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David procedure: surgical technique step-by-step

David procedure: técnica quirúrgica paso a paso

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ABSTRACT

The David procedure, also known as aortic root reimplantation, is a surgical technique used to treat aortic root aneurysms, with or without aortic valve insufficiency. This article presents a step-by-step guide to the surgical technique of the David procedure, supplemented by personal insights and oral contributions from Dr. Tirone David, the creator of the reimplantation technique.

Keywords: aortic aneurysm, aortic root, aortic valve, aortic valve sparing, aortic valve regurgitation, David procedure.

RESUMEN

El procedimiento de David, también llamado aortic root reimplantation, se utiliza para tratar quirúrgicamente los aneurismas de raíz aórtica, con o sin insuficiencia valvular aórtica. En este artículo se presenta paso a paso la técnica quirúrgica del procedimiento de David, incluyendo aportaciones personales del autor, así como comunicaciones personales del Dr. Tirone David, creador de la técnica de reimplantación.

Palabras clave: *aneurisma aórtico, raíz aórtica, válvula aórtica, preservación de la válvula aórtica, insuficiencia aórtica, procedimiento de David.*

The aortic valve-sparing operations (AVS) have represented a paradigm shift in the surgical management of aortic aneurysms, aiming to preserve the native aortic valve in patients with aortic aneurysm, with or without aortic insufficiency. To optimize the outcomes of these procedures, it is essential to elucidate the underlying pathophysiological mechanisms driving aneurysm formation.

Furthermore, understanding the impact of aneurysm formation on the three-dimensional dynamics of the aortic root and ascending aorta is crucial for the successful implementation of aortic valve-sparing operations. This requires a comprehensive analysis of the spatial and temporal relationships between the aortic valve, aortic root, and ascending aorta, as well as the biomechanical properties of these structures. Indeed, a major obstacle hindering progress in AVS operations, aside from the complexity of the surgical technique itself, lies in the fact that many professionals involved fail to accurately differentiate between aortic root aneurysms and ascending aortic aneurysms. This is critically important for selecting the right surgical technique. A comprehensive comparison of the distinguishing characteristics between aortic root aneurysms and ascending aortic aneurysms is provided in *Table 1*.[1]

In order to facilitate a full understanding of this subject, it is imperative to begin by exploring the fundamental concepts, including the anatomy and morphology of the aortic root and ascending aorta.

ANATOMY OF THE AORTIC ROOT

The aortic root is a complex anatomical entity composed of five primary elements; namely, the aortic annulus, aortic

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leaflets (also known as aortic cusps), sinuses of Valsalva, interleaflet triangles, and the sinotubular junction. The ascending aorta originates just above the sinotubular junction. By definition, the aortic root encompasses the region between the sinotubular junction and the basal ring aortic or aortoventricular junction, including both structures. The total height of the aortic root is no more than 2-3 cm *(Fig. 1)*.[2]

Aortic annulus and aortoventricular junction

A supplementary component that can be incorporated into the aortic root complex is the aortoventricular junction, which represents the interface between the left ventricular outflow tract and the aortic root itself. This junction is situated below the level of the true aortic annulus, where the aortic leaflets are anchored to the aortic root. The collagenous tissue at the attachment point of each leaflet is referred to as the annulus. Notably, the aortoventricular junction is predominantly muscular, whereas the aortic annulus is essentially fibrous. Moreover, the aortoventricular junction exhibits a circular configuration, situated immediately below the "surgical" aortic annulus, which exhibits a crown-like shape, situated just superior to the aortoventricular junction. The interleaflet triangles deserve special consideration into the pathogenesis of aortic insufficiency.[3,4] The dilation of the aortic root results in a geometric alteration of the subcommissural triangles, characterized by a widening of their bases and a reduction in commissural heights, ultimately affecting the coaptation area.[1]

As depicted in *Fig. 2*, the distinct morphological characteristics of both the true and "surgical" annuli are clearly discernible.[2]

Aortic leaflets (aortic cusps)

A pivotal consideration in the decision-making process for AVS surgery is the evaluation of the aortic leaflets. The morphology and, more importantly, the extent of the leaflets are critical determinants. As a general rule, a leaflet length < 13 mm (measured from the aortic annulus to the nodule of Arantious) contraindicates AVS. Additionally, an aneurysmal diameter exceeding 60 mm at the level of the Valsalva sinuses often results in compromised aortic cusps (fenestrated, detached, or shortened). The best way to assess the aortic cusps is by transesophageal echocardiography.[1]

To ensure durable repair, sufficient leaflet tissue must be preserved to facilitate optimal coaptation. A coaptation height of $\geq$ 8 mm is generally considered necessary to achieve a satisfactory coaptation surface.[5] Inadequate coaptation may lead to early onset of aortic valve regurgitation following repair.

