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Surgical anatomy of the aortic root: Implication for valve-sparing reimplantation and aortic valve annuloplasty

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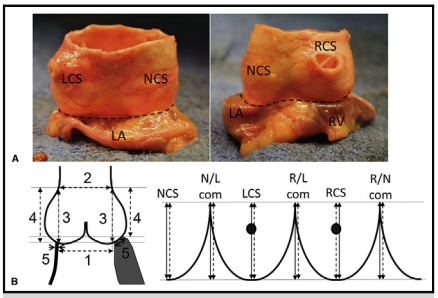
ABSTRACT

Background: To enhance the reproducibility of aortic valve–sparing reimplantation and annuloplasty, we analyzed the topographic relationship between the ventriculoaortic junction (VAJ), basal ring (BR), and sinotubular junction (STJ). The root base thickness is also quantified.

Method: Fifty-eight fresh human aortic valves were analyzed. The root was dissected to the limit where the aortic wall terminates into the cardiac structures (VAJ). Root height was measured externally from the STJ to the VAJ and internally from the STJ to the BR defined as the plane passing through the cusps nadir. The root base thickness was measured at the BR and orthogonal to the internal wall; except at the right coronary sinus, where it was measured between the BR internally and the VAJ externally. Measurements were taken at the middle of the 3 sinuses and commissures.

Results: The VAJ is at the same level as the BR from the noncoronary sinus (−0.1 ± 0.9 mm) to the left coronary sinus (0.5 ± 1.3 mm); it is above the BR from the left/right commissure (4.6 ± 1.4 mm) to the right/non commissure (2.5 ± 1.6 mm). The external root height was highest at the non/left commissure (21.5 ± 2.6 mm) followed by the right/non commissure (19.2 ± 2.3 mm) then the left/right commissure (15.7 ± 2.2 mm) ($P < .05$). The mean root base thickness was 3.2 mm, ranging from 1 ± 0 mm at the left/non commissure to 6.2 ± 1.2 mm at the right coronary sinus ($P < .001$).

Conclusions: The VAJ is not planar; it is above the level of the BR from the left/right to the right/non commissure. As a consequence, the external height of the non/left commissure is greater than the other 2 commissures. These findings should be taken into consideration when performing aortic valve–sparing reimplantation or external annuloplasty. (J Thorac Cardiovasc Surg 2015;149:425-33)



Surgical anatomy of the aortic root.

Central Message

Measurements in 58 fresh aortic roots determined that the external height of the non/left commissure was greater than the other two.

Clinical Relevance

These findings are important for aortic annuloplasty techniques, particularly valve-sparing reimplantation and external ring annuloplasty in which the graft or the ring is fixed around the base of the root. Incomplete proximal root dissection will impede placement of the device down to the basal root level. However, these studies show that dissection to the basal root is possible to secure external fixation.

Aortic valve–sparing root replacement and repair are emerging more and more as an advantageous alternative to replacement with composite grafts or prosthetic valves. However, reconstructive surgery of the aortic valve is technically more demanding compared with replacement and needs in-depth knowledge of the anatomy of the aortic valve and the root. Most anatomical studies on the aortic valve have been performed before the era of aortic valve repair, which explain why several measurements of importance for valve repair have been poorly analyzed if at all.[1-7] The lack of quantitative data on the repair-oriented anatomy of the aortic valve impairs the reproducibility and standardization of surgical techniques.

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Abbreviations and Acronyms
AV = aortic valve
BR = basal ring
LCS = left coronary sinus
NCS = noncoronary sinus
RCS = right coronary sinus
STJ = sinotubular junction
VAJ = ventriculoaortic junction

It has been demonstrated that an untreated large ventriculoaortic junction (VAJ) has a negative impact on repair durability; and noncircumferential annuloplasty, like the commissural annuloplasty stitch described by Cabrol, seems inadequate to provide stable reduction of a large VAJ over time.[8-12] In consequence, a variety of circumferential annuloplasty techniques (eg, internal or external ring, suture annuloplasty) are actually in the experimental or clinical phase of development.[13-16] These techniques have potentially different effects on aortic valve function and root geometry, which suggests that aortic valve and root anatomy need to be reconsidered to make appropriate use of annuloplasty techniques.[17]

