Aortic valve sparing operations I: Sizing the graft

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Las aortic valve sparing operations se están convirtiendo en una herramienta cada vez más frecuente para tratar quirúrgicamente los aneurismas aórticos proximales, ya sean aneurismas de la raíz aórtica o aneurismas aórticos ascendentes. Incluso cuando se han reconocido todos los beneficios, este tipo de técnicas siempre son muy exigentes, y la curva de aprendizaje es demasiado implacable. Incluso el más mínimo error tiene consecuencias desastrosas. Una ejecución perfecta es siempre necesaria. Uno de los problemas más preocupantes es cómo seleccionar correctamente el tamaño del injerto. Analizamos aquí en detalle cómo hacerlo.

Palabras clave: **Aortic valve sparing; Aneurisma de raiz aórtica; procedimiento de David; Valsalva Graft.**

Aortic valve sparing operations are becoming an increasingly frequent tool for surgically treating proximal aortic aneurysms, either aortic root aneusysms or ascending aortic aneurysms. Even when all benefits have been recognized, this kind of techniques are always very demanding, and the learning curve too unforgiving. Even the slightest error takes disastrous consequences. A perfect ejecution is always needed. One of the most worrying issues is how to properly select the graft size. We analyze here in detail how to do it.

Keys words**: Aortic valve sparing; Aortic root aneurysm; David procedure; Valsalva Graft.**

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Aortic valve sparing (AVS) operations are becoming an increasingly frequent tool for surgically treating proximal aortic aneurysms, either aortic root aneusysms or ascending aortic aneurysms. Given the fact this kind of pathology begins at the level out of the native aortic annulus, most of the time the aortic valve structure remanis unaffected. Briefly speaking, lack of 3D relationship in aortic root is mostly responsible for aortic valve regurgitation [1]. As a matter of fact, some of these cases do not exhibit aortic valve regurgitation but important dilation at the level of the sinuses of Valsalva, sinotubular junction or ascending aorta. The aortic annulus can be secondary affected by the pathological process [2].

There are currently two main surgical techniques to treat this entity. David procedure, also called aortic root reimplantation [3], and Yacoub procedure, refered as aortic root remodeling [4]. Both of them work with a dacron graft. One of the most important issue the surgeon should bear in mind is sizing and choosing the correct dacron graft, slightly different for each of them.

In this article, we will analyze and explain in depth how to choose the correct dacron graft for David as well as Yacoub procedure.

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ANATOMY OF THE AORTIC ROOT

The first thing the surgeon must learn is to call a spade a spade. In fact, most of the times absolute ignorance regarding the details in the anatomy of the aortic root is responsible for choosing other techniques than these ones herein, such as composite graft replacement. Let's have a look at this.

Aortic root components are: aortic valve annulus (aortoventricular junction), aortic leaflets (aortic cusps), sinuses of Valsalva, and sinotubular junction. From this point, upwards the aorta is called ascending aorta (**Fig. 1**). Surgeon must learn to make the difference on each of these anatomic structures. This is the first step to propelry indetify the type of aortic aneurysm we are facing. Consequently, a more proper decision can be made in selecting the most appropiate surgical technique for a given case.

Aortic annulus, or aortoventricular junction, is the most inferior component of the aortic root. This anatomic structure can be identified as a double structure. One of them is the true annulus (aortoventricular junction) where the left ventricular outflow tract reaches the aorta. The other one, the most commonly called aortic annulus is where the aortic leaflerts (or cusps) are inserted. This is where sutures are commonly placed for any conventional aortic valve replacement . There is

