regurgitation and resection of the ascending aorta for aneurysm. *Circulation*. 2011;123:896-903.

21. Simon-Kupilik N, Schima H, Huber L, Moidl R, Wipplinger G, Losert U, et al. Prosthetic replacement of the aorta is a risk factor for aortic root aneurysm development. *Ann Thorac Surg*. 2002;73:455-9.
22. Safar ME, Toto-Moukoko JJ, Bouthier JA, Asmar RE, Levenson JA, Simon AC, et al. Arterial dynamics, cardiac hypertrophy, and antihypertensive treatment. *Circulation*. 1987;75:1156-61.
23. Scharfshwerdt M, Sievers HH, Greggersen J, Hanke T, Misfeld M. Prosthetic replacement of the ascending aorta increases wall tension in the residual aorta. *Ann Thorac Surg*. 2007;83:954-7.
24. Kim SY, Hinkamp TJ, Jacobs WR, Lichtenberg RC, Posniak H, Pifarre R. Effect of an inelastic aortic synthetic vascular graft on exercise hemodynamics. *Ann Thorac Surg*. 1995;59:981-9.
25. Walker T, Bail DH, Gruler M, Vonthein R, Steger V, Ziemer G. Unsupported reduction ascending aortoplasty: fate of diameter and of Windkessel function. *Ann Thorac Surg*. 2007;83:1047-53.
26. Bauer M, Pasic M, Schaffarzyk R, Siniawski H, Knollmann F, Meyer R, et al. Reduction aortoplasty for dilatation of the ascending aorta in patients with bicuspid aortic valve. *Ann Thorac Surg*. 2002;73:720-3.
27. Niclauss L, Delay D, Ruchat P, von Segesser LK. Reduction aortoplasty: safe and durable treatment for borderline dilatation in selected patients. *J Heart Valve Dis*. 2012;21:584-90.
28. Mueller XM, Tevæarai HT, Genton CY, Hurni M, Ruchat P, Fischer AP, et al. Drawback of aortoplasty for aneurysm of the ascending aorta associated with aortic valve disease. *Ann Thorac Surg*. 1997;63:762-6.
29. Gill M, Dunning J. Is reduction aortoplasty (with or without external wrap) an acceptable alternative to replacement of the dilated ascending aorta? *Interact Cardiovasc Thorac Surg*. 2009;9:693-7.
30. Mohamed SA, Misfeld M, Hanke T, Charitos EI, Bullerdiel J, Belge G, et al. Inhibition of caspase-3 differentially affects vascular smooth muscle cell apoptosis in the concave versus convex aortic sites in ascending aneurysms with a bicuspid aortic valve. *Ann Anat*. 2010;192:145-50.
31. Svensson LG, Blackstone EH, Cosgrove DM 3rd. Surgical options in young adults with aortic valve disease. *Curr Probl Cardiol*. 2003;28:417-80.
32. Opatowsky AR, Perlstein T, Landberg MJ, Colan SD, O'Gara PT, Body SC, et al. A shifting approach to management of the thoracic aorta in bicuspid aortic valve. *J Thorac Cardiovasc Surg*. 2013;146:339-46.
33. Pape LA, Tsai TT, Isselbacher EM, Oh JK, O'Gara PT, Evangelista A, et al. Aortic diameter ≥ 5.5 cm is not a good predictor of type A aortic dissection: observations from the International Registry of Acute Aortic Dissection (IRAD). *Circulation*. 2007;116:1120-7.
34. Russo CF, Mazzetti S, Garatti A, Ribera E, Milazzo A, Bruschi G, et al. Aortic complications after bicuspid aortic valve replacement: long-term results. *Ann Thorac Surg*. 2002;74:S1773-6.
35. Moody A. Perspective: the big picture. *Nature*. 2013;502:S95.

EDITORIAL COMMENTARY

Bicuspid aortopathy and the development of individualized resection strategies

Paul W. M. Fedak, MD, PhD, FRCSC,^{a,b} and Subodh Verma, MD, PhD, FRCSC^{c,d}

See related article on pages 2072-80.

In an effort to better understand current surgical approaches, we compared the knowledge and attitudes of individual surgeons toward the diagnosis and management of bicuspid aortopathy.¹ Surprisingly, surgeons' approaches often went outside established guidelines, with marked differences in

the timing, extent, and type of operative strategy of aortic resection. Bicuspid aortopathy is a commonly encountered clinical scenario, so why are surgeons so disparate and non-compliant with current recommendations? We believe that the heterogeneous nature of the disease and its diverse clinical phenotypes² may influence a surgeon's threshold for aortic replacement, despite current guidelines. Unfortunately, there are no consensus recommendations on the type or extent of aortic repair for an individual patient with bicuspid aortopathy, and no randomized clinical trials are available to better inform clinicians as to whether an aggressive versus conservative approach is appropriate. Although arm-deep in a patient's chest and inspired by the best intentions, surgeons might avoid the recommendations in selected patients and recognize that contemporary guidelines for aortic resection in patients with bicuspid aortic valve based solely on maximal aortic diameter are deficient and lack an appreciation for the numerous factors that may underlie disease progression.

