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Rethinking the Paradigm: Modern Approach to Proximal Aortic Reconstruction Demonstrates Excellent Outcomes

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ABSTRACT

Background: Techniques for aortic surgery continue to evolve. A real-world snapshot of patients undergoing elective surgery for aneurysm in the modern era is helpful to assist in deciding the appropriate timing for intervention. We herein describe our experience with 100 consecutive patients who underwent primary elective surgery for aneurysm of the proximal thoracic aorta over a two-year period at a single institution.

Methods: The majority of our patients were male, mean age 61.19 ± 13.33 years. Two patients had Marfan syndrome. Twenty-eight patients had bicuspid aortic valve. Thirty-four patients underwent aortic root replacement utilizing a composite valve/graft conduit; 23 had valve-sparing root replacements. The ascending aorta was replaced in 89 patients; 80 (89.9%) of these included a period of circulatory arrest at moderate hypothermia utilizing unilateral selective antegrade cerebral perfusion.

Results: Thirty-day mortality was zero. Perioperative stroke occurred in 2 patients, both of whom completely recovered prior to discharge. No patients required re-exploration for bleeding. One patient developed a sternal wound infection. Fifteen patients required readmission to hospital within thirty days of discharge.

Conclusion: Elective surgery for aneurysm of the proximal aorta is safe, reproducible, and is associated with outcomes that are superior to those seen in an acute aortic syndrome. It may be appropriate to offer surgery to younger patients with proximal aortic aneurysms at smaller diameters, even if their aortic dimensions do not yet meet traditional guidelines for surgical intervention.

INTRODUCTION

Patients requiring aortic reconstruction present with a broad spectrum of pathologies, of varying degrees of severity, with different degrees of aortic valvular and/or left ventricular dysfunction. When reviewing the literature, one is confronted with a heterogeneous group of patients, and it can be difficult to interpret the data in a way that is directly generalizable to real-world practice.

Although aortic root replacement utilizing the classic button technique was originally described in the late 1960s [Bentall 1968], the procedure has undergone a number of iterations, not only in terms of the technical aspects of the surgery, but also with respect to its clinical application [Kouchoukos 1991; Halstead 2005]. Aortic root replacement was originally described as a solution for aneurysm, but its indications have expanded and now encompass a myriad of other pathologies, including acute aortic syndromes, genetic and familial aortopathies, endocarditis, and others.

We describe our experience with 100 consecutive patients who underwent primary elective aortic surgery for aneurysm over a two-year period. By focusing our analysis on the perioperative outcomes of this well-defined group of patients, we provide a modern-day perspective on what may be expected for these individuals, providing real-world data that can guide appropriate timing for surgical intervention.

MATERIALS AND METHODS

Patients

A comprehensive review was undertaken of our prospectively collected database to identify all patients who underwent surgery of the aortic root and/or ascending aorta over a two-year period, between 2014 and 2016.

The Institutional Review Board of Northwell Health approved this retrospective study.

Overall, 196 patients underwent proximal aortic surgery. Patients who underwent surgery for an acute aortic syndrome were excluded from analysis, as were patients with endocarditis. Reoperations were also excluded. Patients who were symptomatic from their aortic aneurysms, but who were otherwise clinically stable, were included in our review. Our final analysis was of 100 consecutive patients who underwent elective aortic root and/or ascending aortic surgery for aneurysm during the time period specified.

Demographics are outlined in Table 1. The majority of our patients were male. Mean age for our male patients was just over 61 years, slightly older than that for our female patients. A significant proportion of our patients had a history of systemic hypertension, not unexpected in an aneurysm cohort.

