Gen Thorac Cardiovasc Surg (2019) 67:77–81
DOI 10.1007/s11748-017-0837-2

PRO-CON debate: valve sparing aortic root surgery. PRO: reimplantation

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Received: 15 June 2017 / Accepted: 18 September 2017 / Published online: 10 October 2017

Abstract The remodeling and the reimplantation procedures were described more than 25 years ago with the aim of sparing, otherwise normal aortic valve in the presence of a root aneurysm. Because of its ability to reconstruct the sinuses of Valsalva, the remodeling procedure was considered to be more physiological than the reimplantation. However, because the remodeling lacked annular stabilization, the long-term stability of the procedure was questioned. However, through the years, both procedures have been significantly improved, so that is now possible to perform a reimplantation procedure with neo-sinuses reconstruction or a remodeling procedure with annular stabilization. In this way, both procedures can now guarantee an anatomical root reconstruction and an increased long-term durability. Today preference for a reimplantation procedure is based on the perception of a better reproducibility of the surgical procedure, an increased procedural safety due to the characteristic hemostatic feature of this surgical approach, and to a much larger amount of data present in the literature on long-term results.

Keywords Valve sparing · Aortic root · Aortic valve · Great vessels

Historical background

As is often the case, the surgical community might not readily accept many new surgical strategies, and usually, it takes a considerable amount of time for any new surgical technique to be accepted, approved, and implemented on a regular basis. Soon after any new technique is proposed to the surgical community, controversies usually arises, and pros and cons are generally discussed at large until the scientific evidence is provided and potential controversies slowly fade away.

The history of valve sparing procedures is peculiar; in that it has generated controversies from the very first years it was put into practice. The reason is that two different techniques, both designed to spare the aortic valve while replacing the whole aortic root, were described more or less at the same time by two well-renowned surgeons who fiercely defended their preferred surgical approach. In fact, in 1983, Sir Magdi Yacoub first shortly described the valve sparing procedure now known as remodeling procedure [1], but the results were not published until the early 1990s [2]. More or less at the same time in 1992, David described the technique that is now known as the reimplantation procedure (or David I) [3]. In that same manuscript, unaware of Dr. Yacoub work, he also described the remodeling technique (referred as David II) and a variation of it (the David III) where a partial annuloplasty was associated with the remodeling technique. Apart from very few surgeons across the world, these two types of valve sparing procedures were rarely utilized and for more than 10 years were almost exclusively performed by those who had originally proposed it. For this reason, the clinical results were slow to build up and the scientific evidence of one technique being superior to the other was lacking.

The reasons of the original controversy between the remodeling and the reimplantation procedure were based on several aspects that are peculiar of each technique. As for the remodeling technique, the greatest perceived advantage was the possibility of providing a good anatomical reconstruction

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of the sinuses of Valsalva while being a somewhat quicker operation and relatively easy to perform. On the other hand, it lacked any annular stabilization and it carried a significant increased risk of bleeding. As for the reimplantation technique, the main advantages were considered the annular stabilization while reducing sensibly the potential risk of bleeding, but, on the other hand, the operation was considered more complex and lengthy, while it altered the normal root anatomy and physiology by abolishing the sinuses of Valsalva. However, behind the consideration of the technicality of each type of valve sparing procedure, the scientific discussion was fueled on the perceived effects that each procedure could have had on the durability of the spared leaflets. In fact, in the remodeling technique, while the reconstruction of sinuses of Valsalva guaranteed a good opening and closing movements of the leaflets, the lack of annular stabilization increased the chance for a progressive annular dilatation leading to recurrent valve insufficiency. On the other hand, the reimplantation technique prevented annular dilatation by a robust annular stabilization, but it lacked the long-term beneficial effects on the sinuses of Valsalva on proper leaflet movements with significant chances for progressive leaflet thickening and cusp deterioration.