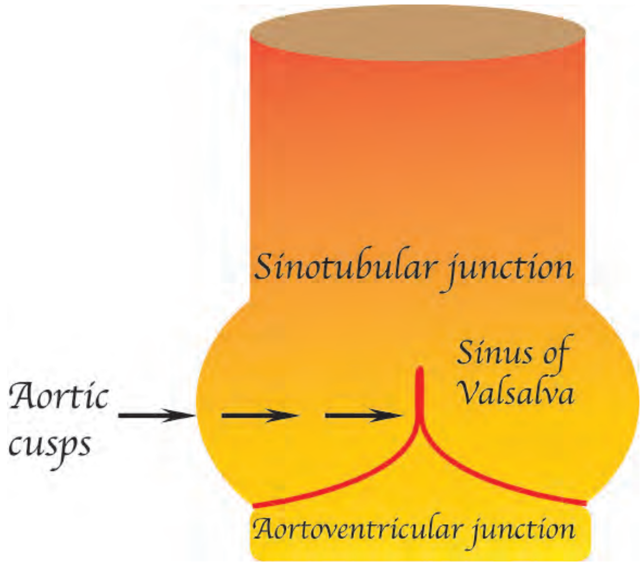

Figure 1. Diagramatic view of the anatomy of the aortic root

an important difference between them. The aortoventricular junction has a circular shape, just below the "surgical" aortic annulus. This other one has a crown shape, being locates just above the aortoventricular junction. In this image (**Fig. 2**), we can clearly observe the main differences between both annulus, true and "surgical" annulus. This is an anatomic disection on a beef heart. In fact, I always recommend to my residents and younger surgeons to make this kind of exercise in order to be familiar with the aortic root anatomy.

The aortic cups, also called aortic leaflets, are the most important componet in determining the quality of our work at mid and long term. They can be dammaged in many cases of aortic root dilation. Determining the lenght of them is a crucial part in the decision-making process for any AVS operation. The best way to assess this issue is watching the echo study. Transesophagic echocardiography is the best way to do that. Several views are required in order to make a conclusion. The more dilated the sinuses of Valsalva or sinotubular junction, the more the dammage on the aortic cusps. Briefly speaking, aortic cusps < 13 mm in lenght (from surgical annulus to nodule of Arantious) preclude an adequate AVS operation [2]. When maximun diameter above is greater than 60 mm, cusps are generally dammaged (fenestrated near the commisures, or even detached, as well as lenght becomes smaller). Just the opposite when maximun diameter is around 50 mm [5]. Enough leaflet tissue must be assured in order to get maximun coaptaiton after the repair. A good coaptation surface is obtained when coaptation height is ≥ 8 mm [6]. Otherwise, aortic valve regurgitaton can quickly apper after the repair. Of course that surgeon must measure each valve during the course of the operation judging whether or not going forward with AVS. Normal or nearly normal aortic cusps with a non dilated aortic annulus are the best option to perform AVS. We are talking about tricuspid valves. Bicuspid valves deserve a special mention, and this is not the scope for this article.

Sinuses of Valsalva are the most damaged structures in aortic root dilation. Indeed, in Marfan patients the dilation mostly begins at this level extending itself up to the sinotubular junction and beyond reaching the ascending aorta, and towards the aortic annuls as well. Sinuses of Valsalva are the space between the aortic annulus and the sinotubular junc-