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Table 1. Preoperative Patient Demographics

Male sex, n	81
Age, male patients, mean ± SD, years	61.19 ± 13.33
Age, female patients, mean ± SD, years	59.85 ± 13.65
BMI, mean ± SD	28.39 ± 5.55
Congestive heart failure (NYHA III/IV)	17
Diabetes mellitus	18
Dialysis-dependent renal failure	1
Hypertension	76
Cerebrovascular disease	4
Peripheral vascular disease	4
COPD	13
Smoking history	11
Marfan syndrome	2
Bicuspid aortic valve	28
Maximum aortic diameter, mean ± SD, cm	5.01 ± 0.68

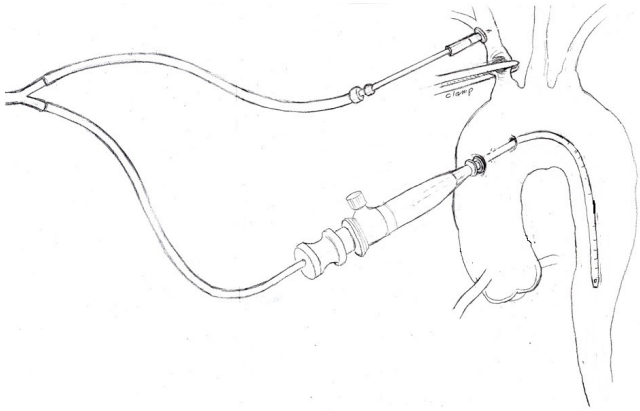
SD indicates standard deviation; NYHA, New York Heart Association; COPD, chronic obstructive pulmonary disease.

Two patients had a diagnosis of Marfan syndrome; 28 patients had aortopathy associated with bicuspid aortic valve. Mean preoperative maximal aortic diameter was 5.01 ± 0.68 cm.

Surgical Techniques

The distal ascending aorta was routinely used for arterial cannulation in all cases. In those patients in whom a period of hypothermic circulatory arrest was anticipated, the innominate artery was cannulated directly with a 7-French standard-tip DLP aortic root cannula (Medtronic, Minneapolis MN, USA) to facilitate selective antegrade cerebral perfusion. The arterial limb of our cardiopulmonary bypass circuit uses standard 3/8" tubing, with a customized 1/4" branched limb that has a perfusion adapter at its end that directly attaches to the innominate artery cannula (Figure).

In those cases requiring hypothermic circulatory arrest, once the patient's core temperature reached the desired target, the base of the innominate artery was clamped. The origin of the left common carotid artery was also clamped, so as to keep the circle of Willis pressurized. Cardiopulmonary bypass was terminated, and the ascending aorta was resected, being sure to include the cannulation and cross-clamp sites. Unilateral selective antegrade cerebral perfusion was initiated via the innominate artery perfusion limb of the bypass circuit, using blood at a temperature that was 2-3 degrees colder than the patient's body temperature. Cerebral perfusion flow was based on an initial flow rate of 6-10 mL/kg/min, but then was modified by arterial pressure, as directly measured by an arterial line sited in the right radial artery (target pressure 40-60mmHg), and then was adjusted according to continuous non-invasive monitoring of cerebral oxygen saturations using near-infrared spectroscopy (Nonin Medical, Plymouth, MN, USA) [Spielvogel 2013]. An appropriately sized Vascutek Gelweave Ante-Flo vascular graft (Terumo Cardiovascular Systems, Ann Arbor, MI, USA) was anastomosed to the base of the aortic arch with a running 4-0 prolene suture, buttressed with Teflon. The side-arm of this graft was used to reestablish cardiopulmonary bypass.



Cardiopulmonary bypass circuit for unilateral selective antegrade cerebral perfusion.

In all root procedures, a modified Bentall technique was employed, encompassing button re-implantation of the coronary arteries into the new aortic graft. The coronary button anastomoses themselves were completed using a running 5-0 prolene suture, supported by a small strip of Teflon. In those procedures that only involved replacement of the ascending aorta above the aortic root, the new vascular graft was anastomosed to the sinotubular junction with a running 4-0 prolene suture, also reinforced with Teflon.

