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Can the Results of Aortic Valve Repair Equal the Results of a Biologic Aortic Valve Replacement?

Mohamad Bashir, MD, MRCS1*, Aung Oo, MD, FRCS(CTh)1, Ruggero De Paulis, MD2, Michael A. Borger, MD, PhD3, Gebrine El Khoury, MD4, Joseph Bavaria, MD5, John A. Elefteriades, MD6

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Abstract

Aortic valve repair (AVR) has been the default procedure for the surgical management of aortic valve disease, with repair techniques heterogeneously and infrequently used. However, surgical aortic valve repair has evolved with improved techniques. Yet many questions remain regarding ideal techniques and real-world applicability and effectiveness of valve repair. The AORTA Great Debate highlighted and discussed the controversies regarding the surgical management of aortic valve disease.

Key Words

Aortic valve replacement · Aortic valve repair · Aortic valve · Aortic valve surgery

Introduction

Type and timing of surgical intervention for significant aortic valve disease continue to be controversial and debated. Historically, aortic valve replacement (AVR) has been the default procedure for the surgical management of aortic valve disease, with repair techniques heterogeneously and infrequently used. However, surgical aortic valve repair has evolved with improved techniques and increased understanding of valve pathology. Yet many questions remain regarding ideal techniques and real-world applicability and effectiveness of valve repair.

The Debate took place at the 2013 Surgery of the Thoracic Aorta (STA) meeting in Bologna, Italy on the 12th of November. The Debate highlighted the aforementioned underlying issues and discussed whether the results of aortic valve repair in different pathologic entities can match the results of bioprosthetic AVR.

As the chairman of the STA meeting, Prof. Di Bartolomeo opened the session with a welcoming note to all the delegates and panel.

The panel of the Debate included Mr. Aung Oo from the Aortic Aneurysm Service at Liverpool Heart and Chest Hospital (LHCH), Dr. Ruggero De Paulis from the Cardiac Surgery Department, European Hospital-Rome, Dr. Michael Borger from the Heart Center Leipzig-Germany, Prof. Gebrine El Khoury from St-Luc Hospital, Belgium, and Dr. Joseph Bavaria from the University of Pennsylvania. The debate was moderated by Dr. John A. Elefteriades of the Aortic Institute at Yale University.

The aim of this article is to provide a transcription of the Debate. A video recording of the Debate is also available via the interactive features of AORTA (http://dx.doi.org/10.12945/j.aorta.2014.14.005.vid.01).

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Dr. Elefteriades. Good morning. Through the journal AORTA, we will be holding regular debates to be published in the journal on important topics in aortic disease. Through this Debate program, we would like to take a thirty thousand foot view of certain issues in our specialty and have experts like we have today assembled to discuss these different issues. For this morning, we have chosen the topic of aortic valve repair and framed it around the question - “Can the results of aortic valve repair equal the results of a biologic aortic valve replacement?”

With these experts here today, we would like to look at a number of specific questions around this topic. I have asked Dr. Mohamad Bashir from LHCH to start off the session by presenting his data from a systematic review and meta-analysis of aortic valve repair (AVRep) in the published literature.

Dr. Mohamad Bashir. Thank you Dr. Elefteriades and good morning Chairman, members of the panel and colleagues.

It is a privilege to be asked by Dr. Elefteriades to present the results of our meta-analysis and I would like to thank also Prof Di Bartolomeo for giving us this excellent opportunity. We have systematically looked at the published literature on aortic valve repair and conducted a meta-analysis from that. Because this will be a brief presentation, I will point out to you the reoperation rates according to etiology, based on bicuspid aortic valve (BAV), cusp prolapse, and aortic root aneurysm. I am just going to set a brief conclusion toward that.

We looked at 8761 papers that reported aortic valve repair pooled from 3 main electronic databases (PubMed, OVID & COCHRANE) (Fig. 1). Out of these 8761 we pulled out 261 papers that potentially matched our inclusion and exclusion criteria. We ended up with 24 relevant papers from which we derived our analysis. All papers reported in-hospital mortality (Fig. 2) and as you can see all papers are listed in the slide. The In-hospital mortality weighted average was 1.46% following aortic valve repair. We also looked at reoperation rates (Fig. 3), and this slide shows reoperation following bicuspid aortic valve repair. These were the papers that mentioned reoperation and as you can see the weighted average is 10.23% with an average follow-up of 4.1 years. This slide shows reoperation following valve cusp prolapse.

Figure 1. Identified results from 3 databases (PUBMED, OVID and COCHRANE). 24 studies were included in the systematic review and meta-analysis.
repair (Fig. 4) and the weighted average for this was 3.83% with an average follow-up of 3.72 years. Moreover, this slide shows also the reoperation on the aortic valve following aneurysm repair (Fig. 5), with a weighted average of 4.25% and an average follow-up of 3.2 years. We concluded that aortic valve repair may be a useful option for selected patients. However, there is a lack of uniformity in data reporting and lack of compelling supportive evidence for valve repair. We obviously encourage an international multi-center study comparing and assessing the results between aortic valve repair and replacement. Thank you.

**Dr. Elefteriades.** Thank you, Mohamad. Now I would like to frame the discussion for the panel around a number of particular questions. I start out with a quotation that “Several repair techniques have been described to correct aortic valve dysfunction. In contrast to mitral valve repair techniques, few of them have become the gold standard because of the unpredictability of their results.” Now this quotation comes from probably the greatest valve surgeon in history, Dr. Alain Carpentier. In particular, it points out that there is a small amount of tissue with a smaller potential surface area of coaptation and this prejudices negatively aortic valve repair compared to mitral valve and tricuspid repair.
I would like to start out by asking the panelists to comment on this. In particular, do you feel that aortic valve repair is in the same league as mitral valve repair or do you share Dr. Carpentier’s thoughts about the lack of adequate substrate of tissue for repair?

Prof El Khoury. I think if we look to the aortic valve as a leaflet only, I think Carpentier is right. But nevertheless, I think we should look at the aortic valve not only as a leaflet but also as a functional unit. So, the goal of any valve repair, as Carpentier says, is really the matching between the orifice and the quantity of tissue we have. So if we have less tissue, we reduce the annulus or we add the tissue; the goal is really to restore the match of quantity between the orifice and quantity of tissue. I cannot really agree with Carpentier that what he says is a limiting factor for us. We should really always find the equilibrium between the quantity of tissue and the orifice. That is my opinion.

Dr. Elefteriades. Thank you Dr. El Khoury. I think everyone in this room has tremendous respect for the techniques you have developed and taught. Do we have other comments from the panel on this question?

Dr. De Paulis. I personally think that what Carpentier was meaning is the quality of tissue is different, of course, between the mitral and the aortic valve. The tissue of the aortic valve is much thicker so it’s difficult to deal with, and besides the leaflet and the annulus, there are other components present in both. I think for the mitral there are the chordae, which is a component we do not have in the aortic valve—and that is what makes things probably more difficult. Also regarding the quality of tissue, I think there is also a difference between the bicuspid and tricuspid in terms of tissue. That is why sometimes it is easier to repair a bicuspid than a tricuspid valve, because anatomically the geometry is different and also the quality of tissue.

Mr. Oo. The answer to the question is yes. I am sure Dr. Carpentier is right. It is easier to repair a bicuspid valve rather than creating a tricuspid from bicuspid valve. Due to the difference in quality and amount of tissue, aortic valve repair has a narrower margin of error. We have seen Professor El Khoury and Professor Schaeffer performing excellent aortic valve repair. We are grateful for their contribution in advancement and progress of aortic valve repair. However, I have to agree with Dr. Carpentier that the margin of error is too much to accept for surgeons like us who started repairing aortic valves.

Prof El Khoury. Only a short answer, I mean it’s difficult, it is a little bit confusing to say that bicuspid valve repair is easier to be repaired than the tricuspid. I mean the problem is that I agree that on the level of the leaflet, yes, because we have two lines of coaptation to control. But the big problem in bicuspid is not only the leaflet; it is really the (aortic) root, the annulus. So for me it is much more difficult to have a good valve repair in bicuspid aortic valve than in tricuspid aortic valve. It is really, for me, more difficult. It is not only the problem of the leaflet, but we should take care of the VAJ (ventricular aortic junction), which is really very difficult to treat in bicuspid aortic valve.

Dr. Bavaria. I think the substrate issue is the answer to your question. There is a difference between leaflet surface area availability and substrate. I think you can answer the substrate issue with one simple question or simple observation: How many times in your practice have you ever seen a Marfan’s patient need an aortic valve replacement in the absence of an aneurysm? The answer is zero—never. So the substrate and, even the worst patient of all is the Marfan’s patient, has nothing to do with need to repair. So if you can take a Marfan’s patient, with their crummy substrate, and you put in a normal geometric aortic root, then that valve will last forever, because you never see an isolated aortic valve replacement in the absence of an aneurysm in Marfan’s patients. So I do not think the substrate issue has any issue.

Dr. De Paulis. I would like to make another comment regarding what Gebrine just said. It is true when you speak about bicuspid and tricuspid you are speaking about two entities, but while tricuspid is more or less looking the same, bicuspid has a lot of variability. So it is true in some cases that it can be easy to repair, so the spectrum of bicuspid is so variable, that probably can make comments different depending on what the presentation of bicuspid is like. The unicuspid we saw yesterday is very different too.

Dr. Elefteriades. Thank you; let us move on to some other particular questions. This is some very recent published data about the longevity of biological valves (Fig. 6), and as we can see, in patients over 70 there is no reoperation whatsoever. In patients
60-70, results are very good, and even patients less than 60 at 10 years have greater than 90% freedom from reoperation. Let me ask the panel, how do you feel about biological valves in the aortic position? Are you concerned that the poorer performance in younger people is an “Achilles’ heel” of the biological valve?

Mr. Oo. In my opinion, biological valves in most of our hands are reliable and predictable. If you look at the recent results published in the paper that you kindly alluded to, as well as the published results of aortic valve repair by Professors El Khoury and Schaffer, demonstrating 90% freedom from structural degeneration at three years, I think biological valves perform better at three years. The second question is if we feel that the results in younger patients are the Achilles’ heel of the biological valve?

Dr. Elefteriades. In my opinion, the main issue is the selection of patients. Young patients with normal leaflets are excellent candidates for aortic valve repair. We should really highlight the difference, as with the mitral valve, if we have a leaflet problem or annulus problem. The annulus problem for me is the aneurysm, the dilatation of aortic root, sinotubular junction or ventriculo-annular junction. We should really look to this functional aortic annulus exactly the same way as the mitral annulus. So if we are talking about the pathology of [the] annulus of the aortic valve with normal leaflets, the result will be perfectly reliable. That valve will function forever. If you look to the cusp pathology—leaflet pathology, prolapse, calcification, thickening—those are different. So if you are talking only about prolapse with normal leaflets, then I think when you repair the prolapse you achieve immediate good results and the valve will last for a long time. I think we should really insist [upon] now—because this is evolving surgery—the aortic valve repair. We should insist more and more on the selection of patients for aortic valve repair in young patients with normal leaflets or dilated aortic root. This is really my opinion.