To achieve optimal clinical outcomes for bicuspid aortopathy, individualized surgical approaches for patients with bicuspid aortic valve disease may be a necessity. In their report in this issue of the *Journal*, Sievers and

From the Bicuspid Aortic Valve Program,^a Bluhm Cardiovascular Institute, Northwestern Memorial Hospital, Northwestern University, Chicago, Ill; Libin Cardiovascular Institute of Alberta,^b University of Calgary, Calgary, Alberta, Canada; Division of Cardiac Surgery,^c Li Ka Shing Knowledge Institute of St Michael's Hospital, Toronto, Ontario, Canada; and Department of Surgery,^d University of Toronto, Ontario, Canada.

Disclosures: Authors have nothing to disclose with regard to commercial support.

Received for publication Sept 18, 2014; accepted for publication Sept 18, 2014

Address for reprints: Subodh Verma, MD, PhD, FRCSC, Division of Cardiac Surgery, St Michael's Hospital, Suite 8-003, Bond Wing, 30 Bond St, Toronto, Ontario M5B 1W8, Canada (E-mail: vermasu@smh.ca).

J Thorac Cardiovasc Surg 2014;148:2080-1

0022-5223/\$36.00

Copyright © 2014 Published by Elsevier Inc. on behalf of The American Association for Thoracic Surgery

<http://dx.doi.org/10.1016/j.jtcvs.2014.09.059>

colleagues³ examine the outcomes with use of their preferred approach to manage the ascending aorta during bicuspid valve surgery. The approach is novel and provides individualized resection strategies and includes “in the moment” assessments going far beyond maximal aortic diameter. It is not surprising that this group of expert surgeons observed excellent clinical results. The approach acknowledges and then attempts to balance the surgical risk with the perceived extent and magnitude of the aortopathy for each individual patient and then tailors the type and extent of aortic resection accordingly. The strategy is unique such that patients at intermediate risk were treated with aortoplasty compared with complete resection. Aortoplasty does address the issue of maximal aortic diameter, but without resection it may also retain affected aortic tissues at risk of future expansion, rupture, or dissection. Although the clinical outcomes were adequate, these patients may not have needed any aortic intervention. Determination of intermediate risk may not be simple using current criteria. The lack of randomization or a comparative group with appropriate analysis is lacking. Surgeons would not be wrong to adopt the proposed approach. But would they be right? We simply do not know. Further study with longer follow-up periods, serial imaging of the aortoplasty patients, and additional comparative analysis will be needed to determine whether this approach is indeed preferred and can be widely recommended.

To optimally address each patient with bicuspid aortopathy on an individual basis with a tailored surgical strategy, the science must first advance. We must develop and validate the predictive tools needed to appropriately risk stratify patients, and only then can the optimal treatment strategy be used.⁴ In this study, intraoperative criteria were used to estimate the degree of aortopathy and then guide the surgeon to the extent and best approach to aortic resection. Sadly, the “look and feel” of the aorta are subjective criteria that are nonvalidated and likely suffer from problems of poor sensitivity and specificity. Many surgeons use wall thinning and friability in decision-making, and certainly this is reasonable in the absence of better alternatives. We believe that the use of advanced imaging

modalities in combination with biomarkers may prove to be superior. By using 4-dimensional flow magnetic resonance imaging technology, we recently showed that valve fusion patterns predicted the degree and location of aortic dilatation.⁵ Imaging of regional flow abnormalities may help identify areas at risk of long-term complications that should be resected. Biomarkers are being explored and may help identify individual patients with aggressive phenotypes that may benefit from more extensive and perhaps earlier resections.⁶ In combination with advanced imaging, these predictive tools could be used to enhance decision making preoperatively and avoid crucial decisions “in the moment.”

To develop individualized resection strategies, we must advance the science of bicuspid aortic valve aortopathy and determine the key molecular and cellular mechanisms underlying its progression.⁷ Until such time, expert surgeons will continue to use their own individualized approaches for each patient. The results of this study provide reassurance that even without the science needed to develop and validate best practices, surgeons using individualized aortic resection strategies can and do provide substantial benefits for their patients with bicuspid aortic valves.

References

1. Verma S, Yanagawa B, Kalra S, Ruel M, Peterson MD, Yamashita MH, et al. Knowledge, attitudes, and practice patterns in surgical management of bicuspid aortopathy: a survey of 100 cardiac surgeons. *J Thorac Cardiovasc Surg.* 2013; 146:1033-40.e4.
2. Verma S, Siu SC. Aortic dilatation in patients with bicuspid aortic valve. *N Engl J Med.* 2014;370:1920-9.
3. Sievers H-H, Stierle U, Mohamed SA, Thorsten H, Richardt D, Schmidtke C, Charitos EI. Toward an individualized management of the ascending aorta in bicuspid aortic valve surgery: the role of valve phenotype in 1362 patients. *J Thorac Cardiovasc Surg.* 2014;148:2072-80.
4. Fedak PW. Bicuspid aortic valve syndrome: heterogeneous but predictable? *Eur Heart J.* 2008;29:432-3.
5. Mahadevia R, Barker AJ, Schnell S, Entezari P, Kansal P, Fedak PW, et al. Bicuspid aortic cusp fusion morphology alters aortic three-dimensional outflow patterns, wall shear stress, and expression of aortopathy. *Circulation.* 2014;129: 673-82.
6. Fedak PW, Verma S. The molecular fingerprint of bicuspid aortopathy. *J Thorac Cardiovasc Surg.* 2013;145:1334.
7. Losenno KL, Goodman RL, Chu MW. Bicuspid aortic valve disease and ascending aortic aneurysms: gaps in knowledge. *Cardiol Res Pract.* 2012;2012: 145202.