For external ring annuloplasty and for the valve-sparing reimplantation technique, the base of the aortic root must be dissected free to allow the ring or the graft to be placed, ideally at the level of the basal ring (BR), defined as the plane passing through the nadir of the aortic cusps. However, the instigators of the valve-sparing reimplantation technique have reported that the BR level may not be reachable for the entire root circumference in all cases.[18,19] The limit of proximal dissection of the aortic root corresponds to the external aspect of the VAJ, also defined as the zone where the ventricular structures join the wall of the aortic root. In the early 1990s, Anderson and colleagues[5] described the anatomy the VAJ as a relatively plane circle passing through the lower third of the 3 sinuses of Valsalva, thus crossing the cusp insertion above the plane of the BR. Since this report, he and his collaborators nuanced the description of the VAJ placing it at the level of the BR or above where the cusp insertion lines cross the ventricular myocardium.[7,20] This last configuration concerns the right and left coronary cusp. The resulting muscular inclusion at the base of the sinus of Valsalva varies in size from heart to heart and its width in humans has rarely been measured.[1,20]

In this anatomic study, our aim was to analyze quantitatively the topographic relationship between the VAJ and the BR in the human aortic valve. In addition, we sought to quantify the thickness of the VAJ at different levels of the root circumference including the width of the muscular inclusion at the base of the right coronary sinus (RCS).

MATERIALS AND METHODS

Origin and Management of the Specimen

We analyzed 58 fresh aortic roots obtained from a homograft bank (n = 41) or from donated cadavers (n = 17). The specimens obtained from the homograft bank had been rejected for clinical use and therefore allocated for research. All specimens were tricuspid aortic valves. Each specimen was harvested initially as a bloc of tissue including 3 to 4 cm of heart tissue around the aortic root. No chemical fixation was applied to the specimens, which were cryopreserved between the different phases of root preparation and the measurements. Root preparation and measurements were performed by 1 senior cardiac surgeon (L.D.K.).

The general characteristics of the specimen were recorded including donor age, gender, and the presence of calcification (graded as mild, moderate, or severe). Valve or root calcifications were not considered as exclusion criteria.

The study was approved by the institutional ethics committee.

Root Preparation

All specimens were prepared similarly before the measurements were taken (Figure 1, *A*). The aorta was transected at the level of the sinotubular junction (STJ). Left ventricular outflow tract structures (anterior mitral leaflet and interventricular septum) were trimmed to leave 1 to 1.5 cm of tissue below the BR. Coronaries were cut at the ostia. The aortic root was dissected free from the surrounding cardiac structures, similar to the valve-sparing reimplantation technique.[21] The root dissection was performed caudally to the limit where the heart structures terminate and give way to the wall of the aortic root. This limit was considered as the external aspect of the anatomical VAJ. A rim of 1 to 2 cm of tissue surrounding the base of the aortic root was preserved to maintain a clear demarcation of the VAJ (Figure 1, *A*).

Root Measurements

The measurements taken on the aortic root were the diameter of the left ventricular outflow tract at the level of the BR (BR diameter), the STJ diameter, the internal and external root height, and the root base thickness.

Measurements were taken with a dry point compass or a ruler at 6 points around the root circumference: the middle of the 3 commissures and the middle of the 3 sinuses of Valsalva (Figure 1, *B*). The diameters of the BR and STJ were taken from the inner to inner side of the ventricular or aortic wall. The external root height was measured from the STJ to the VAJ and the internal root height was measured from the STJ to the BR. The external root height was measured on the intact aortic root specimen; then the root was opened longitudinally at the middle of the non/left commissure to measure the internal root height (Figure 1, *C*). The BR level was defined as a plane passing through the ventricular side of the nadir of the aortic cusps. To measure the internal root height at the commissures, the BR level was marked on the specimen by tracing a mark at the middle of the straight line joining the nadir of adjacent cusps (Figure 1, *C*). The specimens were held in place to maintain a normal anatomic configuration but no additional tension was applied on the tissues to take the measurements. The difference between the internal and external root height was calculated to estimate the relative distance separating the BR level from the VAJ level. A positive difference between the internal and external root height indicates that the VAJ was above (distal to) the BR level; conversely, a negative difference indicates that the VAJ was below (proximal to) the BR level. A zero difference indicates that the VAJ and the BR were at the same level. Root base thickness was measured at the BR level and orthogonal to the wall of the left ventricular outflow tract. At the level of the RCS, root