Dr. Elefteriades. Thank you. Let’s move on (to a) couple other questions. These are very recently published results from Mayo from Dr. Schaff (Fig. 7) applying all of the aortic valve repair techniques, and they show a 20% reoperation rate at 10 years. So I would like to ask the panel: Do you think we can really match the durability of biological valves in the aortic position and how do you feel about a 20% reoperation rate, especially if it’s a young patient? How do you feel about these data?
Dr. Bavaria. I think these data are wrong. This is data from way back. Especially bicuspid, but even three cusps aortic valve repair techniques, really have only matured in the last decade, and the results now are so much better than looking at that old commissural operation that they did in Mayo for all these years. I actually don’t believe this data, and I think it’s irrelevant. It is kind (of) like a text book; it is already gone in history. I think if you look at the newest data, though, about the newest repair techniques, both for bicuspid and three cusps aortic valve, especially if you use reimplantation techniques, the reoperation rates are much lower than what you are seeing here. And also, going back to that last slide, the average age of patients in these aortic valve repair series are in their 40s and tissue valves are not very good for that age group. How I feel about this data, I think it is irrelevant.

Dr. De Paulis. I think if you consider the last slide you showed, I think it shows a 10% reoperation at 10 years for biological valve below the age of 60. Just briefly, there have been published reviews or known results for valve repair, bicuspid or tricuspid. The average at five years was 10% (reoperation) among all the most relevant studies. So now, I think because in recent years many advances (have) been made (in valve repair), at five years the result is the same as biological prosthesis, also at 10 years. The problem is—if we can reach 10 years with the valve repair, it is much better than with bioprosthesis, because after 10 years the bioprosthesis [results] at that age will go steeply (downward).

Dr. Elefteriades. These are all very important points. Let me move on to a couple more questions. Basically all the experts have made major changes in their techniques of repair within the last ten years, just to the point you were making that some of the old data have been outmoded. What are the implications for patients treated earlier, and do we know that our new, current techniques will be durable? Can I have some comments on that, please?

Mr. Oo. Can I start with that. We are mixing up different patient groups here. I have no problem with the valve reimplantation (David) procedure. These are
(a) different group of patients compared to the group where you perform leaflet repair. If you perform a good reimplantation procedure, I have no doubt that the operation would be durable. This is a technique that we should teach surgeons to perform to a high standard. However, the leaflet repair techniques and annuloplasty techniques, over the last decade, have undergone so many modifications. These techniques have been evolving with variable results even in the best hands. We can still see three year results of valve repair with the freedom from structural dysfunction of 90%. It would be worse in the hands of average surgeons like me. Therefore, at this time point in the aortic valve repair era, I do not think that the leaflet repair on its own will be durable.

Prof El Khoury. I agree, and if you go back to the last slide, I do not know about what patients they are talking about. That is really the problem now in aortic valve repair and the entire published articles. I think some years ago I wrote a paper about the comparison between mitral and aortic repair; and if you want to progress in our communications and in our aortic valve work, I think we should know what we are talking about. If you look into the sparing surgery, for me that is an annulus problem; so then we talk about only (an) annulus problem, like the mitral. And, if you talk about the leaflet, then that is another problem. We should look at the prolapse case of yesterday. So, we should really know what we are talking about, and that is the big problem in aortic valve repair. We should have analogous work when talking about valve repair. When you see the 20% recurrence following aortic repair operation, I do not know if it was aneurysm, rheumatic, endocarditis, calcific, bicuspaid or tricuspid. We do not know. I think in order to progress we should now separate when we talk about valve-sparing surgery, about tricuspid aortic valves, about prolapse, about rheumatic vales, so in that way we can compare our results meaningfully. Really, going forward we need to focus on identifying the excellent candidate for valve repair regarding the most appropriate surgical techniques, yielding the most appropriate immediate results. We know that was necessary for mitral valve progress, and in order to progress on the aortic side, we should do the same work and focus on the pathol-

ogy and the selection of patients and see about what we are talking.

Dr. Elefteriades. Let me ask one more question before I invite each panelist to give his summary. If there is mild or moderate aortic insufficiency after aortic valve repair, are you concerned about that? Are you concerned that it may be dangerous, like what we are seeing for AI after Transcatheter Aortic Valve Implantation (TAVI)?

Dr. De Paulis. In our analysis of the aortic valve sparing operation, the most important finding, or variable, was the AI after operation, meaning that if you accept 2+ AI that is not central, then you will have bad results in the long term.

Dr. Borger. Residual AI is a very suboptimal result, but it does not lead to decreased survival. In TAVI patients, AI does affect survival because the AI is acute. A hypertrophied left ventricle that has been pumping against a stenotic, but not insufficient, valve for the last 20 years very poorly tolerates new AI. It is a dangerous situation for these patients. Patients presenting for aortic valve repair surgery, however, have had AI for many years and therefore mild to moderate AI is not going to have a significant impact on their survival. But it does result in these patients coming back earlier for re-operation. So, that brings us back to the previous question regarding the unknown durability of newer repair techniques. The best way to ensure durability is to make sure you have as little AI as possible at the end of the operation, and then you are more confident that the repair is going to be durable no matter what technique you used to get there. But it involves also learning from our colleagues. Even Joachin Schaefers, who is the world’s biggest supporter of the Yacoub operation, admits that his colleagues have convinced him that you should not perform a Yacoub operation if the patient’s annulus is more than 27 mm. What we learned from Gebrine’s group is that if there is residual cusp prolapse, even if the valve is competent, that has a negative effect on durability. So it is a constant learning process and we are also learning from each other.

Prof El Khoury. I totally agree. The big problem is to see what residual regurgitation you have. If we have eccentric regurgitation, we should have zero tolerance for that, if you have an eccentric jet. If you have a central jet with a good coaptation, with a good
configuration of the leaflet, I think this one is not so hard for the future. Again we have our echocardiographers, we have our cardiologists in the OR and our anesthesiologists; they should do an excellent echo and the echo should be excellent in the OR, and if you have any eccentric jet you should not accept it. That is really the message.

Mr. Oo. One thing to add though: over the years, in the name of advancement, we've accepted more and more imperfect operations. When we started with TAVI, it was stated that mild paravalvular leak was acceptable, so as with mild and then moderate mitral regurgitation after mitral valve repair. There is now evidence of poor prognosis with AI following TAVI. We should not go along with the same statement that aortic valve repair is good (with residual AI). We should not be accepting patients leaving theater with mild to moderate aortic regurgitation as I have no doubt that it will affect left ventricular function over (the) next three to five years.

Dr. Elefteriades. These are all valuable comments. Let me, in concluding, just go down the panel and ask you to give me a “yes” or “no” answer about whether you feel aortic valve repair can equal the results of a biological prosthetic aortic valve. Do you want to start, Mr. Oo and go down the panel can you give me please a yes or no answer and a brief concluding comment? [See Table 1 for the panelists’ responses.]

Mr. Oo. Since we cannot categorize different groups in the aortic valve repair patients, I will answer for the repair in general. In my opinion, aortic valve repair cannot be equal to the results of a biological prosthetic aortic valve.

Dr. Elefteriades. What was the answer?

Mr. Oo. No.

Prof El Khoury. (With appropriate) selection of patients and appropriate surgical techniques applied to the patients, I’m convinced that aortic valve repair is even better than bioprosthesis.

Dr. De Paulis. I will say no depending on the age. Let us say at the age of 65-70, I will say repair cannot be equal to a biological valve replacement; it is not worth it. But in the younger patient population, it is worth a try because techniques are getting close to that point, and any necessary redo operation will be much easier.

Dr. Borger. I say yes if the cusps are pliable and if it is done in a referral center.

Dr. Bavaria. I think anybody who has pure AI, no calcification, bicuspid or tricuspid aortic valve repair is not only equal, but superior at all age groups compared to a biological prosthesis. I remember 20 years ago, 15 years ago when we said “Oh, we are not going to do a mitral valve repair in a 75 year old”. That is history.

Prof El Khoury. One last item, maybe we should also talk about the survival of the patients and young patients. The survival when we have a prosthetic is much less than aortic valve repair. We forgot to talk about the survival. When you have a prosthesis—a lot of patients disappear.

Dr. De Paulis. Yes, but I think in survival the conditions of the patients are different, that is what influences the survival. Not the technique, but the general condition of the patients.

Prof El Khoury. The young patients survive better.

Dr. Borger. There is a 10% survival gap in biological valve patients compared to normal age-matched population that nobody can explain. That is, an additional 10% of patients are dead 10 years postoperatively and nobody knows why. And that does not seem to be the case for aortic valve repair or for the Ross operation.

Mr. Oo. May I ask a few questions to the audience, please?

Dr. Elefteriades. Please.

Mr. Oo. You have seen the great surgeon(s) who have developed the techniques on valve repair, operate on two cases. First of all, I would like to know—how many of you perform regular aortic valve repair?
repair? Could you give me a show of hands, please? Maybe 10-12 people in the audience.

Prof El Khoury. Some years ago it was two!

Mr. Oo. And the next question I would like to ask is—how many of you perform more than 20 aortic valve repairs per year? Maybe 10? How many of you perform more than 20 bioprosthetic valve replacements per year? Everybody in the audience. The final question is—if you are 50 year(s) old and have aortic valve disease with some calcification and thickening (like yesterday’s first case), would you like your valve to be repaired or replaced? How many in favor of repair? One. How many want valve replacement? Majority. I rest my case.

Dr. Elefteriades. We got some animation from the panel here in this debate. I want to thank all the panelists for sharing their expertise with us. Thank you!

Conflict of Interest

The authors have no conflict of interest relevant to this publication.

Comment on this Article or Ask a Question

References


Aortic Valve Repair: A Systematic Review and Meta-analysis of Published Literature

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Abstract

Background: It is widely accepted that aortic valve disease is surgically managed with aortic valve replacement (AVR) using different available prostheses. The long-term survival, durability of the valve, and freedom from reoperation after AVR are well established in published literature. Over the past two decades, aortic valve repair (AVr) has evolved into an accepted surgical option for patients with aortic valve disease. We review and analyze the published literature on AVr.

Methods: A systematic review of the current literature was performed through three electronic databases from inception to August 2013 to identify all relevant studies relating to aortic valve repair. Articles selected were chosen by two reviewers. Articles were excluded if they contained a pediatric population or if the patient number was less than 50.

Results: Twenty-four studies conformed to the inclusion criteria for inclusion in the systematic review. In total, 4986 patients underwent aortic valve repair. 7 studies represented bicuspid aortic valve (BAV) repair, 5 studies represented cusp prolapse, and 3 studies represented valve repair with root dilation or aneurysm. Overall weighted in-hospital mortality for all studies was low (1.46% ± 2.46). Although there are limitations and complications of prosthetic valves, especially for younger individuals, there is ample published literature that confers strong evidence for AVR. On the contrary, aortic valve repair may be a useful option for selected patients, but there is lack of uniformity in data and absence of compelling supporting evidence. An international multi-center study comparing and assessing the results between AVR & AVr is the next step required. Currently, higher levels of evidence do not exist for aortic valve repair.

Key Words
Aortic valve repair · Aortic valve replacement · Aortic valve surgery · Meta-analysis · Aortic valve

Introduction

It is widely accepted that aortic valve disease is surgically managed with aortic valve replacement (AVR) using different available prostheses. The long-term results and survival, durability of the valve, and freedom from reoperation after AVR are well established in published literature. Over the past two decades, aortic valve repair (AVr) has evolved into an accepted surgical option for patients with aortic valve disease. Current understanding of the mech-
anisms of valve dysfunction and the etiology of lesions enabled surgeons to modify their techniques in aortic valve repair. Although early results are acceptable, the long-term results, durability of the repair, and freedom from reoperation are still variable. This systemic review and meta-analysis examines the worldwide published literature to draw conclusions on the applicability, durability and outcomes of aortic valve repair as a surgical option to treat aortic valve pathology.