For all valve-sparing root replacements, we utilized the reimplantation technique, as originally described by David and Feindel [David 1992], with slight modifications. We used a Vascutek Gelweave Valsalva graft (Terumo Cardiovascular Systems, Ann Arbor, MI, USA) to replace the aortic root, and the graft was anchored into the sub-annular plane using six mattress sutures. The native aortic valve was reimplanted within the new root graft using a number of running 5-0 prolene sutures.

Graft-to-graft anastomoses, when required, were completed with a running 3-0 prolene suture.

RESULTS

Intraoperative Data

Operative data is summarized in Table 2. Fifty-seven patients underwent aortic root replacement, of which 23 were valve-sparing procedures. Twenty-five patients required aortic valve replacement concomitant with supracoronary ascending aortic reconstruction. Only two patients in our entire cohort had mechanical aortic valves implanted. In those patients in whom the aortic valve was not replaced, 11 required some type of repair to the native valve.

Of those 89 patients who underwent replacement of the ascending aorta, the majority (89.9%) involved hemiarch

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Table 2. Operative Data

Aortic root replacement with valve/graft conduit	34
Valve-sparing aortic root replacement	23
Aortic valve replacement/ascending aortic replacement	25
Ascending aortic replacement	89
Hemiarch reconstruction	80
Aortic valve repair	11
Concomitant procedures	
CABG	20
Mitral valve repair	5
Septal myomectomy	2
Cryoablation maze	3
VSD repair	2
Ligation of coronary-cameral fistula	2
Cardiopulmonary bypass time, mean ± SD, min	133.93 ± 41.12
Cross-clamp time, mean ± SD, min	109.02 ± 39.38
Circulatory arrest time, mean ± SD, min	11.67 ± 3.39
Lowest core body temperature recorded, mean ± SD, °C	29.29 ± 2.39

CABG indicates coronary artery bypass grafting; VSD, ventricular septal defect.

Table 3. Postoperative Outcomes

Reoperation for bleeding	0
Stroke	2
New renal failure	0
Prolonged ventilation	6
Perioperative MI	0
Deep sternal wound infection	1
Sepsis of any cause	3
Transfusion during hospital stay	52
Length of postoperative hospital stay, median ± SD, days	7.74 ± 4.78
Readmission to hospital within 30 days	15
30-day mortality	0

MI indicates myocardial infarction.

reconstruction, with a period of circulatory arrest (mean 11.67 ± 3.39 minutes), at moderate hypothermia (mean body temperature 29.29 ± 2.39 degrees Centigrade).

A number of other procedures were completed in conjunction with the aortic reconstruction, encompassing pathologies that would be normally expected in an adult population presenting for cardiac surgery. The most common adjunctive procedure was coronary artery bypass grafting, done in 20 patients.

Perioperative Mortality and Morbidity

Perioperative outcomes are outlined in Table 3. Thirty-day mortality was zero. Two patients sustained a perioperative stroke, but both fully recovered prior to hospital discharge. One patient had an early sternal wound infection that required surgical reconstruction. No patients required reexploration for bleeding, although just over half of our patients required transfusion at some point during their admission. Fifteen patients were readmitted to hospital within 30 days of discharge. The 2 most common reasons for readmission were pleural effusion requiring drainage, and new-onset atrial fibrillation.

DISCUSSION

Our results demonstrate that proximal aortic reconstruction can be performed safely and reproducibly. We focused only on those patients who underwent primary elective surgery for aneurysm. This cohort of patients had zero 30-day mortality at our institution over the time period reviewed.

Our excellent perioperative results have been echoed by others, particularly by other larger volume aortic centers. Bilkhu and associates reported 1.2% in-hospital mortality in a cohort of 344 patients who underwent root replacement in a large-volume institution [Bilkhu 2016]. Similarly, McCarthy and colleagues described their experience with elective root replacement for aneurysm in a group of 220 patients, and they reported 2% 30-day mortality for patients with severe aortic insufficiency (AI), and 0% mortality for patients with moderate (or less) AI [McCarthy 2016].