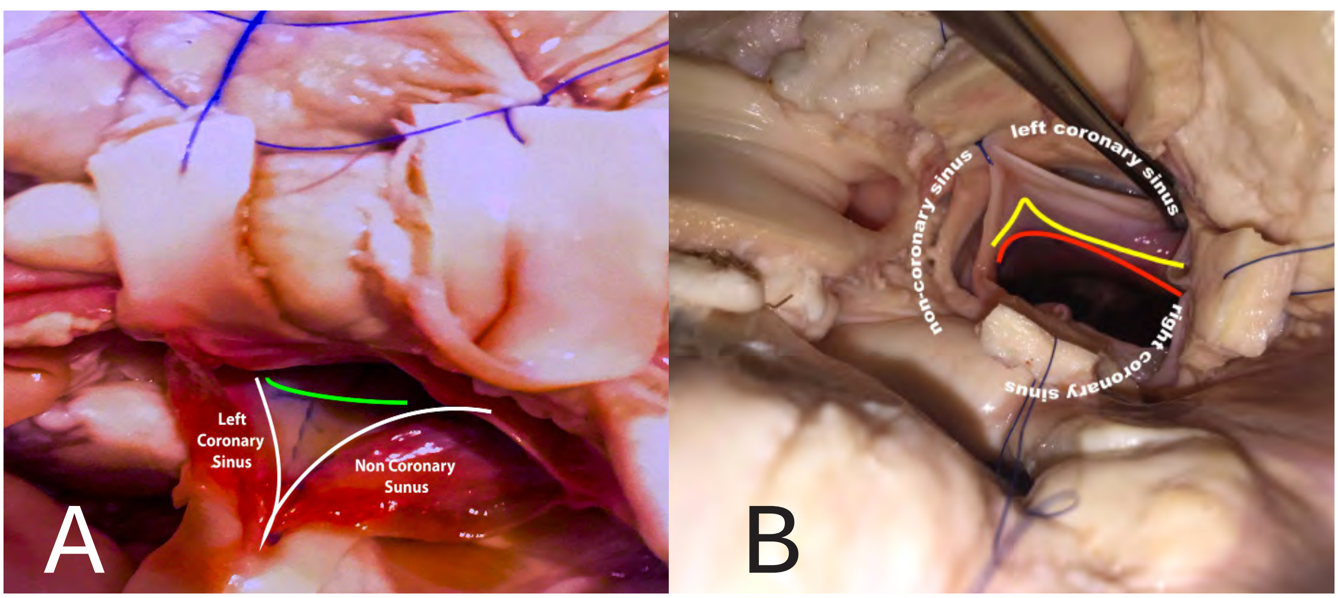

Figure 2. Disection on a pig heart. A. Green line= aorto-ventricular junction, white line= aortic annulus. B. Red line= aorto-ventricular junction, yellow line= aortic annulus.

tion (**Fig. 1**). When they are larger than 65 mm, AVS may be contraindicated because of the bad results at mid and long term [2]. This is largely linked to the fact described above. Important remarks must be done here with regard to dissection or rupture depending on the sinuses of Valsalva dimensions [7].

In patients with genetic syndromes, it is very common to find dilation at the level of sinuses of Valsalva as well as the aortic annulus. Annuloaortic ectasy is a term used in this kind of pathology, first introduced by Denton Cooley in 1961[2]. It is also extremely important to highlight how dilation of this structure can affect our final results in AVS. The more dilation in sinuses of Valsalva, the lesser the interleaflet triangle with the concommitant lack of enough coaptation after the diameter correction. As a general rule, sinuses of Valsalva lesser than 50 mm are rarely affecting this issue nor structural leafleat dammage is observed [5].