Methods

Search Strategy

Electronic searches were performed in PubMed, Ovid Medline and Cochrane. No limits were placed on dates and included studies from database inception to August 2013. Limits were placed for studies published in the English language. Search terms were charted to Medical Subject Headings and combined using Boolean operations. Search terms included: aortic valve repair OR aortic valve preservation OR aortic valve reconstruction. Reference lists of papers found in the literature search were manually searched to assess suitability for inclusion in this review. Articles were first screened by two reviewers (M.B. and M.F.) based on their titles and abstracts. All identified articles were systematically assessed using the inclusion and exclusion criteria for further study.

Selection Criteria

Articles deemed eligible for inclusion were those in which patient cohorts underwent surgical repair of the aortic valve for any type of pathology, including aortic regurgitation, cusp prolapse, bicuspid aortic valve, root dilation or aneurysm, infective endocarditis, rheumatic disease, or a combination of any of those listed.

Articles were excluded if they contained a pediatric population, defined as patients aged < 18 years, if the patient number was less than 50, if there was less than 100 patient years follow up, if the paper did not report mortality or morbidity, or only included patients operated on an emergency basis.

Data Extraction

All data were extracted from selected articles by two reviewers (M.B. and M.F.). Results were collected on Microsoft Excel for Windows. Statistical analysis was performed using GraphPad Prism. Patient-years (pt- yrs) were either recorded from the article or calculated if not reported by multiplying the number of patients with the mean follow-up time reported. Studies reported from the same center were addressed in data analysis, and if patient cohorts from each study overlapped, the study with the smaller cohort was excluded to prevent patient duplication in the study. Data are presented as mean ± standard deviation. Weighted means are calculated utilizing either total sample size or patient follow up years.

Results

Identification of Studies

A total of 8761 studies were identified from 3 databases (PUBMED, OVID and COCHRANE) (Fig. 1). After exclusion of duplicates (3982), papers deemed irrelevant from the titles (4518), and papers deemed irrelevant from the abstracts (178), 83 papers remained for full text review. Of these, 59 were excluded as not conforming to the inclusion criteria. The remaining 24 studies were included in the systematic review and meta-analysis [1–24].

Study Characteristics

Study characteristics are displayed in Table 1. In total, 4986 patients underwent aortic valve repair. After excluding studies that may represent overlap of patient cohorts, 15 studies remained: 7 studies representing BAV repair, 5 studies representing cusp prolapse, and 3 studies representing valve repair with root dilation or aneurysm. Studies included were published between 2004 and 2013. The majority of studies originated from 2 centers (Belgium and Germany). All studies bar one were retrospective in nature. There was a single prospective multi-center trial [6].

In all studies, males represented the majority of treated patients (79.8% ± 10.7) and mean age was 50.8 ± 5.9 (range 41-65). Average follow up was 4.0 years ± 1.8 with average follow up-patient years 931.5 ± 1209.6. Bicuspid valves were present in approximately half of the patient cohort (52.4%). Preoperative AI greater than 2+ was present in 68.2% of patients reported in 58.3% of studies.

Early Outcomes

In-hospital mortality was reported in all studies. Overall weighted in-hospital mortality for all studies was low (1.46% ± 1.21) (Fig. 2). Cardiopulmonary bypass (CPB) time was reported in 6 studies (Fig. 3), which did not correlate with in-hospital mortality. Preoperative AI ≥ 2+ did not correlate to reoperation for valve failure (Pearson’s Rs 0.2705, P = 0.2585) (Fig. 4). AI at discharge was reported in 9 studies, with a mean AI ≥ 2+ in 6.1% of patients (Table 2).
Late Outcomes and Valve Related Events

BAV repair represented the majority of patients undergoing aortic valve repair (Table 3). Of all studies, 7 solely assessed BAV repair. Average follow up in this cohort was for one year. In this group, reoperation required due to operated valve failure was reported in all studies. Weighted average percentage for reoperation to valve following BAV repair was 10.23% ± 3.2 (Fig. 5). Valvular endocarditis following BAV repair was reported in 5 studies with a weighted average of 1.72% ± 1.3 (Fig. 6). Other late outcomes such as stroke/TIA (transient ischemic attack) rates were reported in 4 studies with an average rate of 2.7%.

Studies solely investigating cusp prolapse were 5 (Table 4). Average follow up in these studies was 3.72 years ± 0.74. Of these studies, 3 reported reoperation due to valve failure (Fig. 7). Weighted average reoperation following cusp prolapse repair was 3.83 ± 1.96. Negligible rates of TIA and stroke were reported in 3 studies (average 0.53%) (Table 4).
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<td>Germany</td>
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<td>427</td>
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<td>le Polain de Waroux et al (19)</td>
<td>2009</td>
<td>Belgium</td>
<td>Blinded retrospective</td>
<td>186</td>
<td>55.3</td>
<td>79</td>
<td>37</td>
<td>19</td>
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<td>279</td>
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<td>2008</td>
<td>Germany</td>
<td>Retrospective</td>
<td>146</td>
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<td>93</td>
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<td>3.5</td>
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<td>Jeanmart et al (21)</td>
<td>2007</td>
<td>Belgium</td>
<td>Retrospective</td>
<td>71</td>
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<td>83.3</td>
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<td>El Khoury et al (22)</td>
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<td>Retrospective</td>
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<td>Minakata et al (23)</td>
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<td>Retrospective</td>
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<td>34</td>
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<tr>
<td>Langer et al (24)</td>
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<td>Germany</td>
<td>Retrospective</td>
<td>179</td>
<td>54.5</td>
<td>73.8</td>
<td>44.1</td>
<td>5</td>
<td>2.6</td>
<td>465.4</td>
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</table>

NR = not reported.
Aortic valve sparing procedures with root replacement were reported in 3 studies (Table 5). Of these 3 studies, 2 used the remodeling technique with the other using the reimplantation technique. Average follow up in this group was 3.2 years ± 0.97.

Reoperation in these studies for valve failure was reported in all 3, with a weighted average of 4.25% ± 2.46 (Fig. 8). Stroke and TIA rates were reported in all 3 studies with an average of 0.98% (Table 5).

Discussion

Every diseased aortic valve may ultimately require replacement. There are few, if any, medical procedures...
that are as effective in relieving symptoms, improving quality of life, and also increasing long-term survival as much as AVR for aortic stenosis (AS) or aortic regurgitation (AR). AVR is associated with low perioperative morbidity and mortality. The average perioperative mortality in the Society of Thoracic Surgeons database is 3.0% to 4.0% for isolated AVR and 5.5% to 6.8% for AVR plus coronary artery bypass grafting (CABG) [25,26]. A review of Medicare data, involving 684 US hospitals and more than 142,000 patients, indicates that the average in-hospital mortality for AVR in patients over the age of 65 years is 8.8% [27,28].

The use of a mechanical valve exposes the patient to lifelong need for anticoagulation and the risks of anticoagulant-related bleeding. Thromboembolic events and valve thrombosis can occur, especially if anticoagulation therapy is altered or suboptimally delivered. The risk of major bleeding with long-term anticoagulation is approximately 1% per year; however, this significantly increases with increasing age [27]. Anticoagulation in females of reproductive age poses its own complexities and risks. There are several advantages to aortic valve replacement, including ease of insertion, safety, durability, excellent hemodynamic and long-term track record of performance. However, aortic valve replacement inherently is associated with certain disadvantages, in addition to the aforementioned. These include issues of durability, infection, valve degeneration and patient-prosthesis mismatch. Banbury et al confirmed that younger age decreases durability of biological prostheses [29]. They found that freedom from explant due to structural valve damage (SVD) was 99%, 94%, and 77% at 5, 10, and 15 years. Studies analyzing factors influencing structural valve damage (SVD) post AVR conclude that SVD is promoted by the age at implantation (younger age), site of implantation (mitral position), gender (male), and valve type (porcine) [30–33]. Also, not all patients with SVD undergo reoperation within the time frame of the 15-year follow-up.

### Table 2. Study AI Characteristics Preoperative and At Discharge

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>No. pts</th>
<th>Mean age</th>
<th>F/U</th>
<th>F/U pt yrs</th>
<th>LVEF ≥50</th>
<th>Preop AI (≥2+)</th>
<th>Discharge AI (≥2+)</th>
<th>Reop due to valve (%)</th>
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<tr>
<td>Kari et al</td>
<td>2013</td>
<td>50</td>
<td>45</td>
<td>3</td>
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<td>32</td>
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<tr>
<td>Vohra et al</td>
<td>2013</td>
<td>471</td>
<td>52.1</td>
<td>11.2</td>
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<td>Aicher et al</td>
<td>2013</td>
<td>559</td>
<td>47.2</td>
<td>4.6</td>
<td>2559</td>
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<tr>
<td>Price et al</td>
<td>2013</td>
<td>475</td>
<td>53</td>
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<td>2152</td>
<td>88.4</td>
<td>57.5</td>
<td>NR</td>
<td>5.9</td>
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<td>Luciani et al</td>
<td>2012</td>
<td>58</td>
<td>43</td>
<td>3.8</td>
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<td>NR</td>
<td>72.4</td>
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<td>Fattouch et al</td>
<td>2012</td>
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<td>73</td>
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<td>Boodhwani et al</td>
<td>2011</td>
<td>55</td>
<td>65</td>
<td>4.3</td>
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<tr>
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<td>2011</td>
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<td>47.2</td>
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<td>167</td>
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<td>NR</td>
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<td>45.5</td>
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<td>187</td>
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<td>108</td>
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<td>427</td>
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<td>1238</td>
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<td>Schäfers</td>
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<td>le Polain de Waroux et al</td>
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<td>186</td>
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<td>1.5</td>
<td>279</td>
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<td>146</td>
<td>50</td>
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<td>185.5</td>
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<td>2007</td>
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<td>1.3</td>
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NR = not reported.
The alternative option to aortic valve replacement is aortic valve repair. This was even attempted before the advent of cardiopulmonary bypass using different techniques like circumclusion [34] and bicuspidization [35]. Lillehei in 1958 [36], using cardiopulmonary bypass, also applied the bicuspidization technique as well as single cusp enlargement using Ivalone sponge. Later, other techniques were developed, such as plication of the aortic annulus [37] and annuloplasty [38,39]. Mulder described in 1960 a variety of techniques referred to as valvuloplasty [40]. Later, Starr [41] and Spencer [42] described their techniques to repair aortic valve prolapse concomitant with VSD. Surgeons became more involved with the concept of aortic valve repair after annular disruptions and other balloon-induced injuries that caused acute insuffi-
The techniques of aortic valve repair have been modified since those early times. Modern techniques have been grouped into the following categories: 1) Nonaneurysmal related annular dilation of the valve may be corrected with circular annuloplasty, commissural annuloplasty (commissural plication), and complex valve extension using pericardium. 2) Cusp prolapse is dealt with using techniques of triangular resection, leaflet resuspension, and plication of the free edge of the leaflet. 3) Valve stenosis is corrected via commissurotomy. 4) Cusp perforation is directly patch repaired.

The key questions that need to be clarified in aortic valve repair include the following.

1) What is the durability of aortic valve repair? Given the variable strategies, the different techniques, and the short term results, the answer remains ambiguous. Initially, aortic valve repair was reserved for young patients, thus avoiding major risks related to anticoagulation and allowing better quality of life. This trend has changed and extended. AVr is now an option to be considered in a wider range of patients, with reported clinical results now extending to the early midterm stage. Our meta-analysis revealed that reoperation is 10.2% for repair of bicuspid aortic valve. BAV repair makes up the mainstay of patients undergoing aortic valve repair despite a relatively small number of studies with a relative small average follow up time. Studies looking primarily at cusp prolapse...
repair and root dilation with aortic valve repair represent a smaller number with reoperation rates between 3-4%. However, these studies include a much smaller average follow up.

