation between bicuspid aortic valve (BAV) disease and aortopathy is not fully defined.

OBJECTIVES This study aimed to prospectively analyze the correlation between functional parameters of the aortic root and expression of aortopathy in patients undergoing surgery for BAV versus tricuspid aortic valve (TAV) stenosis.

METHODS From January 1, 2012 through December 31, 2014, 190 consecutive patients (63 ± 8 years, 67% male) underwent aortic valve replacement ± proximal aortic surgery for BAV stenosis (n = 137, BAV group) and TAV stenosis (n = 53, TAV group). All patients underwent pre-operative cardiac magnetic resonance imaging to evaluate morphological/functional parameters of the aortic root. Aortic tissue was sampled during surgery on the basis of the location of eccentric blood flow contact with the aortic wall, as determined by cardiac magnetic resonance (i.e., jet sample and control sample). Aortic wall lesions were graded using a histological sum score (0 to 21).

RESULTS The largest cross-sectional aortic diameters were at the mid-ascending level in both groups and were larger in BAV patients (40.2 ± 7.2 mm vs. 36.6 ± 3.3 mm, respectively, $p < 0.001$). The histological sum score was 2.9 ± 1.4 in the BAV group versus 3.4 ± 2.6 in the TAV group ($p = 0.4$). The correlation was linear and comparable between the maximum indexed aortic diameter and the angle between the left ventricular outflow axis and aortic root (left ventricle/aorta angle) in both groups (BAV group: $r = 0.6$, $p < 0.001$ vs. TAV group $r = 0.45$, $p = 0.03$, $z = 1.26$, $p = 0.2$). Logistic regression identified the left ventricle/aorta angle as an indicator of indexed aortic diameter >22 mm/m^2 (odds ratio: 1.2; $p < 0.001$).

CONCLUSIONS Comparable correlation patterns between functional aortic root parameters and expression of aortopathy are found in patients with BAV versus TAV stenosis. (J Am Coll Cardiol 2016;67:1786–96) © 2016 by the American College of Cardiology Foundation.

The concept of heterogeneity in bicuspid aortic valve (BAV) disease with markedly different forms of BAV-associated aortopathy has gained increasing acceptance in the last few years (1–3). Several classification systems have been introduced to stratify BAV patients on the basis of valve morphotype (4), phenotype of the proximal aorta (5), or a combination of both factors (1). Despite accumulating evidence on pathogenetically different forms of BAV disease, recommendations for the treatment of BAV-associated aortopathy do not currently take this information into account (6,7).

Recent cardiovascular magnetic resonance (CMR) imaging studies provided some insight into rheological mechanisms potentially involved in the development of BAV-associated aortopathy (8,9). Moreover,

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these imaging studies consistently demonstrate that mid-ascending aortic dilation phenotype is the most common form of BAV-associated aortopathy (8,10). Previous surgical data indicate a strong correlation between presence of BAV stenosis and the development of mid-ascending aortic dilation (11,12). Mid-ascending aortic dilation in patients with tricuspid aortic valve (TAV) stenosis is generally accepted to be a purely hemodynamic "post-stenotic" form of TAV-associated aortopathy (13,14). On the basis of these associations and our previous observations (15), we hypothesized that the expression/severity of aortic valve stenosis-associated aortopathy is a function of transvalvular rheological disturbances and that these are comparable in patients with BAV versus TAV stenosis. We therefore aimed to prospectively analyze the associations between morphological/functional parameters of the aortic root and the expression/severity of aortopathy in patients undergoing surgery for BAV versus TAV stenosis.

METHODS

We prospectively evaluated all patients who were ≤70 years and underwent aortic valve replacement (AVR) with or without concomitant proximal aortic replacement for aortic stenosis at a single institution (Central Hospital, Bad Berka, Germany) from January 1, 2012 through December 31, 2014. BAV patients with pure or predominant aortic regurgitation were excluded because several recent studies suggested that a pattern of aortopathy may be more influenced by congenital factors in these patients (3,16,17).

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A total of 1,526 patients underwent aortic valve surgery at our institution between January 2012 and December 2014. Patients older than 70 years of age (n = 915) were excluded in order to obtain similar risk profiles between BAV and TAV patients. Other exclusion criteria included patients requiring concomitant procedures (other than replacement of the proximal aorta) (n = 201), patients undergoing urgent or emergent surgery (n = 85), reoperations (n = 57), and patients with contraindications for pre-operative CMR (n = 10). All patients with isolated or predominant (i.e., moderate or more) aortic valve insufficiency were also excluded (n = 68). A total of 190 consecutive patients were therefore included in our study. All of these patients (63 ± 8 years of age, 67% male) underwent elective AVR with or without simultaneous proximal aortic surgery for BAV stenosis (n = 137, BAV group) and TAV stenosis (n = 53, TAV group) during the study period and served as a focus of the current study. Our local institutional review board approved the study and all patients gave written informed consent.

The primary endpoint of our study was the relationship between functional/rheological aortic root parameters and the expression/severity of aortopathy (i.e., proximal aortic phenotype, indexed aortic diameter, and histological sum score).

ABBREVIATIONS AND ACRONYMS

AVR = aortic valve replacement

BAV = bicuspid aortic valve

CMR = cardiac magnetic resonance

LV = left ventricle

TAV = tricuspid aortic valve

DEFINITIONS AND MEASUREMENTS. Pre-operative echocardiography and CMR imaging were used to assess the morphology and function of the aortic valve in all patients. BAV was suspected if 2-dimensional short-axis imaging of the aortic valve demonstrated the existence of only 2 commissures delimiting 2 aortic valve cusps. The final decision regarding the bicuspidality versus tricuspidality of the aortic valve was made on the basis of the intraoperative description of valve morphology by the surgeon. Aortic valve stenosis was defined using the published echocardiography guidelines (18).

The maximal cross-sectional diameters of the proximal aorta at the level of aortic annulus, sinuses of Valsalva, sinotubular junction, mid-ascending aorta, and aortic arch were measured pre-operatively by CMR. All aortic diameters were measured as the largest observed cross-sectional diameter perpendicular to the aortic axis in a mid-vessel slice at end-diastole using the inner edge to inner edge technique, in accordance with previously published recommendations for CMR measurements (19). Similar to previous studies (20), we defined the length of the proximal aorta (i.e., longitudinal aortic expansion) as the distance (mm) from the level of aortic annulus to the origin of brachiocephalic trunk (**Figure 1A**). Moreover, the area of the proximal aorta (cm^2) was determined in the most central oblique sagittal plane at end-diastole from the level of the aortic annulus to the origin of brachiocephalic trunk (**Figure 1B**) (21).

Proximal aortic phenotype was determined on the basis of CMR (**Figures 2A to 2D**). Normal aorta phenotype was characterized by all cross-sectional aortic diameters <22 mm/m^2 of body surface area and nonindexed aortic diameters <40 mm (**Figure 2A**). Aortic root dilation was defined as maximal aortic dilation at the level of the sinuses of Valsalva, exceeding 22 mm/m^2 or 40 mm in maximal diameter (**Figure 2B**). Mid-ascending aorta phenotype was determined by maximal aortic diameters at the level of the mid-ascending tubular aorta and