DISECTION OF THE AORTIC ROOT

We need to disect aorund the aortic root well below just until the level of the nadir of each aortic cusps. However, we have to be aware about the level of disection is not the same for all the entire aortic root [8]. There are so many things surgeon have to keep in mind when disecting aortic root. Anatomic limitations such as membranous and muscular interventricular septum as well as the left atrial roof can make this disection hazardous. Once the aortic root has been totally transected 1 cm just above sinotubular junction, aortic root is exposed outside, and the diseciton begins at the level of the non-coronary sinus, slightly reaching the nadir. However, just in case the left atrium disection becomes difficult and the risk of perforation is high, we can just disect a limited area, even when sutures from inside the aorto-ventricular junction be placed over the atrium. This is especially true just below LC/NC commisure and RC/NC commissure. The suture line to hold the points on the aortoventricular junction below NC sinus is at the same level of the mitro-aortic junction extending at this same level just to reach the nandir of the LC sinus. Then the NC sinus is excised and removed leaving 5-8 mm of the free aortic wall remnant attached to the aortic annulus. Now, aortic root disection continues detaching adherences between aortic wall and the right ventricle. This is done just to get an adequate approach to free the right coronary button. The cut begins very close to the LC/RC commisure, always from inside the aorta surrounding all the button, leaving at least 5 mm as a free aortic wall in the RC sinus. The release is completed extending the incision in a similar way from the RC/NC commissure until reaching the other one, almost always in the most inferior part of the right coronary button. No attempts are made for further mobilization of the button at this point. A stay suture is used to pull away the botton. Now disection continues from the RC/NC commissure moving clock counter-wise up to the LC/RC commissure. Extremely caution must be paid here because we need to disect enough right ventricular tissue until reaching the same level of the valve insertion, not more, so risk of ventricular perforation. Now, left coronary button is freed as in the same fashion for the right one, from inside the aorta. Disection of the aortic root is very interesting here. We have to disect just to the same level of the cups insertion below the RC/LC commissure [8]. In fact, disection becomes very difficut and limited here because of the interventricular septum. So, only a few milimeters can be disected before perforing the right ventricle. Later, we will discuss the correct way to put the sutures on the aortoventricular junction from inside the aorta. Finally, enough liberation is made just below LC sinus paying enough attention at the same point of the left atrial roof we have explained above. Sutires can be put over the roof of the left atrium with no adverse consequences in graft distortion. My personal view is that the disection here is made jut to get enough aortic wall tissue in order to make a safe anastomosis between this one and the inner wall of the graft. Not more than 5-7 mm are usually needed. Now, the aortic root disection is complete.

GRAFT SIZING

This is perhaps the most important and crucial point of the operation. My recommendation would be always to take enough time to select the correct graft size. All methods previosly described are focused in only one aim: to restore the normal sinotubular juntion. In normal subjects with no annular dilation, sinotubular junction is 10-15% lesser than the other one. At the same time, normal dimensions for the aortic annuls are not larger than 1.2 cm/m2 of body surface. All of a surgical techniques parade has been described. All of them are based on the fact that aortic leaflets are unable to become longer than original. On the other hand, the aim is joining the three cusps at a central point, just at the noddles of Aranchuis level, and leaving almost 40-50% of the valve extension getting contact between them. So, more than 8-9 mm must be obtained in order to assure a good postoperative long term period without insufficiency. In addition to the annular dilation, even more important is the sinotubular dilation. This is the most responsible for aortic valve regurgitation. As sinotubular dilates, all the three commissures are outward displaced and there is a lack of cusps coaptation. Inspired by these concepts, we can discover several techniques in order to obtain the correct graft size, and thus covering an ample range of possibilities, from the simplest and rustic to the most elaborate ones.

The first thing one should take into account is which AVS technique will be utilized. Generally speaking, graft size is larger for David than for Yacoub procedure. In David procedure the graft is oustide the aortic root. In Yacoub remodeling the graft is integrated to the aortic wall.

The simplest one, but at the same time more inaccurate, is described by Yacoub[4]. Once sinuses of Valsalva have been resected, pull sutures are placing above each commissure. Vertical traction is applied on them. They are slightly put into prixomity just to reach a very good cusps coaptation. The imaginary circle is then measured with Hegar dilator or any valve sizer. This is the correct size for Yacoub aortic remodeling. For David procedure, + 4 or 5 number are added. As we can guess, a great experience judging this maneouver in operating room is needed in order to avoid any big mistake.

Another technique described by Schäfers [9] consists of measuring the width of the aortic leaflets, from their insertion in the native ring up to the node of Arancio. This result is multiplied by 0.6 and then + 1. And the final result is obtained by multipling by 2. In example, each cusp = 20 mm (more usual) x 0.60 = 12 +1 = 13 x 2 = 26 mm. The graft size for Yacoub aortic remodeling is 26 mm. Let's explain the principle of this technque. Wide cusp is equal to the radius. Sixty percent of each aortic cusp is actually working by filling the space between the annulus and the central point of the aortic valve. The remaining 40% is working on the coaptation surface of the cusp. We add + 1, because this is the thickness value for the aortic wall. And the final result is multipled by 2 in order to get the total diameter of the circle. Just in case for David procedure, we would need to add + 4 or 5. So, 26 + 4 = 30 mm would be the correct graft size.