There are no clear indications on when repair should be applied, and data showing its safety and durability are limited. AVr is confounded because most reports describe mixed groups of patients, including those with tricuspid and bicuspid valve repairs, as well as valve repair performed during procedures for aortic root reconstruction. Long-term survival data are scarce, and comparison is currently made with no control group undergoing aortic valve replacement. In the published literature, the incidence of valve-related complications is low, with recurrent aortic regurgitation being the most frequent late complication of repair. While surgical mortality is low, reoperation rates are high.

During our study, aortic insufficiency was not always reported in a standardized way. Thus comments on only a small number of studies can be made. The majority of studies operated on patients with Al ≥ 2+. However, there was significant variation and reoperation rates were analyzed to see if there was a correlation with degree of preoperative Al. No correlation was seen between preoperative Al and reoperation rates. At discharge Al ≥ 2+ was 6.1%. Al at follow up was not reported in a standardized way, in grading technique or time, and was therefore not included in this study. However, future studies addressing both these factors would be of considerable interest in assessment of the durability of the repair.

Table 5. Outcomes of Studies Evaluating Aortic Valve Repair in Patients with AR Secondary to Root Dilation or Aneurysm

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>No. pts. (n)</th>
<th>Mean age (m, n)</th>
<th>F/U (years)</th>
<th>F/U pt yrs</th>
<th>Reimplantation (%</th>
<th>Remodeling (%</th>
<th>in-hosp mort</th>
<th>resp due to valve (%)</th>
<th>Valve post op endocarditis</th>
<th>in-hosp resp due to valve (%)</th>
<th>TIA</th>
<th>Stroke</th>
<th>in-hosp resp due to valve (%)</th>
<th>Valve post op endocarditis</th>
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<tr>
<td>Kari et al</td>
<td>2013</td>
<td>50</td>
<td>45</td>
<td>3</td>
<td>190</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>2</td>
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<td>Boodhwani et al</td>
<td>2011</td>
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<td>65</td>
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<td>237</td>
<td>100</td>
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<td>0</td>
<td>6</td>
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<td>Lansac et al</td>
<td>2010</td>
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<td>2.4</td>
<td>455.9</td>
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<td>1.1</td>
<td>1.1</td>
<td>0</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Figure 8. Percentage of patients requiring reoperation due to valve failure following aortic valve repair with concomitant aneurysm repair. (Average follow up 3.2 ± 0.97 years.)
2) What are the reasons for valve repair failure?

Our meta-analysis found a reoperation rate of 10.3% for repair of bicuspid aortic valve. Ashikhmina et al. (15) report the potential risk factors related to BAV repair failure, which are: time of operation: age at original BAV repair; sex; body mass index; year of operation; era of operation (before 2000 or after 2000); left ventricular function; concomitant cardiac pathologic factors (eg, coarctation); AV morphologic characteristics as described by the operating surgeon, including calcification; AV repair techniques; concomitant procedures; and mean AV gradient at follow-up transthoracic echocardiographic analysis.

Conclusion

Although there are limitations and complications of prosthetic valves, especially for younger individuals, there is ample published literature that provides strong evidence for AVR. On the contrary, aortic valve repair may be a useful option for selected patients, but there is lack of uniformity in data and lack of compelling long-term evidence in its favor. An international multi-center study comparing results between AVR and AVR is the next step required.

Limitations

Primarily, this study is limited due to the small number of published reports available. Furthermore, the majority of available studies are observational in nature. Currently, higher levels of evidence do not exist for aortic valve repair. Only a select number of centers and surgeons perform aortic valve repair. In this study, we identified only one prospective trial. Single-centered studies mean that patient numbers remain relatively small reducing the potential to draw definitive conclusions even when studies are combined. Analysis of type of repair is complicated by surgeon preference and valve dysfunction etiology.

There is a process and a learning curve in aortic valve repair and the relation to morbidity and mortality is a function of time and case load. This may imply that studies published earlier do not reflect the current practice. Importantly, there are limited data on long term follow up available, particularly in regards to the need for aortic valve reoperation following repair, repair related events, and mortality. Average follow up in this study was only four years.

Conflict of Interest

The authors have no conflict of interest relevant to this publication.

References


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EDITOR’S COMMENT

The reoperation rate for aortic valve repair is 10%. A tremendous amount of surgical experience, talent, and creativity has gone into achieving this level of success. But, we find ourselves now in a “glass half full or glass half empty” situation. Is a 10% reoperation rate a triumph or a tragedy? It is a triumph in terms of surgical science. But, for those unfortunate young people in the 10% who need an early reoperation, that is a rather tragic outcome. One’s overall take on this is all a matter of point of view. Each reader needs to decide this for himself.
Effects of Hemodynamic Instability on Early Outcomes and Late Survival Following Repair of Acute Type A Aortic Dissection

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Abstract

Background: The goal of this study was to compare operative mortality and actuarial survival between patients presenting with and without hemodynamic instability who underwent repair of acute Type A aortic dissection. Previous studies have demonstrated that hemodynamic instability is related to differences in early and late outcomes following acute Type A dissection occurrence. However, it is unknown whether hemodynamic instability at the initial presentation affects early clinical outcomes and survival after repair of Type A aortic dissection. Methods: A total of 251 patients from four academic medical centers underwent repair of acute Type A aortic dissection between January 2000 and October 2010. Of those, 30 presented with hemodynamic instability while 221 patients did not. Median ages were 63 years (range 38-82) and 60 years (range 19-87) for patients presenting with hemodynamic instability compared to patients without hemodynamic instability, respectively (P = 0.595). Major morbidity, operative mortality, and 10-year actuarial survival were compared between groups. Results: Operative mortality was profoundly influenced by hemodynamic instability (patients with hemodynamic instability 47% versus 14% for patients without hemodynamic instability, P < 0.001). Actuarial 10-year survival rates for patients with hemodynamic instability were 44% versus 63% for patients without hemodynamic instability (P = 0.007). Conclusions: Hemodynamic instability has a profoundly negative impact on early outcomes and operative mortality in patients with acute Type A aortic dissection. However, late survival is comparable between hemodynamically unstable and non-hemodynamically unstable patients.

Key Words
Aortic dissection · Hemodynamics · Surgery

Introduction

Acute Type A aortic dissection exists as a medical crisis with heightened mortality attributable to an increased risk of aortic rupture or malperfusion [1–10]. Patients presenting with hemodynamic instability after Type A aortic dissection have been documented to have excessive operative mortality ranging from

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31.4% to 55% [11]. This operative mortality is not different from medical management alone, which has been cited as high as 60% in-hospital [8,9]. There is a paucity of studies investigating the effect of hemodynamic instability on early clinical outcomes and late survival, as well as the importance of surgical decision making in patients with acute Type A aortic dissection. Our study sought to evaluate whether patients presenting with hemodynamic instability have worse early clinical outcomes and late actuarial survival following repair of acute Type A aortic dissection compared to patients presenting without hemodynamic instability.

Materials and Methods

Patients
The Society of Thoracic Surgeons Databases at Beth Israel Deaconess, Carolinas Medical Center, Missouri Baptist Medical Center, and Meijer Heart and Vascular Institute were queried to identify all patients who underwent repair of aortic dissection between January 2000 and October 2010. A total of 251 patients underwent repair for acute Type A aortic dissections. Of those, 30 presented with hemodynamic instability and 221 presented without hemodynamic instability. Patients who presented with a Type A dissection but did not have surgery were excluded.

A preoperative diagnosis of aortic dissection was accomplished using computed tomographic angiography (CTA) or transesophageal echocardiography (TEE). The diagnosis was later confirmed at the time of operation. A database was created for entry of demographics, procedural data, and preoperative outcomes. These were prospectively entered by dedicated data-coordinating personnel. Long-term survival data were obtained from the Social Security Death Index (http://www.genealogybank.com/gbnk/ssdi/). Follow-up was 97% complete.

Prior to this analysis, study approval from the Institutional Review Board of each center was obtained. Consistent with the Health Insurance Portability and Accountability Act of 1996 (HIPAA), patient confidentiality was consistently maintained.

Definitions
Definitions for this study were obtained from the Society of Thoracic Surgeons’ national cardiac surgery database (available online at http://www.sts.org). Hemodynamic instability was defined as hypotension (systolic blood pressure < 80 mm Hg) or the presence of cardiac tamponade, shock, acute congestive heart failure, myocardial ischemia, and/or infarction. Acute Type A dissection was defined as any dissection involving the ascending aorta with presentation within 2 weeks of symptoms. Cerebrovascular accident was defined as a history of central neurological deficit persisting for more than 24 hours. Diabetes was defined as a history of diabetes mellitus regardless of duration of disease or need for antidiabetic agents. Prolonged ventilation was defined as pulmonary insufficiency requiring ventilatory support. Operative mortality includes all deaths occurring during the hospitalization in which the operation was performed (even if death occurred after 30 days from the operation), and those deaths occurring after discharge from the hospital, but within 30 days of the procedure.

Operative Technique
The surgical approach did not differ between patients presenting with and without hemodynamic instability. The diagnosis of Type A aortic dissection was confirmed by TEE intraoperatively for all patients. Access was provided via a median sternotomy. Total cardiopulmonary bypass was initiated with venous cannulation of the right atrium and arterial cannulation of the femoral or right axillary artery. Myocardial protection was ensured by cold blood cardioplegia administration through an antegrade approach via the ostia of the coronary arteries and/or a retrograde approach through the coronary sinus. Access through the right superior pulmonary vein was utilized for vent placement in the left ventricle. The aortic root was restored by resection of the intimal tear followed by replacement of the ascending aorta and resuspension or repair of the aortic valve. The aortic clamp was removed and the aortic arch was inspected after attaining a mean cooling temperature range of 15 to 18°C. The distal anastomosis was then completed and antegrade aortic perfusion was established. Patients with irreparable damage of the aortic root or valve underwent either a root replacement with a composite valve graft and coronary button reimplantation, or a valve replacement with mechanical or tissue prosthesis. If the aortic root could not be repaired, a root replacement was performed. Reinforcement of the proximal and distal suture lines was accomplished using Teflon (polytetrafluoroethylene) strips. Some patients required biological glue (BioGlue surgical adhesive, Cryolife, Kennesaw, GA) to reapproximate the dissected layers.

Data Analysis
Univariate Analysis. Univariate comparisons of preoperative, operative, and postoperative variables were performed between patients presenting with hemodynamic instability (n = 30) and those presenting without hemodynamic instability (n = 221). Normal distribution of continuous variables was assessed using the Kolmogorov-Smirnov test. Continuous variables were tested using either the Student t test or the Mann-Whitney test, depending on the distribution of data. Categoric variables were assessed by the $\chi^2$ or Fisher exact test, depending on the distribution of the data.

All tests were two-sided and a p-value < 0.05 was considered statistically significant.

Survival Analysis. Kaplan-Meier unadjusted survival estimates were calculated and compared for patients presenting with hemodynamic instability versus patients presenting without hemodynamic instability using a log-rank test. All analyses were conducted using SPSS statistical software version 21 (IBM Corp, Armonk, NY).
Results

Preoperative Characteristics

Preoperative characteristics are summarized in Table 1. Creatinine was higher in patients with hemodynamic instability compared to those without hemodynamic instability ($P = 0.005$).