Evolution of the techniques

After the first years of clinical practice in the remodeling technique, several scientific manuscripts were, indeed, reporting a progressive but slow increase in the incidence of residual aortic regurgitation leading, in a certain percent of cases, to the need for valve replacement [4, 5]. This was particularly evident especially when the annulus was already dilated preoperatively. As for the reimplantation technique, there were scarce case reports of an unexpected leaflet failure due to abrasion against the Dacron [6] or for progressive leaflet thickening and fibrosis [7] both requiring the need for a second operation. However, more than the clinical results, there was a significant amount of bench scientific research, with the help of computer simulation, demonstrating that the lack of sinuses of Valsalva was, indeed, increasing the stress on the aortic valve leaflet. An increased stress was, in fact, evident in the most critical portion of the aortic leaflet, the commissures, and the free margins and even in the cusp's belly [8, 9]. The presence of increased stress on the leaflets was considered a potential cause for premature leaflet degeneration.

Both operations were, in fact, excellent and promising, both aiming at avoiding any valve replacement and providing long-term valve durability. However, both approaches had some imperfections and the reaction of the surgical community was to explore several ways to ameliorate and refine the technique. From one side, the improvement in the remodeling technique was conceived by adding a complete annuloplasty to the standard technique. Alternatively, and across the following years, this type of annuloplasty has been executed with Dacron or Teflon strips [10], with specifically designed compliant ring [11] or with Goretex sutures [12]. From the other side, the improvements in the reimplantation technique were mainly focused on the possibility of adding neo-sinuses of Valsalva. From the late 1990s, several new techniques were proposed to generate neo-sinuses [13–15]. The most commonly used technique, better known as David V, is a variation of the original technique where a significantly larger than needed Dacron conduit is necked down both at the annulus and at ST junction, and is then utilized to reimplant the aortic valve [15]. In this way, a larger space was provided to prevent the leaflets from impacting the aortic wall and to generate some form of eddy currents during diastole (Fig. 1). Just few years before, in the early 2000, we presented a different approach where, instead of modifying the surgical technique, we modified a standard Dacron conduit in a way to incorporate neo-sinuses of Valsalva [16, 17]. The graft was obtained by inverting the direction of the Dacron pleats to generate a portion (corresponding to the root) that would expand horizontally and, upon implantation, would recreate not only a space around the leaflet but rather a proper tri-foliate, individual sinuses configuration (Fig. 2). Since then, this graft has been commercially available with the name of Valsalva graft™.

Current situation

If we had to compare today the two techniques, the remodeling and the reimplantation, after more than 25 years, since they were first utilized, we would soon realize that the two approaches have now more similarities than differences. In fact, irrespective of the various technical solutions and preferences, it is now possible for both technique to provide neo-sinuses of Valsalva and a satisfactory annular stabilization. In both cases, long-term valve durability can be guaranteed by a proper anatomical root reconstruction associated with stable annular containment.

A practical demonstration of this latter aspect is demonstrated in Figs. 3 and 4. In fact, from a theoretical point of view, we can now easily transform a reimplantation with neo-sinuses reconstruction into a remodeling plus annular stabilization. It is sufficient after the reimplantation procedure (performed with a Valsalva graft) to open up the Dacron graft form the outside between the upper and the lower suture lines and up to the commissures to obtain a standard remodeling procedure associate with the annuloplasty.

At this point, if the two procedures are correctly performed, we could probably expect similar clinical long-term