Dr. Tirone David utilizes the average of the cusps height, and then mutlipling by 2 [3]. For an average adult with Marfan syndome, the most common is 30-32mm. Range can go from 26 to 34 mm.

There is another extremely objective method described by El-Khoury et al [8]. It is based on the principle that the distance between the intertrigonal distance and the highest point of the NC/LC commissure is not affected in aortic root aneurism. So, we can proceed to measure this distance (**Fig. 3**). The measure obtained is the same for the graft size for David procedure both for a straight tube and for a Valsalva graft.

Morishita et al. [10] have described other method based on geometic concepts assuming that the three commissures are equidistant forming an equilateral triangle.

There are several concepts respective to this item, which is worth keeping in mind. If any doubt, choose the 30 mm graft. If the graft is resulting in a smaller size, plication at the centre of each cusp can be done in order to compensate the resulting valve prolapse. If graft is resulting in a larger size, plication may be done at the upper level of the graft on the each intercommissural space, not over the commussure [8].

The most important point here is to align each commissu-

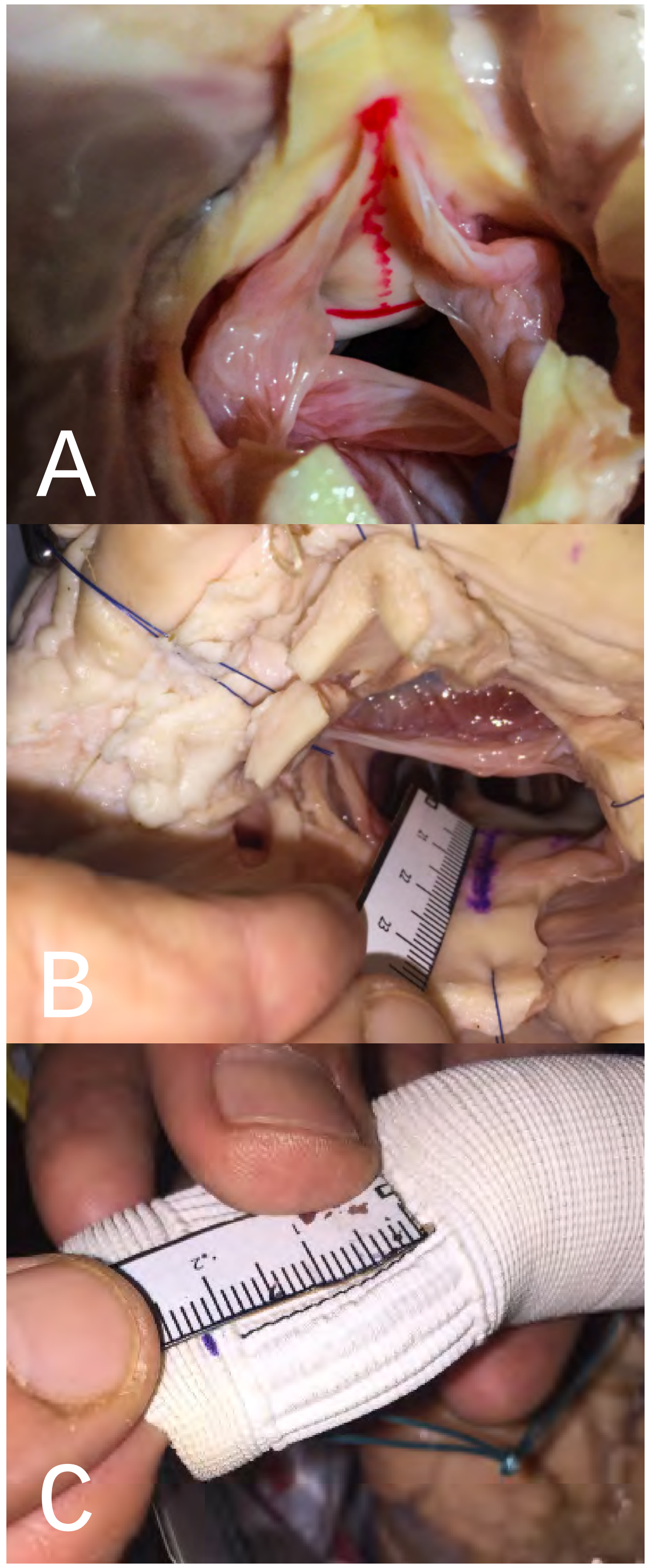

Figure 3. Sizing the graft. A, Distance bewteen inter-nadir line (NC/LC sinuses) and the NC/LC commissure. B, Measuring the distance.C, the same size of the graft, according to the obtained distance above. All the pictures above are working on a pig heart disection.

re perfectly along the tube, especially in the straight tube that is not previously marked. We can mark the tube in the following way: once the straight tube is chosen, it is bent in half in its diameter. Then, we measure the distance obtained. This is divided by three, and the resulting measurement is marked from the opposite point against the pre-existing mark on the tube, marking on both sides thereof. This results in three equidistant parts in the straight tube. Then, each of these marks is signaled in a straight line through the tube.

And finally, based on high volume of trated patients, some hospital centers have actually found extremely useful the following recommendation: for David procedure: > 2.5 m2 SC = 32 mm graft, 2.5-1.6 m2 SC = 30 mm, ≤ 1.5 m2 SC = 28 mm (the same for straight or Valsalva graft); for Yacoub procedure: > 2.2 m2 SC = 28 mm, 2.2-1.9 m2 SC = 26 mm, ≤ 1.8 m2 SC = 24 mm [1]. Keep in mind that major diameters are needed for David procedure because this one is put outside the aortic root. In Yacoub procedure the graft is integrated as close as possible directly to the aortic annulus.