Sinuses of Valsalva (aortic sinuses)

The aortic sinuses of Valsalva and the sinotubular junction are characterized by a predominance of elastic tissue in their walls, which are generally thinner than those of the ascending aorta. Indeed, the sinuses of Valsalva are the most vulnerable structures, where the aortic root aneurysm typically begins to dilate.[6] From this point, the aneurysmal dilation extends both upward, frequently reaching or surpassing the sinotubular junction, and downward, resulting in dilation of the aortic annulus. These three structures are comprised between the basal ring and the sinotubular junction.

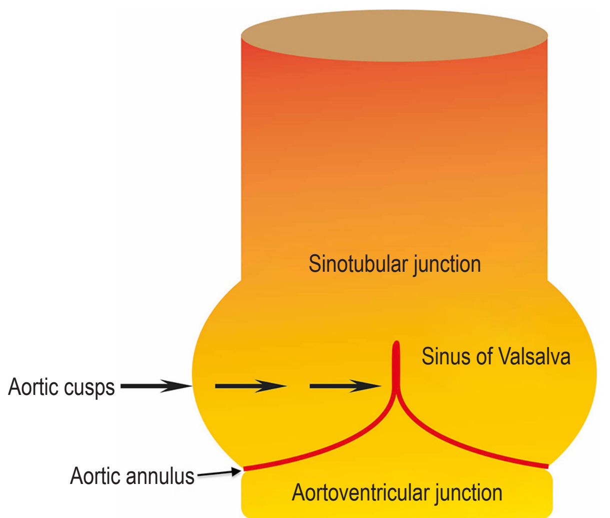

Figure 1: Aortic root.
With permission of: García-Villarreal OA.[2]

Table 1: Main differences between aortic root aneurysm and ascending aorta aneurysm.

Aortic root	Ascending aorta
Starting on the sinuses of Valsalva	Starting on the medial portion of the ascending aorta
Expanding towards sinotubular junction and ascending aorta	Expanding towards up and down the ascending aorta
Annulus dilation almost always	Annulus remains unaffected
Associated to genetic diseases	Associated to degenerative diseases
Between 2nd and 4th decade of life	Between 5th and 7th decade of life

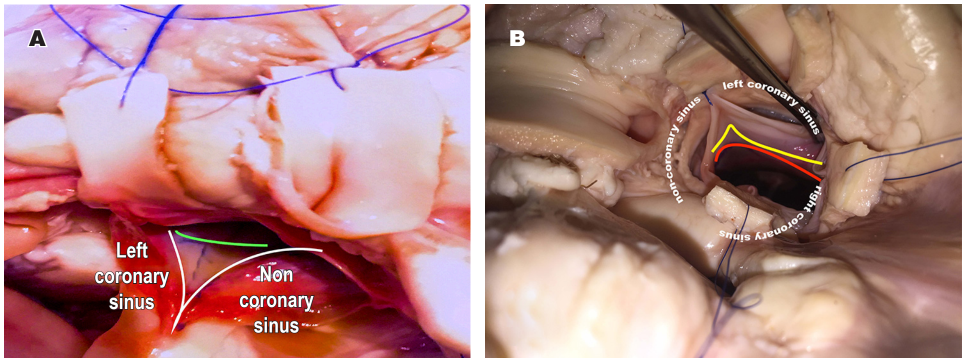

Figure 2:

True (aortoventricular junction) and surgical aortic annuli. Dissection on a pig heart. **A)** Green line= aorto-ventricular junction, white line = aortic annulus. **B)** Red line= aorto-ventricular junction, yellow line= aortic annulus.
With permission of: García-Villarreal OA.[2]

Sinotubular junction

The sinotubular junction exhibits a direct relationship with the extent of aortic valve cusps coaptation. Research conducted by Maselli et al., has shown that the diameter of the sinotubular junction exerts a significant influence on the degree of aortic cusp coaptation.[7] Indeed, the dilation of the sinotubular junction can cause aortic insufficiency due to outward deviation of the commissures.[8]

DAVID PROCEDURE STEP-BY-STEP

There are two surgical techniques to solve the problem of aortic root aneurysm; namely, David procedure (also known as aortic root reimplantation), and the Yacoub procedure (aortic root remodeling). Despite being distinct procedures, they share a common objective. The David procedure is particularly suited for cases with aortic annular dilation, commonly seen in aortic root aneurysms. In contrast, the Yacoub procedure may be preferred (due to its technical simplicity) in cases without aortic annular dilation, such as ascending aortic aneurysms involving the sinotubular junction and the sinuses of Valsalva.