Operative Characteristics

Operative patient characteristics of patients with hemodynamic instability and without hemodynamic instability who underwent repair for acute Type A aortic dissection are presented in Table 2. Patients presenting with hemodynamic instability had a lower cardiopulmonary bypass time compared to patients without hemodynamic instability ($P = 0.039$). A hemiarch technique was employed more frequently for patients with hemodynamic instability compared to patients without hemodynamic instability ($P = 0.002$).

Postoperative Characteristics

Postoperative characteristics are depicted in Table 3. Operative mortality (47% versus 14%) and cardiac arrest (30% versus 6%) were significantly higher for patients presenting with hemodynamic instability ($P < 0.001$), compared to patients without hemodynamic instability. More patients with hemodynamic instability experienced acute renal failure (43% versus 17%) compared to patients presenting without hemodynamic instability ($P = 0.001$).

Survival Analysis

Unadjusted Kaplan-Meier survival estimates are presented in Figure 1. There was a difference in the follow up time between groups ($p = 0.007$). Patients...

---

### Table 1. Preoperative Patient Characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hemodynamic instability</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>Yes (n = 30)</td>
<td>No (n = 221)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>63 (38-82)</td>
<td>60 (19-87)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>23 (79%)</td>
<td>175 (80%)</td>
</tr>
<tr>
<td>Ejection fraction</td>
<td>55 (35-75)</td>
<td>55 (15-73)</td>
</tr>
<tr>
<td>COPD</td>
<td>1 (3%)</td>
<td>18 (8%)</td>
</tr>
<tr>
<td>Creatinine</td>
<td>1.3 (0.8-3.8)</td>
<td>1.1 (0.4-12.5)</td>
</tr>
<tr>
<td>Female gender</td>
<td>9 (30%)</td>
<td>70 (32%)</td>
</tr>
<tr>
<td>NYHA class</td>
<td>3 (14%)</td>
<td>17 (11%)</td>
</tr>
<tr>
<td>I</td>
<td>2 (9%)</td>
<td>10 (6%)</td>
</tr>
<tr>
<td>II</td>
<td>1 (4%)</td>
<td>34 (21%)</td>
</tr>
<tr>
<td>III</td>
<td>16 (73%)</td>
<td>101 (62%)</td>
</tr>
<tr>
<td>History of cerebrovascular accident</td>
<td>2 (7%)</td>
<td>16 (7.2%)</td>
</tr>
<tr>
<td>Number of diseased vessels</td>
<td>0.413</td>
<td></td>
</tr>
<tr>
<td>Zero</td>
<td>24 (80%)</td>
<td>191 (87%)</td>
</tr>
<tr>
<td>One</td>
<td>4 (14%)</td>
<td>12 (5%)</td>
</tr>
<tr>
<td>Two</td>
<td>1 (3%)</td>
<td>7 (3%)</td>
</tr>
<tr>
<td>Three</td>
<td>1 (3%)</td>
<td>11 (5%)</td>
</tr>
<tr>
<td>EF &lt; 40</td>
<td>1 (3%)</td>
<td>13 (6%)</td>
</tr>
</tbody>
</table>

---

### Table 2. Operative Patient Characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hemodynamic instability</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPB time &gt;200 min</td>
<td>Yes (n = 30)</td>
<td>No (n = 221)</td>
</tr>
<tr>
<td>CPB time (minutes)</td>
<td>156 (5-411)</td>
<td>186 (64-684)</td>
</tr>
<tr>
<td>Circulatory arrest time (minutes)</td>
<td>15 (0-73)</td>
<td>16 (0-90)</td>
</tr>
<tr>
<td>Aortic valve procedure</td>
<td>0.609</td>
<td></td>
</tr>
<tr>
<td>Nothing</td>
<td>7 (23%)</td>
<td>55 (25%)</td>
</tr>
<tr>
<td>Replacement</td>
<td>2 (7%)</td>
<td>19 (9%)</td>
</tr>
<tr>
<td>Resuspension</td>
<td>17 (57%)</td>
<td>94 (43%)</td>
</tr>
<tr>
<td>Aortic root replacement</td>
<td>4 (13%)</td>
<td>52 (23%)</td>
</tr>
<tr>
<td>Distal anastomotic technique</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distal with cross-clamp</td>
<td>5 (17%)</td>
<td>59 (29%)</td>
</tr>
<tr>
<td>Open distal</td>
<td>24 (83%)</td>
<td>143 (71%)</td>
</tr>
<tr>
<td>Hemiarch technique</td>
<td>23 (77%)</td>
<td>102 (46%)</td>
</tr>
<tr>
<td>Total arch replacement</td>
<td>1 (3%)</td>
<td>24 (11%)</td>
</tr>
<tr>
<td>Arterial cannulation</td>
<td>0.340</td>
<td></td>
</tr>
<tr>
<td>Axillary</td>
<td>4 (16%)</td>
<td>46 (26%)</td>
</tr>
<tr>
<td>Femoral</td>
<td>12 (48%)</td>
<td>86 (50%)</td>
</tr>
<tr>
<td>Other</td>
<td>9 (36%)</td>
<td>42 (24%)</td>
</tr>
<tr>
<td>Retrograde cerebral perfusion</td>
<td>5 (17%)</td>
<td>24 (11%)</td>
</tr>
<tr>
<td>Antegrade cerebral perfusion</td>
<td>7 (23%)</td>
<td>56 (25%)</td>
</tr>
<tr>
<td>Bioglue/Felt Strip</td>
<td>0.321</td>
<td></td>
</tr>
<tr>
<td>Bioglue</td>
<td>14 (47%)</td>
<td>110 (50%)</td>
</tr>
<tr>
<td>Felt strip</td>
<td>10 (33%)</td>
<td>43 (20%)</td>
</tr>
<tr>
<td>Both</td>
<td>2 (7%)</td>
<td>23 (10%)</td>
</tr>
<tr>
<td>None</td>
<td>4 (13%)</td>
<td>45 (20%)</td>
</tr>
</tbody>
</table>

---

*a*Continuous data are shown as median (range) and categoric data are shown as percentage.

COPD = chronic obstructive pulmonary disease; EF = ejection fraction; NYHA = New York Heart Association.

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with hemodynamic instability had a median follow-up time of 1542 days (range = 1-4082), while those without hemodynamic instability had a median follow up time of 2154 days (range = 1-4800). Actuarial 10-year survival was lower for patients with hemodynamic instability, compared to those without (44% versus 63%, respectively, log-rank P = 0.007).

**Discussion**

Our study is among few studies comparing operative characteristics and early and late postoperative outcomes between patients presenting with and without hemodynamic instability following acute Type A aortic dissection repair. Hemodynamic instability negatively impacted the postoperative outcomes and survival of patients who underwent surgical repair of Type A aortic dissection, compared to hemodynamic instability presentation. These results affirm the notion that patients presenting with hemodynamic instability fare worse than those without hemodynamic instability after surgical repair for acute Type A dissection.

**Principal Findings**

**Operative Mortality.** Patients in our study presenting with hemodynamic instability had significantly higher operative mortality rates compared to patients without hemodynamic instability (P = 0.001). Previous studies have also documented worse survival for patients with hemodynamic instability [11,12]. Specifically, Trimarchi et al. [11] documented 31.4% in-hospital mortality among patients with hemodynamic instability compared to 16.7% for stable patients (P = 0.001). The even higher operative mortality for hemodynamically unstable patients in our study could be explained by the fact that Trimarchi et al. [11] consol-

---

**Table 3. Postoperative Patient Characteristics**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hemodynamic instability</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep sternal wound infection</td>
<td>0</td>
<td>3 (1%)</td>
</tr>
<tr>
<td>Prolonged ventilation</td>
<td>19 (63%)</td>
<td>96 (47%)</td>
</tr>
<tr>
<td>Acute renal failure</td>
<td>13 (43%)</td>
<td>37 (17%)</td>
</tr>
<tr>
<td>Hemodialysis</td>
<td>5 (17%)</td>
<td>16 (7%)</td>
</tr>
<tr>
<td>Hemorrhage-related re-exploration</td>
<td>6 (20%)</td>
<td>37 (17%)</td>
</tr>
<tr>
<td>Cardiac arrest</td>
<td>9 (30%)</td>
<td>12 (6%)</td>
</tr>
<tr>
<td>Stroke</td>
<td>5 (17%)</td>
<td>38 (17%)</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>7 (23%)</td>
<td>52 (25%)</td>
</tr>
<tr>
<td>Hospital length of stay (days)</td>
<td>15 (0-62)</td>
<td>10 (0-99)</td>
</tr>
<tr>
<td>Operative mortality</td>
<td>14 (47%)</td>
<td>30 (14%)</td>
</tr>
</tbody>
</table>

*Continuous data are shown as median (range) and categoric data are shown as percentage.

---

**Figure 1.** Actuarial unadjusted 10-year survival curves for patients with hemodynamic instability versus patients without hemodynamic instability.

---

**Table 4.** Postoperative Patient Characteristics

<table>
<thead>
<tr>
<th>Variable</th>
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</tr>
<tr>
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<td>52 (25%)</td>
</tr>
<tr>
<td>Hospital length of stay (days)</td>
<td>15 (0-62)</td>
<td>10 (0-99)</td>
</tr>
<tr>
<td>Operative mortality</td>
<td>14 (47%)</td>
<td>30 (14%)</td>
</tr>
</tbody>
</table>

*Continuous data are shown as median (range) and categoric data are shown as percentage.
idated patients with neurologic instability, mesenteric ischemia, and acute renal failure into their hemodynamic instability cohort, whereas our hemodynamic instability cohort did not include patients with neurologic instability or intestinal malperfusion.

Operative Characteristics. Hemodynamically unstable patients had shorter cardiopulmonary bypass time and more hemiarch repairs. The shorter cardiopulmonary bypass time in hemodynamically unstable patients is due to the lower rate of patients requiring aortic root replacements (a more time consuming operation compared to the resuspension or replacement of the aortic valve), compared to the patients without hemodynamic instability. The higher incidence of hemiarch repairs in patients with hemodynamic instability may be attributed to the more extensive aortic dissection in this subset of patients compared to the patients without hemodynamic instability.

Postoperative Outcomes and Survival. Early postoperative outcomes such as atrial fibrillation and stroke rates were comparable between patients with and without hemodynamic instability. However, acute renal failure was higher for patients with hemodynamic instability compared to those without hemodynamic instability, secondary to preoperative hypotension in patients with hemodynamic instability. Actuarial 10-year survival was worse for patients who presented with hemodynamic instability than those without (Fig. 1). However, most of the mortalities in the hemodynamic instability group occurred in the early postoperative phase, compared to the later phase where the differences in survival between groups were less pronounced.

Timing of Surgery versus No Surgery

Our study documented an excessive operative mortality of patients who presented with hemodynamic instability compared to those without. The mortality of patients presenting with hemodynamic instability is similar to the mortality for medical management of patients with Type A aortic dissection, according to recent data documenting a 42% 30-day survival in medically treated acute Type A dissections [7]. Our present data, with a 47% operative mortality in Type A dissection patients presenting with hemodynamic instability, suggests that therapy in this subgroup should be individualized and some patients may be candidates for surgery. However, patients with significant comorbidities may be candidates for medical or possibly delayed surgery.

Clinical Implications

We conducted a multi-institutional observational study to assess the impact of hemodynamic instability on operative characteristics and on short- and long-term outcomes following repair of acute Type A aortic dissection. In this study we examined an unselected cohort of patients from four academic institutions. This is among few studies comparing early clinical outcomes and 10-year actuarial survival between patients with and without hemodynamic instability following repair of acute Type A aortic dissection. In our study, hemodynamic instability adversely affected early clinical outcomes and survival following repair of acute Type A aortic dissection. Based on the results of our study, treatment of patients with hemodynamic instability should be individualized because of the excessive early operative mortality. However, long-term survival is comparable between patients with hemodynamic instability and those without hemodynamic instability.