There are many arguments for and against for each of these procedures we have described here. Generally speaking, we can say in advance that David procedure (reimplantation) is indicated for cases of aortic root aneurysm in which aortic annulus is dilated (younger patients with genetic syndromes), whilst Yacoub procedure (remodelling) works very well for those with ascending aorta aneurysm with extension towards sinuses of Valsalva with normal or nearly normal aortic annulus (older patients with degenerative process). Of course that there is nothing wrong in selecting David procedure instead of Yacoub, whatever the case may be [11].

So far, we have seen the first part of the description about how to perform a David procedure step by step. The rest of the operation will be discussed in one or two further articles. The purpose of these article series is to encourage cardiac surgeons going forward with this type of procedures. Improving surgical skills is an essential part of the planning process. My personal recommendation is to get this skills by practicing fistly on pig hearts. Pig hearts are much more amenable for doing this than the beef hearts, given the similarity with the human one.

It is necessary to think in 3 dimensions. While dissecting the aortic root, one must think about what is above and what is below our plane of dissection. This is especially true at specific locations, such as at the ring level in the part corresponding to NC / RC commissure [1].

This all descibed above is only the first part of the David procedure. Further articles will come here. These are very demanding procedures, which require a lot of practice. My suggestion is that much of this skill can be obtained while working on multiple occasions in pig hearts, placing a cloth or dacron tube, in the same way that would be done in the operating room. This allows you to familiarize yourself with the anatomical regions, as well as having a mental map about the course of the procedure, and above all with the handling of surgical instruments in a faster and more efficient way. Just to have an idea; given the fact that in our environment these cases are not very common, and the current trend is to send them for a composite graft, I had to practice on multiple occasions on 12 pig hearts (more than 30 times), before performing perfectly well for real my first David V in Mexico.

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