Lecture Goals

- Understand potential aortic issues in patients with a stenotic aortic valve
- Learn the echocardiographic evaluation of the aortic root/ascending aorta
- Become familiar with the impact of these issues on surgical decision making

Introduction

Over 56,000 aortic valves are replaced annually in the United States, making AS the second most common reason for heart surgery, behind only coronary artery disease.\(^1\) The intraoperative echocardiographer plays a part in confirming the diagnosis of AS, quantifying its severity, and ensuring proper prosthetic valve function postoperatively. However, the aortic valve is only one component of the aortic root / ascending aorta complex. While measurements of these structures are often taken to assist in valve sizing, their impact on surgical decision making is often underappreciated. In particular, aortic dilatation may increase the risk of dissection in AS patients. Conversely, aortas that are too small in size may require surgical manipulation to accommodate a prosthetic valve. Both of these scenarios will be considered.

Anatomy and Measurements

The aortic root begins at the ventriculo-arterial junction, incorporates three bulges and their respective valvar leaflets (the sinuses of Valsalva), and ends at a slightly thickened ridge in the aortic wall where the ascending aorta begins (the sinotubular junction). Histologically, the walls of the aortic root are composed of fibrous tissue, but there is an increase in the elastic fiber content as the upper portion blends into the elastic tissue and smooth muscle in the aortic wall media.\(^2\) Interspersed between the bulging of the sinuses are fibrous triangles and small crescents of ventricular muscle. It is this heterogeneity of tissue that makes the aortic root a complex transition zone from the muscular left ventricle to the elastic proximal aorta.
The hinge lines of the aortic valve leaflets extend from the STJ to a point below the anatomical ventriculo-arterial junction, at the so-called virtual “basal ring.”

This is the point commonly measured via echocardiography as the “annulus,” although the existence of such a structure is a point of debate between surgeons and anatomists.

Echocardiographic measurements of the aortic root are made in the ME AV LAX view. Four measurements are of particular interest in the setting of AV surgery: the “annulus” (i.e. hinge points of the aortic valve leaflets), the diameter at the sinuses of Valsalva (typically the maximal root diameter), the sinotubular junction (STJ), and the proximal ascending aorta (usually measured within 2cm of the STJ). In general, the measurements are made at end diastole using the inner edge to inner edge technique, as this best correlates with other modalities such as MRI or CT. It should be noted, however, that most normative data for echocardiography has been established using the leading edge to leading edge technique and there is not a significant difference in these 4 parameters between systole and diastole. Normal values are given below in Table 1. Of course these measurements do not take into account body surface area (BSA) or age, both of which can significantly influence acceptable dimensions. As a rough guideline, maximum sinus diameters ≥4.5cm or STJ / ascending aorta diameters ≥4.0cm can be considered dilated, while roots <2.8cm and STJs <2.3cm can be considered small.

<table>
<thead>
<tr>
<th>Diameter Measurement</th>
<th>Mean ± SD</th>
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<tr>
<td>Subaortic (annulus)</td>
<td>21±3 mm</td>
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<tr>
<td>Maximum sinus</td>
<td>32±4 mm</td>
</tr>
<tr>
<td>STJ</td>
<td>27±4 mm</td>
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<tr>
<td>Ascending Aorta</td>
<td>33±4 mm</td>
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Table 1: Normal aortic parameters based upon BSA ~2.0m². Adapted from (5, 6).
Post-Stenotic Dilation

Approximately 5-25% of patients presenting for AVR due to aortic stenosis will have some degree of aortic dilatation. Fusiform (versus saccular) aortic dilatation can be broadly classified as either tubular (aka “supracoronary”) which is found at or distal to the STJ, or root-type (aka “teardrop,” or “pear-shaped”) which predominantly involves the sinuses. There can also be a general dilatation of both the root and ascending aorta, although by far the tubular variety is seen most commonly in AS patients. This contrasts with Marfan’s syndrome patients who tend to have root-type dilatation.

There is some debate as to the major etiology of aortic dilatation in AS patients. The theory of altered aortic flow dynamics causing aneurysm formation has been around since the 1950’s. Indeed, it has been shown in experimental models and in Doppler studies that flow development in the aorta is dependent upon the flow at the aortic root, which is affected by aortic valve geometry. Presumably these changes in shear wall stress could be responsible for the observed dilatation. However, the observation that aortic dilatation can occur in the absence of valvular abnormalities, even in patients without known connective tissue disorders (Marfan’s, Ehlers-Danlos, etc.), has lead to the conclusion that genetic structural abnormalities of the aortic wall are the main contributing factor. This is particularly true for patients with a bicuspid AV (BAV), whose aortic walls seem to have a relative deficiency of the structural protein fibrillin, and an increase in matrix metalloproteinases (MMPs – proteins that degrade collagen and other proteins). On the other hand, some studies have shown no difference in the rate of dilation between BAV and tricuspid AV patients without valvular disease. The debate will undoubtedly continue.