This manuscript is exclusively devoted to David procedure.

Aortic root surgical dissection

After aortic cross-clamping, surgical dissection of the aortic root begins by transecting the aorta transversely, 1 cm above the sinotubular junction. The level of dissection is not the same for all the entire aortic root.[9] Typically, the dissection of the aortic root begins after having completely transected the aorta at the height corresponding to the sinotubular junction. The dissection starts at the level of the non-coronary sinus, which is resected leaving a 5 mm free margin from the aortic annulus *(Fig. 3)*. Subsequently, the left coronary ostium is resected from the inside of the sinus of Valsalva, and finally, the right coronary ostium is resected in a similar manner, also from the inside. Minimal dissection around the coronary ostia is recommended, ideally not exceeding 3 mm. This cautious

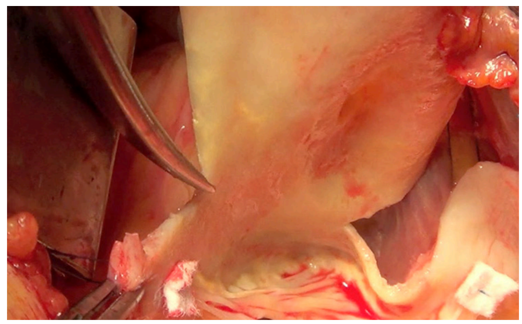

Figure 3: Sectioning of the non-coronary sinus of Valsalva, maintaining a 3-5 mm tissue margin.
With permission of: García-Villarreal OA.[2]

approach reduces the risk of injury to the coronary ostia. Now, the aortic root is dissected from the atrial plane using blunt dissection with scissors, commencing from the midpoint of the nadir of the non-coronary sinus and advancing towards the non-coronary/left coronary commissure. This dissection separates the aortic root from the roof of the left atrium *(Fig. 4)*. At this point, the plane of dissection external to the root corresponds to a level approximately 3 mm below the line of insertion of the aortic annulus internally. The dissection of the anatomical plane continues until the nadir of the left coronary sinus is reached. As a reference point, the plane of dissection external to the root is equivalent to a horizontal line extending from the nadir of the non-coronary sinus to the nadir of the left coronary sinus. In this region, the aortoventricular junction is fibrous, allowing for a more extensive dissection than in the surrounding areas of the aortic root, where the internal aortic annulus and the external plane of dissection converge at a similar level. Afterwards, the dissection then proceeds from the nadir of the non-coronary sinus towards the commissure between the left coronary sinus and the right coronary sinus, using scissors. As the dissection advances, it is crucial to maintain a precise awareness of the anatomical landmarks, including the membranous and muscular interventricular septum, to prevent unintended perforation. A limited dissection area may be necessary to ensure a secure anastomosis between the aortic root and the graft. This necessitates a careful balancing act, as excessive dissection can compromise the integrity of the surrounding tissues. Then, the plane between the aorta and pulmonary artery is dissected by using electrocautery. At this point the dissection is very limited in order to avoid any damage on the pulmonary artery trunk. Finally, as the dissection advances towards the nadir of the left coronary sinus, only a limited dissection is performed to reach the roof of the left atrium.

An entire view of the dissected aortic root can be appreciated in *Fig. 5*.