It seems clear that patients do better in those centers that perform a larger number of aortic procedures per year. In their analysis of over 13,000 aortic root and aortic valve/ascending aortic procedures, utilizing data from the Society of Thoracic Surgeons Adult Cardiac Surgery Database, Hughes and associates demonstrated greater risk-adjusted mortality for patients undergoing surgery in institutions that perform fewer than 30-40 of these operations annually [Hughes 2013]. Stamou and colleagues described pooled data from the Society of Thoracic Surgeons Database, reporting overall mortality for aortic root surgery of 4.2%, higher than what we report in our results, but only 5% of centers performed more than 16 root procedures annually [Stamou 2015]. In another study looking at the outcomes of 954 patients who underwent root replacement over a 12-year period, mortality for elective surgery was reported as high as 3.6%, although it is unclear from this paper as to what extent individual institutional case volumes may have impacted upon the results [Dhurandhar 2016].

A detailed discussion of cerebral protection strategies in aortic surgery is beyond the scope of this paper. The literature is replete with different techniques of cerebral protection that can be employed during circulatory arrest, although there seems to be an evolving trend away from deep hypothermia, towards more moderate hypothermia and the more routine use of antegrade cerebral perfusion. Recent data suggests that unilateral antegrade cerebral perfusion is associated with excellent perioperative outcomes [Leshnower 2013; Poon 2016; Leshnower 2012], and that deep hypothermia does not provide any extra benefit, particularly for shorter circulatory arrest times [Leshnower 2015]. Our data supports this: we

had a mean circulatory arrest time of 11.67 minutes at a body temperature of 29.29 degrees Centigrade.

Bilateral antegrade cerebral perfusion does not seem to result in superior outcomes, as compared with unilateral perfusion techniques [Angeloni 2015; Angeloni 2014; Zierer 2014; Zierer 2012; Preventza 2015], especially for simpler procedures. In their review of the literature, Spielvogel and colleagues comment that unilateral perfusion is adequate for shorter periods of circulatory arrest (defined as less than 40 minutes), but that bilateral antegrade perfusion may be worth considering for more prolonged operations [Spielvogel 2013].

Our technique of unilateral selective antegrade cerebral perfusion is simple and reproducible, using a custom-designed bypass circuit (Figure), and is associated with excellent neurological outcomes. Only two patients in our cohort sustained a perioperative stroke, a result that compares favorably with other contemporaneous reports [Arabkhani 2015; Mok 2017]. In addition to utilizing antegrade cerebral perfusion via the innominate artery, we also clamp the base of the left common carotid artery in order to keep the circle of Willis pressurized and thereby prevent a steal phenomenon. To the best of our knowledge, this technical modification has not, as yet, been widely described.

There is unequivocal data that aortic surgery in the setting of an acute dissection is associated with poorer outcomes. In a review of patients undergoing repair of an acute Stanford type A aortic dissection, utilizing data obtained from the International Registry of Acute Aortic Dissection (IRAD), early mortality was reported as high, even in the current era (17-26%), even in the hands of experienced surgeons in high-volume aortic centers [Berretta 2016; Trimarchi 2005]. In another IRAD study, Pape and colleagues reported that mortality in acute dissection has improved over time, decreasing from 25% to 18% over a 17-year period [Pape 2015], although this is still markedly worse than outcomes expected after elective surgery, as our results confirm.

The 2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM Guidelines for the Diagnosis and Management of Patients with Thoracic Aortic Disease suggest that surgical intervention be considered for patients with asymptomatic aneurysms of the aorta that exceed 5.5 cm (Class IC recommendation), although this threshold is lowered for genetic aortopathies, for patients who demonstrate symptoms referable to their aneurysm or rapid growth of their aneurysm, or for patients who are undergoing an aortic valve procedure for another indication but who have a coincident aortic aneurysm [Hiratzka 2010]. In a recent clarification looking specifically at patients with bicuspid aortic valves, the advisory group still maintains that 5.5 cm is the threshold at which surgical repair should be considered in otherwise asymptomatic patients (Class IB recommendation), although the authors do make the qualifying statement that patients may be considered for surgery if the aorta is greater than 5.0 cm and if the procedure is being performed by an experienced team in a larger volume center [2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM guidelines], reinforcing the relationship between institutional surgical volume and patient outcomes.

