23. Francois CJ, Markl M, Schiebler ML, Niespodzany E, Landgraf BR, Schlensak C, et al. Four-dimensional, flow-sensitive magnetic resonance imaging of blood flow patterns in thoracic aortic dissections. *J Thorac Cardiovasc Surg.* 2013;145:1359-66.
24. Della Corte A, Bancone C, Conti CA, Votta E, Redaelli A, Del Viscovo L, et al. Restricted cusp motion in right-left type of bicuspid aortic valves: a new risk marker for aortopathy. *J Thorac Cardiovasc Surg.* 2012;144:360-9.
25. Girdauskas E, Rouman M, Disha K, Scholle T, Fey B, Theis B, et al. Correlation between systolic transvalvular flow and proximal aortic wall changes in bicuspid aortic valve stenosis. *Eur J Cardiothorac Surg.* 2014;46:234-9.

Key Words: Bicuspid aortic valve, valve-sparing aortic root replacement, 4D flow MRI, thoracic aorta

EDITORIAL COMMENTARY

How pathologic is the function of a bicuspid aortic valve?

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See related article on pages 59-68.

In the past 20 years, the attitude of surgeons to the bicuspid aortic valve (BAV) has changed dramatically. Initially, this valve form was considered to be pathologic in form and function by nature,¹ justifying its liberal replacement. With time the BAV has gained increasing interest, in part because of its associated aortopathy.² It has also been recognized that the prognosis is not uniformly poor, both in its spontaneous course³ and after repair,⁴ and that BAV anatomy is not uniform but varies with respect to degree of fusion, fusion pattern, and also commissural orientation.⁵ The analysis of repair failures has pointed out the clinical relevance of the anatomic variability of BAV.⁴ The aortopathy seen with BAV has been the subject of controversial discussion with regard to whether it is the result of abnormal turbulence characteristic for the BAV or related to genetic abnormalities of the aortic wall that are related to BAV morphology, such as alterations in the endothelial nitric oxide synthase pathway.⁶

The study of Stephens and colleagues⁷ in this issue of the *Journal* contributes additional information on the abnormal flow pattern in the ascending aorta, thus seemingly reinforcing the possible relationship between

aneurysm formation and turbulence. More importantly, the study shows that the presence of turbulence and its severity is related to the morphology of the valve. Patients who had undergone valve-sparing aortic replacement were analyzed according to their type of BAV (ie, no raphe, considered type 0, or asymmetric with 1 raphe).⁸ Stephens and colleagues⁷ found the expected turbulence, with a maximum toward the outer curvature of the tubular ascending aorta with type 1 valves, whereas in patients with type 0 BAV more laminar flow patterns were observed. They concluded that the increased turbulence may be related to a higher probability of secondary aortic complications after valve-preserving surgery in type 1 BAV.

Stephens and colleagues⁷ have generated interesting and important physiologic data regarding flow in the ascending aorta and its possible relationship with aneurysm formation. An even more fascinating dimension of the study is the documentation that symmetric configuration of a BAV leads to flow patterns across the valve and in the ascending aorta that are close to normal. Thus the findings provide new evidence that the anatomic configuration of the BAV is related to its physiologic function. This implies that in reconstruction or preservation of the BAV a symmetric configuration of the commissures should be ideal, as has been concluded previously on the basis of repair durability.⁴

There are limitations of the study that have to be kept in mind, however, and questions remain unanswered. Does the study prove a causal relationship between turbulence and aneurysm formation? Will less turbulence with symmetric orientation of commissures actually result in less aneurysm formation? How high is the probability of downstream

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aortic dilatation after replacement of the ascending aorta? At this time, a causal relationship of turbulence is unproven and may be a coincidental finding; turbulence may also be a cofactor in a more complex biologic process. Larger epidemiologic studies will be required before more definite conclusions can be drawn.

An important limitation is related to the surgical classification used by Stephens and colleagues.^{7,8} It classifies the BAVs primarily according to number of commissures and does not take the variability of commissural orientation⁵ into consideration. This is likely to introduce some degree of inaccuracy into any study by arbitrarily considering geometrically distinctly different BAVs as a single type. The mean commissural angle of $133^\circ \pm 16^\circ$ in the type 1 group even indicates that the morphologies were different from the majority of BAVs seen in clinical practice and in other studies.⁴ It should also be noted that in the study of Stephens and colleagues,⁷ a BAV type 0 with a mean commissural angle of 165° is simply not “naturally perfect”; a naturally perfect valve should have a 180° orientation. The findings of Stephens and colleagues⁷ emphasize that future research on functional aspects of the BAV should probably not cling to a surgical classification but rather create study groups that take the known anatomic variations⁵ into consideration.

In conclusion, Stephens and colleagues⁷ are to be congratulated for investigating the physiology of the BAV. Although the aortic consequences of transvalvular flow still need to be defined, their results give further insights into the relationship between form and function of the BAV and may help in understanding and improving repair results.

References

1. Robicsek F, Thubrikar MJ, Cook JW, Fowler B. The congenitally bicuspid aortic valve: how does it function? Why does it fail? *Ann Thorac Surg.* 2004;77:177-85.
2. Della Corte A, Body SC, Booher AM, Schaefer HJ, Milewski RK, Michelena HI, et al; International Bicuspid Aortic Valve Consortium (BAVCon) Investigators. Surgical treatment of bicuspid aortic valve disease: knowledge gaps and research perspectives. *J Thorac Cardiovasc Surg.* 2014;147:1749-57. 1757.e1.
3. Mills P, Leech G, Davies M, Leatham A. The natural history of a non-stenotic bicuspid aortic valve. *Br Heart J.* 1978;40:951-7.
4. Aicher D, Kuniyara T, Abou Issa O, Brittner B, Gräber S, Schäfers HJ. Valve configuration determines long-term results after repair of the bicuspid aortic valve. *Circulation.* 2011;123:178-85.
5. Sabet HY, Edwards WD, Tazelaar HD, Daly RC. Congenitally bicuspid aortic valves: a surgical pathology study of 542 cases (1991 through 1996) and a literature review of 2,715 additional cases. *Mayo Clin Proc.* 1999;74:14-26.
6. Aicher D, Urbich C, Zeiher A, Dimmeler S, Schäfers HJ. Endothelial nitric oxide synthase in bicuspid aortic valve disease. *Ann Thorac Surg.* 2007;83:1290-4.
7. Stephens EH, Hope TA, Kari FA, Escobar Kvitting J, Liang DH, Herfkens RJ, et al. Greater asymmetric wall shear stress in Sievers' type 1/L-R compared with 0/LAT bicuspid aortic valves after valve-sparing aortic root replacement. *J Thorac Cardiovasc Surg.* 2015;150:59-68.
8. Sievers HH, Schmidtke C. A classification system for the bicuspid aortic valve from 304 surgical specimens. *J Thorac Cardiovasc Surg.* 2007;133:1226-33.