Graft selection

There are several methods for selecting the diameter of the Dacron graft. Some are highly sophisticated, while others are relatively simple. As a general rule, the average length of the aortic leaflets (from the annulus to the nodule of Arantius) can be used as a reference point and multiplied by two.[10] For example, if one cusp measures 13 mm, another 15 mm, and another 16 mm, the average would be 14.6 mm, and multiplied by two would be 29.3 mm (if the result is not a whole number, the next highest size is chosen, i.e., 30 mm). As a general rule, a range of graft tube sizes between 28 mm

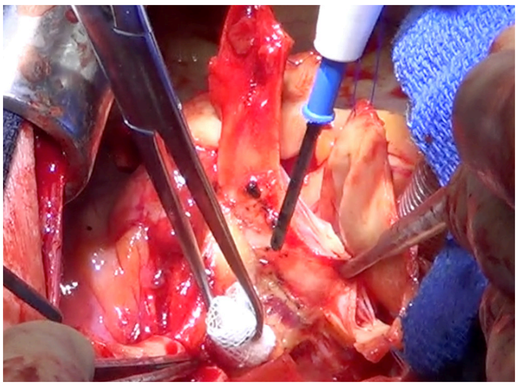

Figure 4: Surgical dissection of the aortic root. The roof of the left atrium is dissected from the aortic root.
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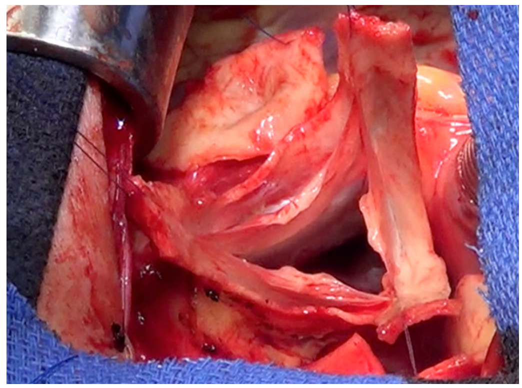

Figure 5: The entire dissection of the aortic root is shown in this intraoperative photography.
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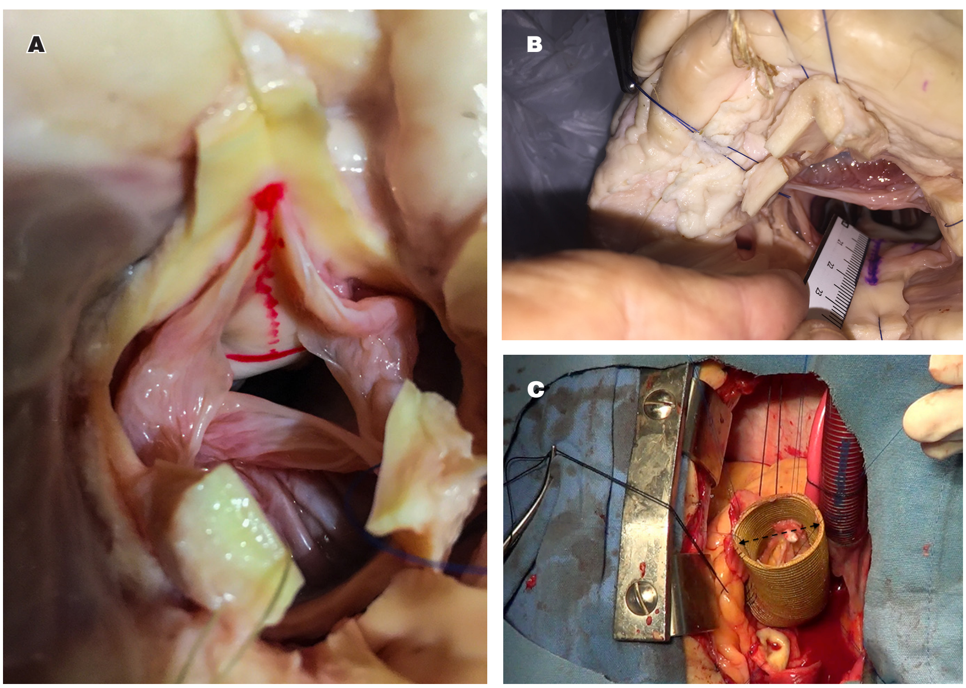

Figure 6:

Sizing the graft. **A)** Distance between internadir line (NC/LC sinuses) and the NC/LC commissure. **B)** Measuring the distance. **C)** Dotted line represents the same distance obtained from the measurement described in B; this is the size of the graft. Pictures A and B are working on a pig heart dissection. Picture C is taken from a surgical procedure.
LC = left coronary. NC = non-coronary.
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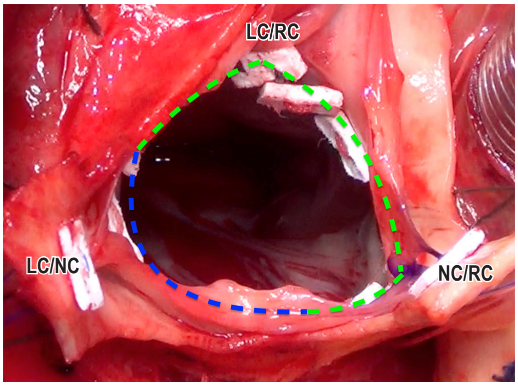