Treatment for mild dilatation is also a matter of unresolved controversy. It is generally accepted that surgical intervention on an ascending aortic aneurysm should occur when the diameter reaches 5.5cm. Furthermore, dissection risk increases following AVR if the aorta is >5.0cm in diameter, and so the majority of surgeons will
address that level of dilation along with the valve replacement. While lower thresholds are typically applied in patients with connective tissue disorders (e.g. 4.0 - 4.5cm for patients with Marfan’s syndrome), it is unclear where BAV patients fit into this algorithm. The recent 2006 AHA/ACC valvular heart disease guidelines recommend repair or replacement of the ascending aorta if the aortic root or ascending diameter is >4.5cm is BAV patients undergoing AVR for either stenosis or regurgitation. However, this is by no means universally accepted. Given that up to half of the patients presenting for AVR with AS may have a congenital BAV, there exists a bit of uncertainty about what to do when the intraoperative TEE unexpectedly reveals a dilated aorta in the 4.0 – 5.0cm range.

The reason for uncertainty, of course, lies in the significant difference in morbidity/mortality between an AVR and an AVR combined with a root or ascending aorta replacement. While isolated AVRs generally carry a mortality risk of <5%, this risk more than doubles with the addition of root procedures. This has lead to the development of more conservative surgical treatments such as reduction aortoplasty and wrapping of the aorta with Dacron or felt grafts. Large scale trials are lacking, however, and the debate of the “correct” surgical treatment will likely continue until further outcome studies are available.

The Small Aorta

At the opposite end of the spectrum from an AS patient with “too big” an aorta is the patient who has one “too small” to accommodate an appropriately sized prosthetic valve. From a practical perspective, the smallest prosthetic valve available is 19mm in diameter (17mm valves are not widely available), and so any annulus smaller than that could be considered undersized. Sizing of prosthetic valves must also take into account overall patients size, however, and so the definition of patient – prosthetic mismatch (PPM) becomes important. In a broad sense, PPM is defined as implanting a valve that causes a significant gradient while the patient is at rest. This happens when the valve’s indexed effective orifice area (iEOA = EOA_{valve} / BSA_{patient}) falls below certain thresholds. Some PPM is said to occur below an iEOA of 0.85 and severe PPM is said to be present when it falls below 0.65. The overall consequence of PPM has been the subject of much debate in recent years. Some groups argue that even mild PPM causes a reduction in survival, while

Graph showing the correlation between resting mean transvalvular gradient and iEOA in >300 patients following AVR with multiple types of prostheses. From (21)
others conclude it has no impact on early or late postoperative survival.\textsuperscript{23} PPM may be particularly detrimental to patients with preexisting LV dysfunction, yet have little effect on patients over 70 or obese patients.\textsuperscript{24}

Regardless of how severe the effects of PPM are, it can largely be avoided by calculating the projected iEOA (the valve EOA is usually given on the package insert, or may be looked up in the latest ASE prosthetic valve guidelines\textsuperscript{25}) for the valve intended for implantation. If the projected iEOA is $< 0.85$ then another valve type can be chosen. Mechanical and stentless valves generally have greater EOAs than stented bioprosthetics for any given size. Alternatively, the patient’s aortic root can be enlarged to accommodate a larger valve size.

The posterior approach (Manouguian’s procedure) for aortic root enlargement is the most commonly performed method in adults. An incision is brought through the interleaflet triangle between the non- and left-coronary sinuses into the anterior leaflet of the mitral valve. It is then closed with a pericardial or Dacron graft, thus widening the ventriculo-atrial junction so the valve’s sewing ring can be inserted.\textsuperscript{26,27} This generally allows an increase in 1 or 2 valve sizes. Complications include AV node injury and mitral regurgitation. A recent large scale study of routine root enlargement for annulus measurements of $\leq 21\text{mm}$ showed significant reduction in the incidence of PPM, although no appreciable long-term survival advantage.\textsuperscript{28}

**Take Home Points**

- Aortic measurements should be routinely done for all AS patients
- Post-stenotic dilatation at or past the STJ is common, particularly in patients with a bicuspid aortic valve
- Management of mild dilatation (4-5cm) is controversial
- Patients with small aortic measurements should have a projected iEOA calculated for the type of valve being inserted
- Patient-prosthesis mismatch can be avoided by use of larger EOA valves (stentless/mechanical) or aortic root enlargement procedures
References


4 Lang RM, Bierig M, Devereux RB, et al. Recommendations for chamber quantification: A report from the American Society of Echocardiography’s guidelines and standards committee and the chamber quantification writing group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. J Am Soc Echocardiogr, 2005;18:1440-63.