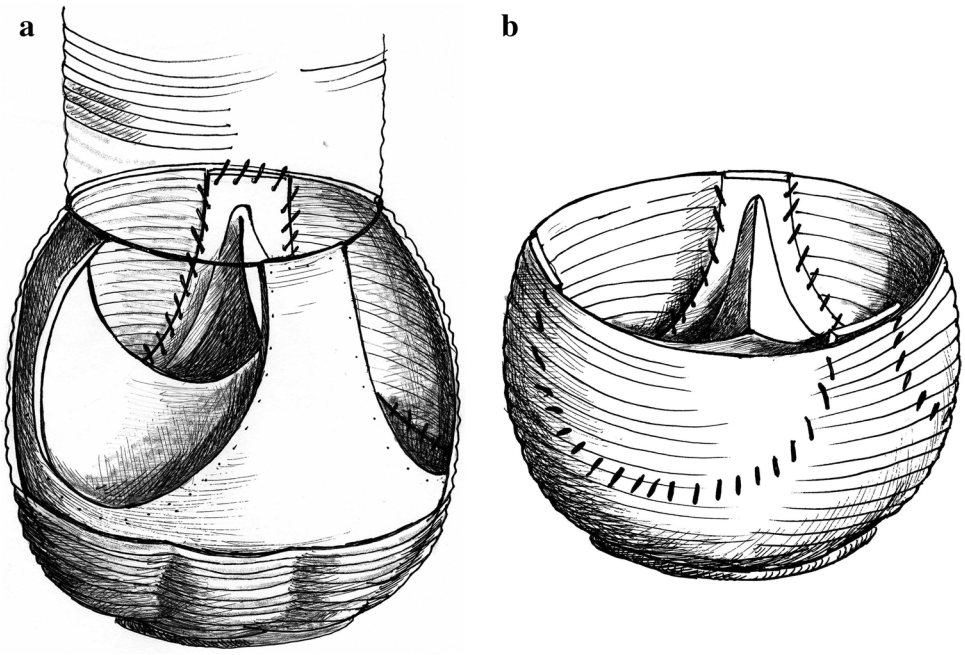

Fig. 1 **a, b** Drawing of a David V type of reimplantation procedure performed using a large bore straight Dacron graft that is narrowed down both at the level of the annulus and at the level of the ST junction. In this way, there is an increase distance form the open leaflets and the neo-sinus preventing any contact with the Dacron wall. However, the commissural posts are forced to follow the curved shape of the oversized Dacron conduit. This can be more easily understood by the inside view of the root (**b**), where is evident that the sinuses and the commissure are along the same radius of curvature. It is not possible in this configuration to re-establish the normal tri-foliate aspect of the root

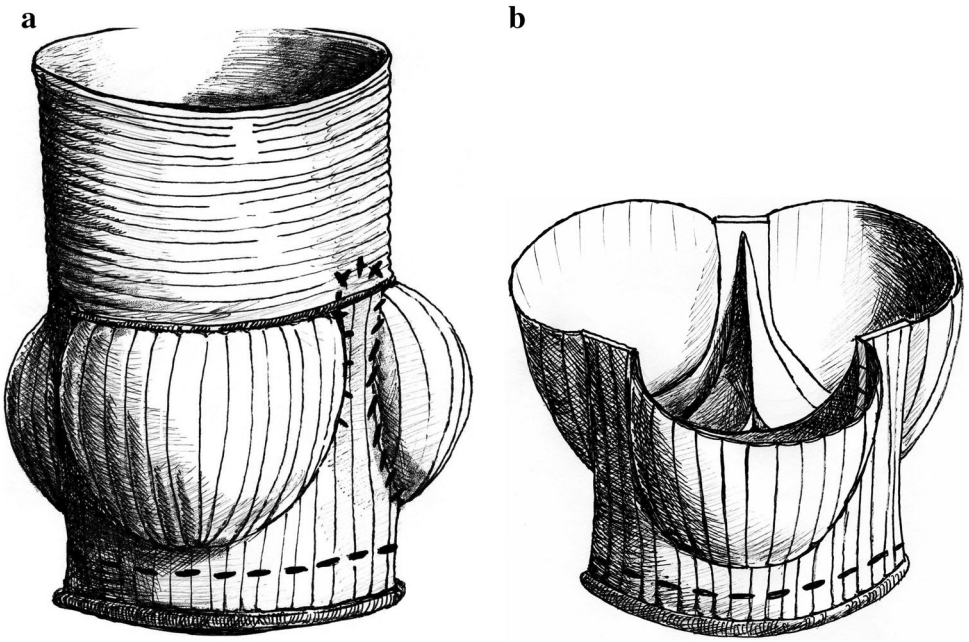

Fig. 2 **a, b** Drawing of a classic reimplantation procedure performed with a Valsalva graft. In this case, the commissural post is stretched between to fixed rings: the annulus at the base and the ST junction at the top. In this way, upon pressurization, the only portions of the Dacron graft that can expand are those between the commissural posts corresponding to the neo-sinuses. The inside view of the graft (**b**) shows the inner position of the commissural posts in respect to the bulged portions of the Dacron neo-sinuses. In this case, the natural tri-foliate shape of the root is obtained

results, as is the case if we analyze the major clinical reports on the two techniques present in the literature [18–21].