In his landmark paper assessing the natural history of aortic aneurysm, Elefteriades demonstrated an exponential increase in the risk of aortic-related complications at aortic diameters that exceed 6.0 cm [Elefteriades 2002], and this important data underlies a large component of the recommendations for intervention. However, in the same report, the author comments that the perioperative mortality for elective aortic surgery was 2.5% at that time, somewhat higher than our results would indicate as the current acceptable norm. Moreover, the very same study estimates a cumulative annual risk of aortic rupture/dissection/death of 6.5% for ascending aortas that exceed 5.0 cm, and 5.3% for aortas greater than 4.0 cm. In another IRAD study, Pape and associates reported that over half of acute dissections occurred in aortas smaller than 5.5 cm [Pape 2007]. This sobering information was also echoed by Parish and colleagues who analyzed aortic diameters in 177 non-Marfan patients who presented with acute type A dissections; they found that 62% of patients had aortic diameters that were less than 5.5 cm at the time of dissection, 42% had aortas that were less than 5.0 cm, and over 20% had maximal aortic dimensions of less than 4.5 cm [Parish 2009]. There seems to be little doubt that aortic catastrophe is still possible even in those smaller aortas that do not meet the traditional indications for surgical repair.

It may no longer be appropriate to wait for aortic aneurysms to reach 5.5 cm prior to surgical repair, especially if the procedure can be performed with reproducibly low morbidity, as our results indicate. In a more recent review, Elefteriades comments that "we use 5.0 cm for our intervention criterion for the ascending aorta in healthy individuals because the operations can be performed safely, making a lower criterion point reasonable" [Elefteriades 2015]. Our data parallels this approach: the mean maximum preoperative aortic diameter in our patient group was 5.01 ± 0.68 cm.

This is particularly important when one recognizes that patients who present with aneurysms tend to be relatively young. In a meta-analysis of over 7600 root replacements, Mookhoek and colleagues reported a mean patient age of 49.8 years [Mookhoek 2016]. Similarly, in a 30-year review of aortic root surgery for aneurysm, Zehr and co-workers reported a mean patient age of 54 years for those patients undergoing standard root replacements, and a mean age of 51 years for those patients who underwent a valve-preserving procedure [Zehr 2004]. Our patients were hovering around the 60 year-old mark, with males being slightly older than females.

The multidisciplinary Heart Team approach has evolved from the realms of coronary artery surgery and transcatheter valve therapy to become the standard of care in cardiovascular disease [Passeri 2015; Holmes 2013]. We have aggressively adopted this model of patient care into our aortic surgery program. The patient with aortic disease requires regular clinical assessment and timely referral for surgery, and needs high-quality, dynamic, multi-modality imaging. They need a safe and reproducible operation which may involve complex circulatory management, and that may incorporate both open and endovascular components. Rigorous postoperative care is also vital to ensure success, best accomplished by a team that is well-versed in the specifics of patient management more

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typically seen in the aortic surgery patient. Our Heart Team approach does not stop when the patient leaves the hospital, but continues with frequent outpatient follow-up and monitoring. The Heart Team concept perfectly aligns with the data that higher-volume centers afford superior outcomes, as the entire multidisciplinary team continues to evolve and improve with each and every case.

This retrospective study has a number of limitations, the most significant of which is that it only includes a relatively small number of patients, and it is largely observational in nature. Additionally, we have not addressed longer-term follow-up, although, since we only chose to include those patients undergoing elective aneurysm surgery, we would anticipate late survival to be not too dissimilar from age and sex-matched controls, as has been shown by others [Etz 2010].

In conclusion, we suggest that elective primary surgery for aneurysm of the proximal thoracic aorta is safe, reproducible, and associated with excellent results. It may be appropriate to offer surgery earlier to younger patients, even if their aortic diameters do not yet meet traditional guidelines for intervention, particularly in larger-volume centers that are experienced with these procedures.