Study Limitations

Inherent limitations of a retrospective multi-institutional investigation unavoidably affected our study. The analysis may also have introduced bias since nine different surgeons from four different institutions performed the operations. Patients who were lost to follow-up were not contacted for this study. Further examination regarding reoperations on the remaining dissected aorta, the causes of late mortality, and the fate of the false lumen were outside the scope of our analysis. These should be the focus of future studies evaluating long-term outcomes of acute Type A aortic dissection repair.

Conclusions

Hemodynamic instability has a profoundly negative impact on early outcomes and operative mortality in patients with acute Type A aortic dissection. However, late survival is comparable between hemodynamically unstable and non-hemodynamically unstable patients.

Conflict of Interest

The authors have no conflict of interest relevant to this publication.
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Treatment of Hostile Proximal Necks During Endovascular Aneurysm Repair

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Abstract
Endovascular aneurysm repair (EVAR) is a therapy that continues to evolve rapidly as advances in technology are incorporated into new generations of devices and surgical practice. Although EVAR has emerged as a safe and effective treatment for patients with favorable anatomy, treatment of patients with unfavorable anatomy remains controversial and is still an off-label indication for endovascular treatment with some current stent-grafts. The proximal neck of the aneurysm remains the most hostile anatomic barrier to successful endovascular repair with long-term durability. Open surgery for unfavorable necks is still considered the gold standard treatment in contemporary practice, despite the increased mortality and morbidity attributed to suprarenal cross-clamping, particularly in high-risk patients. Evolving technology may overcome the obstacles preventing endovascular treatment of unfavorable proximal neck anatomy; current approaches include purely endovascular as well as hybrid approaches, and generally include strategies that either extend the length of the short neck, move the proximal neck more proximally, or keep the short neck intact. These approaches include the use of debranching techniques, banding, chimneys, fenestrated and branched devices, filling the sac with endobags, endoanchors, and other novel devices. These newer-generation devices appear to have promising short- and midterm results. However, lack of good evidence of efficacy with long-term results for these newer approaches still precludes wide dissemination of endovascular solutions for the hostile proximal neck.

Key Words
Aneurysm · EVAR · Hostile neck · Angulated neck · Short neck

Introduction
One of the fundamental criteria for proper selection of patients who are good candidates for endovascular repair of an abdominal aortic aneurysm (AAA), to provide long-term success in prophylaxis of aneurysm rupture, is the anatomic characteristics of the aortoiliac arteries [1]. In particular, the most important area to consider is the proximal neck, e.g., the characteristics of the aorta below the lowest major renal artery and the beginning of the aneurysm. A short and/or angulated neck is considered hostile anatomy and can lead to complications after endovascular aneurysm repair (EVAR), such as loss of endograft fixation or seal, device migration, type 1 endoleak, sac enlargement, and, ultimately, aneurysm rupture and death [1,2].

The most common anatomic guidelines for successful EVAR, stated in most device manufacturers’ instructions for use, are the presence of a proximal neck length of at least 1.5 cm with maximal angula-
tion of the neck up to 60°. Therefore, the presence of a short (<1.5 cm) and/or highly angulated proximal aortic neck (>60°) portends reduced long-term efficacy of EVAR and is currently an off-label indication for repair with most commercially available devices [1]. Since traditional open surgical repair of aneurysms with short necks, e.g., juxtarenal aneurysms, is associated with increased mortality and impaired renal function in long-term, particularly high-risk patients [3], there remains impetus to improve the current approach to EVAR in patients with short necks. We review several of the current approaches to improving EVAR in patients with hostile proximal necks.

Extending the Length of the Short Proximal Neck

One approach to treat the short neck is to extend the neck length proximally so it is >1.5 cm. Since this approach may cover renal or visceral vessels, alternative approaches to revascularization of these vessels is critical. Several approaches have been evaluated; revascularization of the excluded renal or visceral vessels was traditionally performed using open surgical techniques, although newer approaches use exclusively endovascular techniques.

1. Extra-anatomic Bypass for Renal Debranching. In order to increase proximal neck length, the endograft is simply deployed more proximally into the pararenal aorta, covering the origins of the renal arteries. Revascularization of the covered vessels is performed in traditional fashion, typically with performance of a hepatic-renal bypass for the right renal artery and/or a spleno-renal bypass for the left renal artery. Alternatively, an ilio-renal bypass can be performed on either side. The endograft is placed conventionally, except for the exclusion of the debranched renal artery [4,5]. The extra-anatomic revascularization is typically performed prior to the endograft placement to avoid any renal ischemic time; in addition, this procedure may be staged, a potential advantage for some patients. This hybrid procedure requires a laparotomy, negating this potential advantage of EVAR.

2. VORTEC (Viabahn Open Revascularization Technique). This is a variant of the above hybrid debranching procedure, with the distal anastomosis of the debranching procedure performed using a covered stent, avoiding a sutured distal anastomosis in the target visceral vessel [6]. A self-expanding covered stent or stent-graft, such as a Viabahn or Hybrid graft (W. L. Gore & Associates, Flagstaff, AZ) is placed via Seldinger technique into the target renal or visceral artery; the proximal end of the covered stent or graft that remains outside the artery is directly sutured to the proximal native artery or main endograft to complete the extra-anatomic revascularization (Fig. 1). The advantage of this technique is that it preserves the target vessels that are difficult to dissect and control, or are otherwise encased in scar tissue. However, the experience with this type of procedure is limited and still requires laparotomy to be performed in a hybrid fashion.

3. Proximal Aortic Neck Banding. In order to extend the short aortic proximal neck, the neck is extended distally onto the proximal aspect of the aneurysm through a banding procedure to reinforce the strength of the neck. Typically the banding is performed via a suprarenal mini-laparotomy, or it can be performed laparoscopically by surgeons with these skills. After dissection of the infrarenal aortic neck, potentially including a small amount of the proximal aneurysm, a strip of Dacron felt is passed circumferentially around it and tightened firmly [7]. EVAR is then performed in the usual fashion, anchoring the device proximally within the banded zone (Fig. 1). The advantage of this procedure is that it avoids moving the neck proximally and does not require revascularization of the visceral branches. A potential disadvantage of this technique is the limited experience and the inclusion of a small area of aneurysm within the landing zone, although this technique has often been used in open aneurysm repair as well.

4. The Chimney or Snorkel Technique. This technique is an endovascular extension of the proximal neck. A stent is placed with its distal end into the renal or visceral artery, and with its proximal aspect placed parallel to and within the proximal aorta; the EVAR is then performed, with the proximal end of the main body of the stent-graft placed alongside the newly placed stent (Fig. 1). The newly placed stent acts as a “chimney” or “snorkel” around the stent-graft, creating a “double barrel” or dual-channel flow path, perfusing the target vessel alongside the aortic endograft. The stent-graft and the chimney graft are sealed together in the new proximal neck, avoiding a proximal type 1
endoleak. This technique is simpler and cheaper compared to using fenestrated and/or branched devices (discussed below), and is readily available (“off-the-shelf”), particularly in the emergency setting [8,9].

Long-term durability of chimney grafts will likely be related to the degree to which the two parallel stent-grafts are apposed to each other; incomplete apposition may compromise the aortic seal zone and even lead to deformation of one or both stent-grafts, ultimately leading to kinks, fractures, or leaks.

Antoniou et al. [10] reviewed 21 studies treating the juxtarenal or suprarenal aorta with this technique. In 102 patients, there was a technical success rate of 91%, and perioperative mortality was 5% and major morbidity was 17%; there was type 1 endoleak in 13%. The authors concluded that this technique may serve as a complementary technique in high-risk patients.

Moulakakis et al. [11] reviewed the use of the chimney graft technique in the visceral vessels of 93 patients, 77.4% of whom had abdominal aortic aneurysms. A total of 134 stents were placed with primary technical success in 100%. However, type 1 endoleak occurred in 13 patients (14%). Three of these 13 were diagnosed intraoperatively, and two of these were

\[ \text{Navarro, T.P. et al.} \quad \text{Hostile Necks in EVAR} \]
treated with an aortic stent-graft, while the third was corrected with an Amplatzer occluder device. Of the 10 cases that were detected during follow-up, only 4 needed reintervention whereas in 6 cases the endoleak sealed spontaneously. The 30-day in-hospital mortality was 4.3%; 12% of patients suffered renal function impairment. During a mean follow-up of 9 months, 97.8% of the stents remained patent.

Early results with the chimney technique suggest safe and effective treatment of the patient’s aneurysm, considering the traditional limitations of a hostile proximal aortic neck. However, long-term endograft durability and proximal fixation will remain a significant concern until these results are reported. In the absence of long-term data, there has been a reasonable hesitation to adopt this technique.

Moving The Proximal Neck More Proximally

Another approach to treating aneurysms with hostile proximal necks is to abandon the site and move the proximal sealing zone entirely more proximally to a more appropriate site. This approach is more suitable for an entirely endovascular approach; however, the need to revascularize the visceral segment makes this approach more technically complicated. The current approach generally uses fenestrated and/or branched grafts.

Fenestrations and branches are two approaches to revascularization of the visceral arteries. Fenestrations or scallops are complete or partial holes in the stent-graft fabric that provide direct access to a branch artery; after the main body is placed, these arteries are typically accessed, a balloon-expandable covered stent is placed, and the proximal end of the covered stent is then flared against the inside of the stent-graft, providing a seal around the branch artery (Fig. 1). Although branched aortic stent-grafts can be used to revascularize visceral arteries in thoracoabdominal aortic aneurysms [12-14], application to treat AAA with a hostile neck is not currently popular. The main limitation of the use of this technique in AAA with a hostile neck is the anatomy. Branched aortic stent-grafts require deployment in an aneurysmal area in order to have sufficient working room to facilitate manipulating the branches. This condition is rarely met in AAA with a hostile neck. Branched endografts have prefabricated branches for the visceral arteries that are integral to the main device. In general, in fenestrated systems, the covered stents for the branches are oriented perpendicularly away from the main body, through the fenestration and into the branch artery. Branched systems often allow the covered stents to curve at other angles away from the main body (Fig. 1) [15]. The fenestrated and branched approach allows extension of the proximal seal zone or moving it entirely more proximally, depending on the number of fenestrations and branches.

Since the first implantation of a fenestrated graft in 1996, there has been tremendous advancement in the technology driving these devices [16]. The fenestrated endovascular aneurysm repair consensus working group of the British Society of Endovascular Therapy concluded that the current role of fenestrated devices remains unclear [17]. Literature review showed heterogeneous case series without clear indications for use of fenestrated devices. A survey of current practice in the United Kingdom showed wide variations in practice. Consensus agreement on the role of fenestrated devices was present, at most, in only 68%, with more consensus present on the risk associated with open repair and suprarenal cross-clamping, and less consensus for age over 85 years, 5.5-6 cm aneurysms, and short-necked infrarenal aortic aneurysms.

Cross et al. [18] reported a meta-analysis of 660 fenestrated procedures. Definitions of aneurysm morphology were variable, and clear inclusion and exclusion criteria were not always clearly documented. Target vessel perfusion rates ranged from 90.5 to 100%. The 30-day mortality was 2.0%. Morbidity was poorly reported. The authors concluded that fenestrated repair for juxtarenal and suprarenal aneurysms is a viable alternative to open repair; however, there is currently no level 1 evidence supporting its efficacy, with current evidence being weak and leaving many unanswered questions.