Why do I prefer a reimplantation procedure?

Given the possibility of obtaining annular stabilization and neo-sinuses reconstruction in both techniques of aortic valve sparing operation, what are today the reasons for preferring one technique to the other? First of all, I suggest any surgeon who is willing to approach this type of surgery to first choose the procedure he might prefer and then master it for a considerable amount of time. It is not advisable to switch between one technique over the other. Both techniques are rather complex and require a certain learning curve before all aspects and small details are truly and deeply understood. Attention to detail is in fact necessary to prevent many mistakes that can compromise the aortic valve integrity and overall the final result.

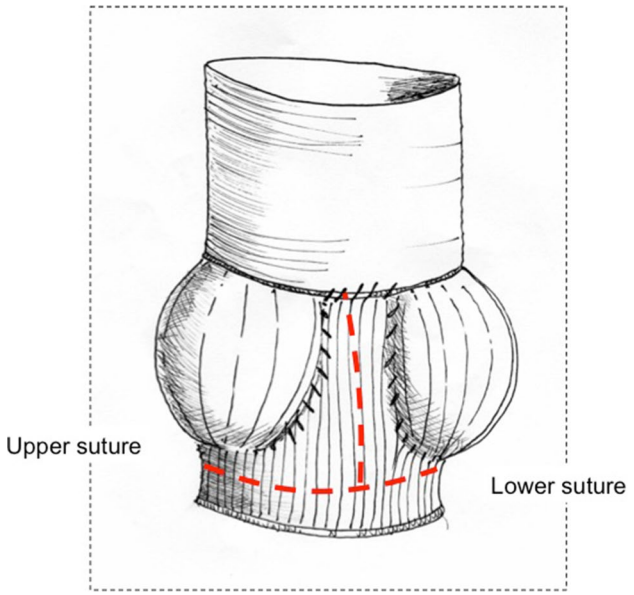

Fig. 3 Typical aspect of a reimplantation procedure with a Valsalva graft as seen from the outside. The red dotted lines indicate the portion of Dacron that can be cut open to demonstrate how is theoretically possible to transform a reimplantation procedure into a remodeling procedure (plus annuloplasty). The horizontal line is located between the lower suture line (used to fix the graft to the annulus) and the upper suture line (used to fix the valve remnant), while the vertical line is located behind each commissural post

All this been said I still strongly prefer the reimplantation procedure, because it retains some practical advantages over the remodeling technique that make it easier and more reproducible.

First of all, there is a significant reduced risk of bleeding in the reimplantation technique due to the fact that all sutures are performed from inside the Dacron graft and small discrepancies between valve remnants and Dacron graft are well tolerated. Only the coronary button anastomoses are in fact the points that need to be checked at the end of the procedure. Conversely, in the remodeling procedure, all sutures are exposed and small discrepancies at the interface between Dacron and valve remnants, so-called dog's ears, can bleed into the pericardial space. For this reason, all anastomoses need to be very meticulous and executed right at the level of the aortic annulus where a stronger tissue is present. In particular, at the end of the procedure, once the aorta has been pressurized, it might be difficult to fix small bleeders especially if they happen to be located below the reimplanted right or left coronary buttons. Furthermore, when repair such potential source of bleeding care should be taken not to pinch the aortic leaflet that is moving inside.

The second aspect is the ability to maintain proper sinus geometry when suturing each individual sinus. When doing a remodeling, suturing a tong of Dacron to the valve remnants within two commissures shapes each individual