JREFERENCES

2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM guidelines for the diagnosis and management of patients with thoracic aortic disease representative members. Hiratzka LF, Creager MA, Isselbacher EM, Svensson LG; 2014 AHA/ACC guideline for the management of patients with valvular heart disease representative members. Nishimura RA, Bonow RO, Guyton RA, Sundt TM III. Surgery for aortic dilatation in patients with bicuspid aortic valves. A statement of clarification from the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. J Thorac Cardiovasc Surg 2016; 151:959-66.

Angeloni E, Benedetto U, Takkenberg JJ, et al. 2014. Unilateral versus bilateral antegrade cerebral protection during circulatory arrest in aortic surgery: a meta-analysis of 5100 patients. J Thorac Cardiovasc Surg 147:60-7.

Angeloni E, Melina G, Refice SK, et al. 2015. Unilateral versus bilateral antegrade cerebral protection during aortic surgery: an updated meta-analysis. Ann Thorac Surg 99:2024-31.

Arabkhani B, Mookhoek A, Di Centa I, et al. 2015. Reported outcome after valve-sparing aortic root replacement for aortic root aneurysm: a systematic review and meta-analysis. Ann Thorac Surg 100:1126-31.

Bentall H, De Bono A. 1968. A technique for complete replacement of the ascending aorta. Thorax 23:338-9.

Berretta P, Patel HJ, Gleason TG, et al. 2016. IRAD experience on surgical type A acute dissection patients: results and predictors of mortality. Ann Cardiothorac Surg 5:346-51.

Bilkhu R, Youssefi P, Soppa G, et al. 2016. Aortic root surgery: does high surgical volume and a consistent perioperative approach improve outcome? Semin Thorac Surg 28:302-9.

David TE, Feindel CM. 1992. An aortic valve-sparing operation for patients with aortic incompetence and aneurysm of the ascending aorta. J Thorac Cardiovasc Surg 103:617-22.

Dhurandhar V, Parikh R, Saxena A, et al. 2016. The aortic root replacement procedure: 12-year experience from the Australian and New Zealand Society of Cardiac and Thoracic Surgeons database. Heart Lung Circ 25:1245-51.

Elefteriades JA. 2002. Natural history of thoracic aortic aneurysms: indications for surgery, and surgical versus nonsurgical risks. Ann Thorac Surg 74:S1877-80.

Elefteriades JA, Ziganshin BA, Rizzo JA, et al. 2015. Indications and imaging for aortic surgery: size and other matters. J Thorac Cardiovasc Surg 149:S10-3.

Etz CD, Bischoff MS, Bodian C, et al. 2010. The Bentall procedure: is it the gold standard? A series of 597 consecutive cases. J Thorac Cardiovasc Surg 140:S64-70.

Halstead JC, Spielvogel D, Meier DM, et al. 2005. Composite aortic root replacement in acute type A dissection: time to rethink the indications? Eur J Cardiothorac Surg 27:626-32.

Hiratzka LF, Bakris GL, Beckman JA, et al. 2010. 2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM guidelines for the diagnosis and management of patients with thoracic aortic disease: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, American Association for Thoracic Surgery, American College of Radiology, American Stroke Association, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society of Interventional Radiology, Society of Thoracic Surgeons, and Society for Vascular Medicine. Circulation 121:e266-369.

Holmes DR Jr, Rich JB, Zoghbi WA, Mack MJ. 2013. The heart team of cardiovasc care. J Am Coll Cardiol 61:903-7.

Hughes GC, Zhao Y, Rankin JS, et al. 2013. Effects of institutional volumes on operative outcomes for aortic root replacement in North America. J Thorac Cardiovasc Surg 145:166-70.

Kouchoukos NT, Wareing TH, Murphy SF, Perrillo JB. 1991. Sixteen-year experience with aortic root replacement. Results of 172 operations. Ann Surg 214:308-18.