Tambyraja et al. [19] reported midterm results of 29 patients who were treated with fenestrated devices. No procedures required conversion to open surgery, but one procedure was abandoned. A total of 79 visceral vessels were treated and documented as patent at completion angiography. No patient died within 30 days of surgery. Follow-up was for a median of 17 months during which there was 14% mortality that was not aneurysm related. However, 62% of patients had graft-related complications and 38% required reintervention. The authors concluded that fenestrated devices are a safe option to treat juxtarenal aneurysms in patients at high risk for open surgery;
however, the high rate of graft-related complications and reinterventions, even during medium-term follow-up, is concerning.

Currently there are three classes of fenestrated devices:

- **Customized devices**, such as the Zenith (Cook Medical Inc., Bloomington, IN), Jotec, or Anaconda (Terumo, Ann Arbor, MI) devices, typically require a 6- to 8-week period for custom manufacturing for patient-specific anatomy. This is a good option for elective patients, but it is not widely available or for patients in need of urgent or emergent repair [20].

- **Surgeon-modified devices** are immediately available, formed as needed from off-the-shelf devices available to the surgeon, and overcome the long manufacturing time required for custom devices. However, these modified devices often require considerable time and effort to create and use, and in many instances, these devices cannot be tested prior to deployment; in addition, the legal ramifications of using these devices in elective patients is not clear [16, 20].

- **Standard devices** that can treat patients with particular anatomic specifications can be stocked and ready for emergent use. The Ventana system is designed with two renal fenestrations, a superior mesenteric artery fenestration, and a scallop for the celiac artery. Interestingly, it is possible to access a wide range of renal artery anatomies, as the device has a dome with an outer 15 mm diameter and an inner 6 mm diameter fenestration [21]. Initial experience in 7 patients showed 100% success in target vessel catheterization and one renal artery occlusion at 2 months [21].

**Keeping The Short Proximal Neck**

A third approach to treating aneurysms that have a hostile proximal neck is to use a device that treats the aneurysm using an entirely different paradigm.

1. The NELLIX System. The Nellix (Endologix, Irvine, CA) endoprosthesis consists of dual, balloon-expandable endoframes, surrounded by polymer-filled endobags, which obliterate the aneurysm sac and maintain endograft position. Its use is intended for both favorable and adverse anatomy, including neck length < 10 mm, neck angle > 60°, and iliac diameter > 23 mm (Fig. 1) [22]. Initial experience with 34 patients reported no change in aneurysm size or endograft position and no new endoleaks in follow-up up to 2 years, without any differences in outcome between patients with favorable and adverse anatomy [18].

2. The Multilayer System. The Cardiatis (Isnes, Belgium) 3D multilayer braided stent is fabricated in several interlocking layers (Fig. 1); this configuration reduces the trans-stent flow up to 90%, reducing sac pressure and risk of rupture, but apparently preserves flow in branches [23–25]. However, aortic rupture after stent placement has been reported [26].

3. Endostapling and Endoanchoring Systems. There are two current systems available to improve the device fixation to the hostile proximal neck, endostapling systems [27] and endoanchoring systems (Aptus, Sunnyvale, CA) (Fig. 1) [28]. The endostapling systems were developed to improve sealing at the proximal neck and prevent migration. However, a systematic review of the literature was not conclusive, as no randomized controlled trials have been published [29]. Use of these systems is associated with reduced rates of type 1a endoleak and migration, suggesting reduced future need for reintervention.

4. Reinforcement With a Palmaz Stent. Farley et al. [30] reviewed 18 cases in which Palmaz stents were placed as an adjunct to EVAR in patients with a hostile aortic neck after a type 1 endoleak was detected. The authors concluded that this approach was effective. Chung et al. [31] reviewed midterm outcomes and reported that this strategy does not appear to compromise durability of this procedure. However, patients requiring adjunctive Palmaz stent placement are likely to be at high risk for subsequent graft-related events.

5. Use of Thoracic Endografts. To treat severe aortic neck angulation, Silingardi et al [32] reported placement of the EVAR main body stent graft within a thoracic stent graft placed just below the most distal renal artery, a clever but expensive adjunct to achieve a proximal seal.

6. The Ovation Abdominal Stent Graft System. The Ovation Abdominal Stent Graft System (TriVascular Inc. Santa Rosa, CA) consists of a device with a main body with polymer-filled rings on its top that can seal the aortic neck, a
suprarenal stent with anchors for suprarenal fixation, and polytetrafluoroethylene (PTFE)-covered nitinol stents for the iliac limbs (Fig. 1).

Mehta et al. [33] published the 1-year results of a multicenter trial using the Ovation stent graft. The authors included patients with the following characteristics of the proximal neck length. (1) Proximal neck length should be ≥ 7 mm and inner diameter from 16 to 30 mm. (2) If the proximal neck length is < 10 mm, then the neck angulation should be ≥ 45°. (3) If the proximal neck length is ≥ 10 mm, then the neck angulation should be ≤ 60°. The device implantation succeeded in 161 patients (100%). There was one major adverse event (death) at 30 days (0.6%); in this patient the polymer-filled rings became disconnected and the polymer was injected intravascularly, which resulted in anaphylaxis and culminated in a fatal outcome. After 1 year, AAA-related mortality was the same (0.6%) and all-cause mortality was 2.5%. There was no stent-graft migration and the only type of endoleak observed was type II (34% of patients). There was sac enlargement in only one patient, which did not rupture. The authors suggested that the Ovation stent graft was safe and effective in the treatment of AAA with a hostile neck. However, longer follow-up is needed.

The Angulated Neck

One important cause of a hostile proximal neck, in addition to the short neck, is the angulated neck. In this situation, the use of EVAR may be difficult and unsafe. Most aortic stent-grafts are not recommended for use in those aortas with a neck having > 60° of angulation. However, new grafts have been designed to be used in extremely angulated aortic necks.

(1) Aorfix. A new device that has been approved by the FDA is the Aorfix from Lombard (Oxfordshire, UK). Weale et al. [34] studied the safety and early outcome of 30 patients with severe proximal neck angulation (mean 81.2°) treated with the Aorfix endovascular stent-graft. Three patients had type 1 endoleaks noted intraoperatively and treated immediately by balloon angioplasty. Clinical success at 30 days was 96.7% with no type 1 or type 3 endoleaks, and no graft thrombosis or migration. At 6 months, two patients developed type 1 endoleaks that did not require intervention; no patient died due to aneurysm rupture or required removal of the endograft. The authors concluded that the Aorfix graft was a reasonable option to treat patients with aneurysms that have highly angulated necks. However, no mid- or long-term results are available.

(2) Endurant. One of the Endurant (Medtronic, Minneapolis, MN) stent-graft’s design features is to expand applicability of EVAR. Verhagen et al. [35] reported the first-in-human European trial and concluded that it can be delivered and deployed safely even in the presence of severe angulation. Bastos Gonçalves et al. [36] compared treatment of patients with hostile proximal necks (mean 80.8° angulation) to patients with favorable necks and concluded that the Endurant device has satisfactory outcomes in both angulated and nonangulated anatomies. However, long-term results are needed to verify its durability.

(3) C3 Excluder. The C3 Excluder (Gore, Flagstaff, AZ) stent-graft claims to have increased accuracy with controlled deployment at the proximal landing zone due to the ability to constrain the graft after initial deployment, allowing repositioning [37]. An early experience with this system demonstrated good function of the deployment system, allowing repositioning as needed. Additional cuffs were not required in the 25 patients of this study, with no mortality and no type 1 endoleaks at early follow-up; no long-term data are available [37].

Perspective on Development of New Technology

Many EVARs are performed in cases that do not meet the manufacturers’ instructions for use due to hostile anatomy [1,2,38,39]. This practice is likely a reflection of the need to treat increasing numbers of high-risk patients, especially as the population ages and lives with a greater number of comorbid conditions. The literature suggests that it is reasonable to expect satisfactory rates of aneurysm palliation in the midterm and possibly even the long term for these patients, as long as type 1 endoleaks are detected and treated [2,38,39]. However, treatment of persistent type 1a endoleaks in this group of patients is challenging and remains a persistent criticism of EVAR in patients with hostile neck anatomy [40].

In specialized and tertiary centers, traditional open surgery still remains the gold standard to treat stan-
standard-risk patients with anatomy that is poorly suited for EVAR. Chisci et al. [41] compared outcome of open repair and EVAR, using both standard and fenestrated stent-grafts, and concluded that despite increased numbers of reinterventions after EVAR in patients with hostile necks, the results of open surgery and EVAR were similar. Greenberg et al. [42] questioned, “Should patients with challenging anatomy be offered endovascular aneurysm repair?” Comparing outcomes in patients at high and low anatomic risk, the authors reported similar perioperative mortality (0.7% versus 1%) and increased frequency of endoleak in patients with high-risk anatomy (25% versus 11%), but this increase was not statistically significant ($P > 0.05$). Despite acceptable short-term technical results, reduced long-term survival (largely unrelated to the procedure) and slightly higher frequency of endoleak may temper enthusiasm for EVAR in patients with hostile necks with current generation devices.

These conflicting results reflect the continuing evolution of the endovascular devices and their reception in the general vascular surgical community. The promise of new technology to treat an ever-shrinking number of patients with challenging anatomy is both exciting and threatening. However, given manufacturers’ incentives to treat as many patients as possible, patients may benefit with continuing refinements and less invasive procedures.

Some intraoperative maneuvers help achieve effective and durable fixation and sealing of stent-grafts in patients with hostile proximal neck anatomy: use of high-pressure balloons to reinforce the seal, deployment of a proximal cuff, controlled slow deployment of the main body of the stent-graft, use of the bending-the-wire technique to realign the axis of the aneurysm with the neck, and use of appropriate C-arm angulation to adequately visualize the landing zone [44]. As endovascular technology continues to evolve, it is likely that additional maneuvers will evolve, enhancing the surgeon’s skill in dealing with hostile anatomy.

**Conclusions**

An issue that will need attention in the future is the observation that we and others have made, that neck angulation after EVAR can change during follow-up [45]. As such, endografts must be durable to changing seal zone anatomy and forces as the aneurysm continues to remodel, a challenge to the long-term durability of these devices. However, recent improvements in technology have allowed current generation devices to better deal with difficult anatomy [46]. As technology evolves, treatment will expand to additional patients and will prevent complications inherent in older devices [46].

Unfavorable anatomy, and, in particular, a hostile neck, represents a major limitation to performing EVAR. Despite a number of devices and techniques that have been developed to treat short and/or highly angulated necks, the results of EVAR in this setting remain suboptimal, limited in length of follow-up time, and supported by insufficient numbers of large series. Perhaps the major barrier to successful aneurysm treatment is the lack of understanding of the biology of aneurysms, in particular, the long-term natural history of aneurysms, especially with a stent-graft in place. It is imperative to understand the magnitude and types of forces that the aneurysm continues to exert on the stent-graft so the durability of EVAR as a treatment can be effective in the long-term, both for individual patients and as a cost-effective treatment for society and payers. Until we understand aneurysm biology more completely, long-term durability will continue to rely on appropriate patient selection, outstanding operator training, and continued improvements in technology [46].

**Conflict of Interest**

The authors have no conflict of interest relevant to this publication.