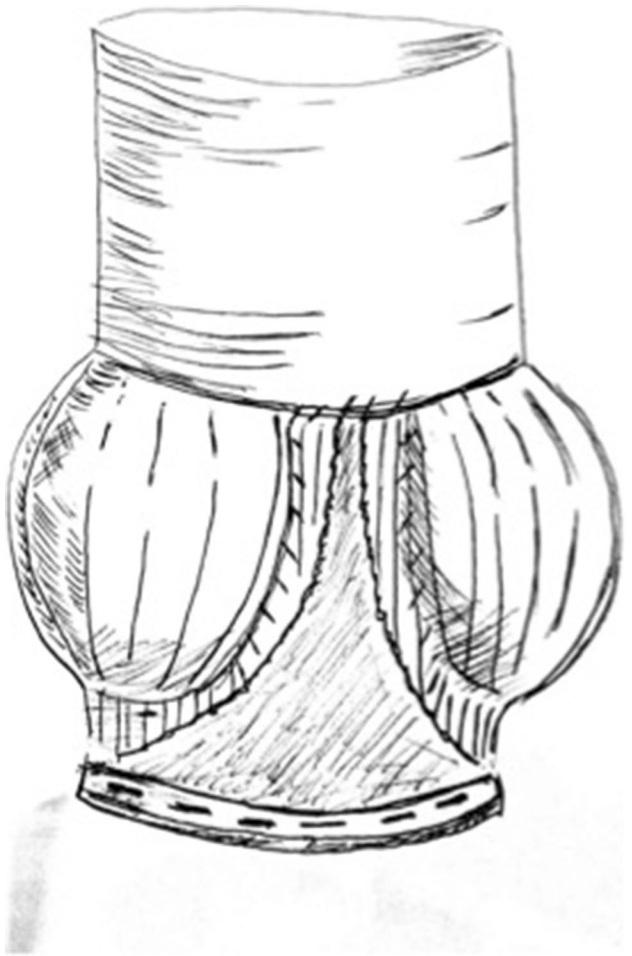

Fig. 4 After cutting along the lines as indicated in Fig. 3, a typical remodeling procedure is obtained. Three independent sinuses are visible as are the posterior wall of each commissural post. A strip of Dacron graft fixed to the annulus acts as annuloplasty

neo-sinus. In doing so, the surgeon has to take into consideration the different length between the Dacron graft and the native tissue to obtain enough Dacron necessary to form the neo-sinuses. Although this is not, per se, difficult, it might be not so easy reproducing the same geometry for all three neo-sinuses. It is, therefore, likely that after suturing all three tongues of Dacron to the valve remnants, the overall geometry of the valve inside the root might somehow result imperfect, and some distortion of the valve might be the direct consequence. An induced prolapse of a leaflet will then require additional maneuvers to the valve cusps to achieve valve competency. Conversely, when doing a reimplantation procedure, the valve geometry is assessed before suturing the valve remnants to the Dacron graft. In this way, correct level of commissure height, accurate distance between each commissure, and overall assessment of geometry inside the neo-root is checked when is still possible to slightly modify their position and their orientation inside

the root. Once a satisfactory position is obtained, suturing the valve to the Dacron conduit cannot modify anymore the established geometry of the valve. This would most likely avoid and prevent any valve distortion and reduce the chance of inducing a valve prolapse.

The third aspect that makes me preferring the reimplantation procedure is the feeling that valve containment is truly achieved from the annulus, along the commissure to the neo-sinotubular junction. Having the whole valve inside the conduit is somehow an assurance that the whole anatomy cannot undergo any major changes with time and that all aortic tissue are somehow supported by the Dacron graft. A significant example of this increased safety can be verified in the case of an acute aortic dissection. In this specific condition, the non-coronary sinus is often dissected. Once the whole sinuses have been removed, the two commissural posts are still left with the two layers of dissection. Attaching and suturing these two layers to the inside of the Dacron conduit that will also act as a supporting wall give much more confidence. In the same case, a remodeling procedure would expose the suture of a dissected commissural post to a much-increased tension and a significantly higher risk of suture dehiscence.

In conclusion, after having performed few remodeling procedures and a large number of reimplantation procedures, I feel confident that I can achieve a good anatomical root reconstruction in both cases. Although speculative, it is also possible that an equivalent long-term durability of the spared valve could be achieved. However, I continue to strongly favor the reimplantation technique because of a good standardization along with a distinctive root stability and characteristic hemostatic features that increase the safety and reproducibility of the whole surgical procedure.

Compliance with ethical standards

Conflict of interest The author might have a potential conflict of interest: The author receives royalties from Vascutek Terumo in conjunction with the design of the Valsalva graft described in this article.

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