Leshnower BG, Myung RJ, Thourani VH, et al. 2012. Hemiarch replacement at 28◦C: an analysis of mild and moderate hypothermia in 500 patients. Ann Thorac Surg 93:1910-5.

Leshnower BG, Myung RJ, Chen EP. 2013. Aortic arch surgery using moderate hypothermia and unilateral selective antegrade cerebral perfusion. Ann Cardiothorac Surg 2:288-95.

Leshnower BG, Thourani VH, Halkos ME, et al. 2015. Moderate versus deep hypothermia with unilateral selective antegrade cerebral perfusion for acute type A dissection. Ann Thorac Surg 100:1563-8.

McCarthy FH, Bavaria JE, McDermott KM, et al. 2016. At the root of the repair debate: outcomes after elective aortic root replacements for aortic insufficiency with aneurysm. Ann Thorac Surg 102:1199-205.

Mok SCM, Ma W, Mansour A, et al. 2017. Twenty-five year outcomes following composite graft aortic root replacement. J Card Surg 32:99-109.

Mookhoek A, Korteland NM, Arabkhani B, et al. 2016. Bentall procedure: a systematic review and meta-analysis. Ann Thorac Surg 101:1684-90.

Pape LA, Tsai TT, Isselbacher EM, et al. 2007. Aortic diameter > or = 5.5 cm is not a good predictor of type A aortic dissection: observations from the International Registry of Acute Aortic Dissection (IRAD). Circulation 116:1120-7.

Pape LA, Awais M, Woznicki EM, et al. 2015. Presentation, diagnosis, and outcomes of acute aortic dissection: 17-year trends from the International Registry of Acute Aortic Dissection. J Am Coll Cardiol 66:350-8.

Parish LM, Gorman JH 3rd, Kahn S, et al. 2009. Aortic size in acute type A dissection: implications for preventive ascending aortic replacement. Eur J Cardiothorac Surg 35:941-5.

Passeri JJ, Melnitchouk S, Palacios IF, Sundt TM. 2015. Continued expansion of the Heart Team concept. Future Cardiol 11:219-28.

Poon SS, Estrera A, Oo A, Field M. 2016. Is moderate hypothermic circulatory arrest with selective antegrade cerebral perfusion superior to deep hypothermic circulatory arrest in elective aortic arch surgery? Interact Cardiovasc Thorac Surg 23:462-8.

Preventza O, Simpson KH, Cooley DA, et al. 2015. Unilateral versus bilateral cerebral perfusion for acute type A aortic dissection. Ann Thorac Surg 99:80-7.

Spielvogel D, Kai M, Tang GH, Malekan R, Lansman SL. 2013. Selective cerebral perfusion: a review of the evidence. J Thorac Cardiovasc Surg 145(3 Suppl):S59-62.

Stamou SC, Williams ML, Gunn TM, et al. 2015. Aortic root surgery in the United States: a report from the Society of Thoracic Surgeons database. J Thorac Cardiovasc Surg 149:116-22.

Trimarchi S, Nienaber CA, Rampoldi V, et al. 2005. Contemporary results of surgery in acute type A aortic dissection: The International Registry of Acute Aortic Dissection experience. J Thorac Cardiovasc Surg 129:112-22.

Zehr KJ, Orszulak TA, Mullany CJ, et al. 2004. Surgery for aneurysms of the aortic root. A 30-year experience. Circulation 110:1364-71.

Zierer A, El-Sayed Ahmad A, Papadopoulos N, et al. 2012. Selective antegrade cerebral perfusion and mild (28◦C - 30◦C) systemic hypothermic circulatory arrest for aortic arch replacement: results from 1002 patients. J Thorac Cardiovasc Surg 144:1042-9.

Zierer A, Risteski P, El-Sayed Ahmad A, et al. 2014. The impact of unilateral versus bilateral antegrade cerebral perfusion on surgical outcomes after aortic arch replacement: a propensity-matched analysis. J Thorac Cardiovasc Surg 147:1212-7.

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