Figure 7: Intraoperative view of the placement of "U" fashioned sutures using teflon felt pledgets at the aortoventricular junction. Note that the plane of the sutures is not uniform around the aorta. The plane is entirely horizontal from the nadir of the non-coronary sinus to the nadir of the left coronary sinus (dotted line in color blue). The remainder is placed immediately below the fibrous aortic annulus in a crown-shape fashion (dotted line in green color).
LC/NC = left coronary/non-coronary commissure. LC/RC = left coronary/right coronary commissure. NC/RC = non-coronary/right coronary commissure.
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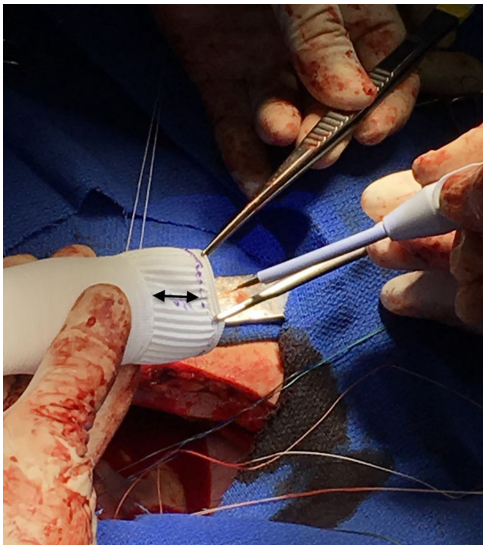

Figure 8: A line is drawn in the inferior aspect of the Valsalva graft, according to the height corresponding to each commissure in the aortic root. The black arrow indicates the same distance as obtained measuring the height of the commissure in the aortic root.
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and 34 mm is usually employed. Alternatively, another method of measurement involves obtaining the distance between the midpoint of the basal line of the interleaflet triangle and the highest point of the corresponding commissure. The most accessible commissure is the left coronary/non-coronary commissure. The obtained length corresponds to the size of the tube to be used[11,12] *(Fig. 6)*.

Graft placement including the coronary button anastomoses

Classically, sutures are placed using 3/0 polyester material reinforced with Teflon felt pledgets. The sutures are placed in a U-stitch fashion, from the interior to the exterior, with a total of 12 sutures: one suture below each commissure and two additional sutures between each commissural pair. The precise

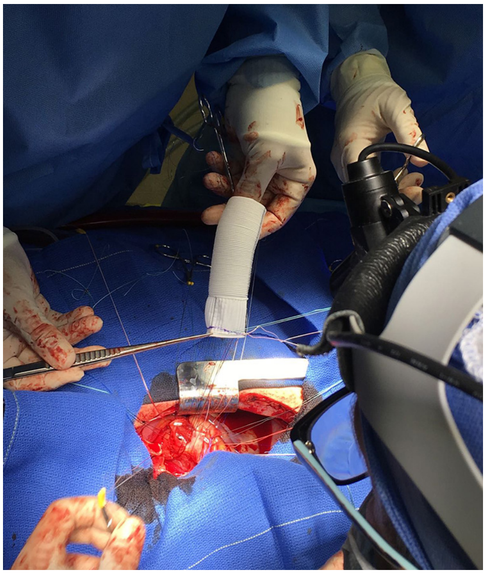

Figure 9: Attachment of the aortoventricular junction sutures to the Valsalva graft, facilitating secure fixation and optimal positioning.
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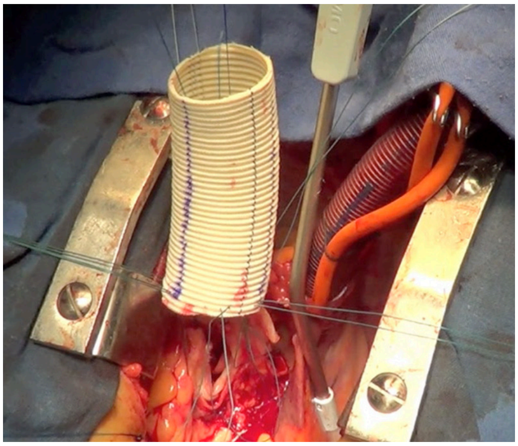