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State-of-the-Art Review


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Aortic Esophageal Fistula After Thoracic Endovascular Aortic Repair: Successful Open Treatment

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Abstract
We present the case of a 56-year-old patient suffering from an aorto-esophageal fistula after complex treatment of acute Type A dissection including thoracic endovascular aortic repair (TEVAR) of the descending aorta. Open surgical descending replacement using a pericardial patch, as well as esophagectomy, was performed. After a long and complicated hospital stay, the patient finally recovered and was discharged in stable condition. By choosing an aggressive surgical approach the patient survived this devastating complication of TEVAR, which is associated with high mortality.

Key Words
Secondary surgical procedure · TEVAR · Aorto-esophageal fistula · Case description

Introduction
We present the case of a 56-year-old patient who underwent replacement of the ascending aorta and aortic arch due to acute Type A dissection at an external department. The patient suffered from arterial hypertension and unilateral paresis of the recurrent laryngeal nerve after the primary surgery.

During follow-up, the patient showed a progressive aneurysm of the descending aorta and was therefore treated with subclavian transposition in combination with thoracic endovascular aortic repair (TEVAR) (Medtronic Valiant, 42 × 100, Medtronic Vascular, Santa Rosa, CA) 8 months after emergency surgery. Two months after TEVAR the patient was readmitted with hematemesis and significant blood loss. Computer tomography (CT) scan revealed contained rupture of the descending aorta distal to the stent graft. The patient then again underwent TEVAR (Medtronic Valiant, 42 × 140, Medtronic Vascular, Santa Rosa, CA) for distal elongation of the stent graft in an emergency setting. Gastroscopy revealed erosion of the esophagus, which was treated with an esophageal stent placement. Ten days after TEVAR and esophageal stent placement, control gastroscopy was performed and the patient was discharged home under stable conditions.

One month after the second intervention the patient was scheduled for removal of the esophageal stent. Gastroscopy after removal of the stent revealed a large defect in the esophagus with an aorto-esophageal fistula, covering approximately a third of the esophageal circumference (Fig. 1). Based on these findings, a CT scan was performed, which confirmed the diagnosis of an aorto-esophageal fistula with signs of mediastinitis (Fig. 1).

At this time point the patient was stable and was transferred to our center for surgical repair. Preopera-
tively, a percutaneous endoscopic gastrostomy (PEG) tube was placed due to the planned surgical esophagectomy. Through left lateral thoracotomy the aorto-esophageal fistula was identified (Fig. 2). The patient was placed on femoral-femoral bypass through the groin vessels. The descending aorta was clamped distal to the aortic arch and proximal to the diaphragm. As a first step, evaluation of the defect of the esophageal wall was performed. As the fistula covered nearly half of the esophageal circumference, resection of about 8 cm of the esophagus was performed with a stapling method (Endo-GIA, blue cartridge, Covidien Intl., Mansfield, MA). The descending aorta was transected and the two stent grafts could successfully be removed. Due to infection risk of the surrounding tissue, a biological replacement of the descending aorta was performed using a pericardial patch (Fig. 3). The aortic graft was de-aired and the aortic cross-clamp was removed after 124 minutes. The patient was weaned from bypass after 140 minutes. After successful partial esophagectomy and descending aortic replacement, a cervical salivary fistula (T-Tube, 12F) was created via a left cervical approach and the patient was taken to the intensive care unit (ICU).

The patient had a complicated and long postoperative recovery at the ICU, requiring reintubation and tracheotomy on the 12th postoperative day. He suffered from two episodes of pneumonia presumably due to aspiration and received extensive antibiotic treatment. Three months after esophagectomy, a reconstruction of the esophagus was

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**Figure 1.** (A) CT scan revealing migration of the stent graft into the esophageal wall. (B) Gastroscopic finding showing a big defect of the esophageal wall and presence of an aorto-esophageal fistula.

**Figure 2.** Intraoperative view of defect in the esophagus and aortic wall.

**Figure 3.** Descending aortic replacement using a pericardial tube.
performed by gastric tube pull up with a stapled (CEEA, blue load, Covidien, Intl., Mansfield, MA) end-to-side esophagostomy, a pyloromyotomy, and a jejunal catheter placement.

Nearly 4 months after descending aortic replacement, the patient recovered completely without wound healing disorders. He was in a stable respiratory state and could be discharged without neurologic impairment and in stable condition.

The patient was seen in outpatient clinic for a follow-up visit 6 months after descending replacement. He was still in recovery with complaints about pain along the thoracotomy wound. Furthermore, the patient was still in a cachectic nutritional status.

Discussion

Secondary surgical interventions after TEVAR are needed in 2.2-7.4% of all patients [1,2]. While overall mortality in those challenging cases ranges from 11.5 to 19%, survival of patients undergoing surgery due to aorto-esophageal fistula is still very poor [2–6]. Muradi et al. [7] summarized published cases on secondary aorto-esophageal fistula after TEVAR and reported a mortality of 75%. Analysis of 36 patients in the European registry of endovascular aortic repair also pointed out the high mortality of this devastating complication and the best 1-year survival rate in patients undergoing aggressive surgical treatment [6].

The mechanisms of aorto-esophageal fistula might consist of a combination of stent graft coverage of the arteries in the midesophageal segment causing ischemic necrosis or, in cases of contained rupture, possible development of a resorption hematoma leading to wall fatigue of the esophagus [1,2]. Further hypotheses on the pathomechanism include direct erosion of the relatively rigid stent graft through the aortic wall into the esophagus, pressure necrosis of the esophageal wall due to the continuing forces of self-expanding endoprosthesi, and infection of stent graft prosthesis leading to erosion of the esophageal wall [5]. Opening the mediastinal pleura via lateral thoracotomy and decompressing the posterior mediastinum could emerge as a preventive treatment [2].

In this case, development of the aorto-esophageal fistula was most probably based on a combination of different mechanisms. Erosion of the esophagus occurred probably due to ischemia induced by a resorption hematoma of the descending aorta in the first instance. By placing an esophageal stent, malperfusion of the esophageal wall was aggravated and finally resulted in a pressure necrosis induced by the forces of two self-expanding devices. The patient was initially treated at an external department and was transferred for treatment of the aorto-esophageal fistula to our department. Occurrence of esophageal erosion after TEVAR was probably the first sign of malperfusion and impending fistulation. In accordance with published data, the esophageal stenting-only approach is associated with poor 1-year survival of only 17% [6]. After confirmation of aorto-esophageal fistula, aggressive surgical treatment was chosen, which finally resulted in a prolonged and complicated hospital stay and survival of the patient.

Similar cases are described in the literature using either a bovine pericardial patch or other material for descending replacement, such as silver-coated polyester grafts or autografts [3,4,6]. All these materials aim to avoid Dacron grafts, which might be at higher risk for reinfection. Removing all infected material, performing extensive debridement, and using a self-made pericardial tube as neoorta provides excellent and durable results [8].

Conflict of Interest

The authors have no conflict of interest relevant to this publication.

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Dumfarth, J. et al. Aorto-Esophageal Fistula After TEVAR
How Often Do You Perform Aortic Valve Repair?

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(on behalf of the Editorial Office)

Key Words
Aortic valve repair · Aortic valve replacement · Bioprosthesis · Surgical techniques

Mitral valve repair has become the norm of current cardiac surgical practice and, in most cases, can be successfully implemented to treat degenerative and myxomatous valve disease. On the other hand, aortic valve repair has not been unequivocally accepted by the cardiothoracic community as a norm for treatment of aortic valve disease. There are proponents of aortic valve repair who argue that it is very effective, safe, and durable. At the same time, others do not believe it is an effective technique.

Therefore, the question for this “Poll the Editorial Board” series was:

Pertaining to Your Practice, How Often Do You Use Aortic Valve Repair Techniques in the Adult?
- I use Aortic Valve Repair techniques frequently
- I seldom use Aortic Valve Repair techniques and favor Aortic Valve Replacement

The respondents who selected the first answer option (I use Aortic Valve Repair techniques frequently) were asked:

Do you believe Aortic Valve Repair in the adult is (multiple choices possible)
- Durable
- Adequately proven
- An important part of modern surgical practice
- Able to provide equal durability with an aortic bioprosthesis

The respondents who selected the second answer option (I seldom use Aortic Valve Repair techniques and favor Aortic Valve Replacement) were asked:

You do not use Aortic Valve Repair in the adult since you believe it is (multiple choices possible):
- Not as durable as aortic valve replacement (aortic bioprosthesis)
- Not adequately proven
- Not an important part of modern surgical practice

The poll was distributed among all current members of the Editorial Board, who were asked to submit their responses via an online survey tool. The list of Editorial Board members can be found on the AORTA journal website (http://aorta.scienceinternational.org). The members of the Editorial Board whose practice does not lie within the scope of this question were asked to disregard this poll. Here we present the results of this poll.

Results of the “Poll the Editorial Board”

Twenty-six members of the Editorial Board submitted responses through our online survey tool. The results are presented in Figures 1, 2, and 3.

Comment

Interestingly, 61% of the respondents noted that they seldom use aortic valve repair techniques in their routine practice and prefer aortic valve replacement (Fig. 1). When these respondents were asked to provide reasons for not using aortic valve repair techniques, the respondents split into two equal categories:
those who believe repair techniques are not as durable as valve replacement with a bioprosthesis (64%) and those who do not find the efficacy of repair techniques adequately proven (64%) (Fig. 2). Only one respondent (7%) considers aortic valve repair not to be an important part of modern surgical practice.

The remaining 39% of the responding members of the Editorial Board mentioned that they frequently use aortic valve repair techniques in their practice (Fig. 1). The majority of members of the Editorial Board who do use aortic valve repair (78%) believe that valve repair plays an important part in modern surgical practice. More than half of the respondents (56%) believe that aortic valve repair is durable, while 44% consider that aortic valve repair is able to provide equal durability with an aortic bioprosthesis (Fig. 3). Interestingly, only one respondent (11%) among members of the Editorial Board who favor aortic valve repair techniques believes that the efficacy of repair techniques is adequately proven.

**Conflict of Interest**

The authors have no conflict of interest relevant to this publication.

**Comment on this Article or Ask a Question**

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List of Upcoming Meetings

March 2014

1. Aortic Valve Repair: A Step by Step Approach
   March 6–7, 2014
   Paris, France
   Meeting information available at:
   www.caviaar.com

2. The Houston Aortic Symposium: Frontiers in Cardiovascular Diseases, the Seventh in the Series
   March 6–8, 2014
   Houston, Texas
   Meeting information available at:
   www.promedicacme.com

3. Advanced Module: Open and Endovascular Aortic Therapy
   March 19–21, 2014
   Windsor, United Kingdom
   Meeting information available at:
   www.eacts.org/academy/2014-program/

April 2014

1. American Association for Thoracic Surgery Aortic Symposium
   April 24–25, 2014
   New York, New York
   Meeting information available at:
   www.aats.org/aortic


3. 61st Annual Conference of the Israel Heart Society
   April 30–May 1, 2014
   Tel-Aviv, Israel
   Meeting information available at:
   http://en.israelheart.com/

April 26–30, 2014
Toronto, Canada
Meeting information available at:
www.aats.org/annualmeeting/

May 2014

1. London Core Cardiothoracic Surgery Review Course 2014
   May 8–9, 2014
   London, United Kingdom
   Meeting information available at:
   www.corereview.co.uk

2. New Cardiovascular Horizons Foundation Fellows Course: Complex Strategies in Peripheral Interventions
   May 27, 2014
   New Orleans, LA
   Meeting information available at:
   www.ncvh.org

3. New Cardiovascular Horizons 15th Annual Conference
   May 28–30, 2014
   New Orleans, LA
   Meeting information available at:
   www.ncvh.org