Figure 10: Placement of the basal sutures in a straight graft.
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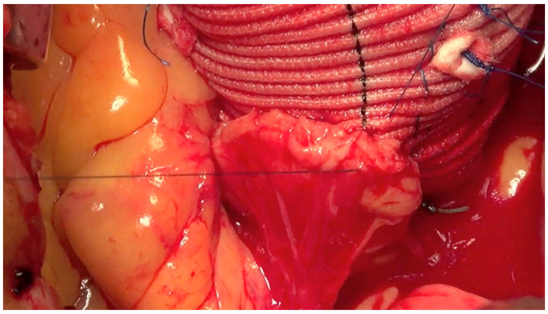

Figure 11: Anastomosis of the coronary artery button to the prosthetic Dacron graft.
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placement of sutures and the careful management of tissue planes are critical in order to prevent inadvertent damage to the aortic cusps.[2] The final arrangement of the sutures inside the aortic root is illustrated in *Fig. 7*.[11,13]

Similarly, the sutures are placed on the inferior aspect of the Dacron graft, from the inside to outside, following a more or less equidistant pattern with respect to the aortic root. The portion of the tube corresponding to the commissure of the left and right coronary sinuses typically receives a small notch, corresponding to a horizontal plane slightly higher than the rest. Once the tube is positioned, encompassing the three commissures with their corresponding leaflets, each suture is gently tied, bearing in mind that these sutures are not hemostatic, but rather serve to secure the tube in position. The graft is gently pulled upwards. and the commissures are fixed into the graft by 4/0 polypropylene pledgeted suture, in "U" fashion.

Alternatively, when using a Valsalva graft (David V), the method for placing sutures in the tube is substantially different. Since the tube is divided into thirds, as well as the height in the horizontal plane that marks the height of the commissures, the way to place the basal sutures is marked at the bottom of the tube, according to the measured distances between a commissure and the midpoint of the corresponding internadir line. This is done for each commissure. Usually, there is a smaller commissural distance than the others, which almost always corresponds to the commissure between the left and right coronary sinuses. Taking as a reference the highest horizontal line in the transverse plane of the tube, the distance is measured and marked at the bottom of the graft. Next, a continuous line is drawn to discreetly connect each of the points circumferentially *(Fig. 8)*. This line will serve as the reference point for passing each of the sutures from the aortoventricular junction *(Fig. 9)*. Of note, with this variation, every commissural suture corresponds exactly to the horizontal margin in the graft.

The idea is to include the entire aortoventricular junction, including the interleaflet triangles, within the Dacron tube, since these triangles represent an extension of the muscular aortoventricular junction and are prone to future dilation.[14]

On the other hand, when a simple and straight graft is utilized (David I), all sutures are placed at the same horizontal level *(Fig. 10)*. Consequently, the level at which each commissure is anchored is slightly different from one another.

Next, to facilitate the procedure, the graft is transected above the level of the commissures, as the subsequent step involves performing the true hemostatic anastomosis of the free edge of the aortic root with the Dacron graft, using a 4/0 polypropylene running suture entering and exiting the tube. The procedure begins at the right coronary sinus, from the non-coronary/coronary right commissure to the coronary right/left commissure. Subsequently, the same procedure is performed from the coronary left/right commissure to the coronary left/non-coronary commissure. Throughout this process, it is crucial to constantly verify that the leaflets are not incorporated into the suture line, which exclusively includes the free edge of the aortic root.

By clamping the upper end of the tube, a hydrostatic test is now performed to assess the degree of competence of the aortic valve. Subsequently, the left coronary button is anastomosed to the Dacron graft. The location of the orifice in the tube is slightly above the hemostatic suture line. Next, the right coronary button is anastomosed in a horizontal plane between the superior level of both commissures. Consequently, the right button ends up being positioned in a more superior plane than the left one. This approach avoids any potential kinking of the right coronary artery. Both anastomoses are performed with polypropylene 5/0 running suture *(Fig. 11)*.

Finally, the anastomosis of the Dacron graft to the normal aortic wall tissue is performed, preferably using a telescoping technique with a 4/0 polypropylene running suture.

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