Surgical Technique

# Sparing aortic valve techniques

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**Abstract:** Prosthetic valve implantation is the most widely used therapeutic option for aortic regurgitation (AR), but complications associated with prosthetic valves, with an incidence of 3–5% patient/year, and the need for anticoagulation in mechanical valves, force us to consider aortic valve repair as an alternative to the prosthetic implant, especially in young people with many potential years of life for these complications. Aortic valve repair techniques are not excessively complicated, but there is no standardization, so they are not reproducible in all medical centers. There are multiple repair procedures, but to study them we can divide, arbitrarily, into two large groups, techniques for treatment of aortic root dilatation (reimplantation and remodeling); and repair techniques without treatment of the aortic root, that act on annulus and on aortic leaflets. The two sets of techniques are often used together, but it is easier to understand them if this arbitrary division is made. Our goal is to publish our experience and knowledge of repair techniques to facilitate their learning by other professionals. In this article, we will focus on the procedures on the aortic annulus and leaflets, because they can be applied in patients without aortic root dilatation, but they are also complementary to the reimplantation and remodeling techniques. We will present the procedures describing them individually, with an explanation in text accompanied by three videos in which the application of each technique is visualized in several cases. The standardization of sparing aortic valve techniques is difficult, because each patient requires its individualized application, yet we have tried to illustrate reproducible procedures so that professionals have more tools to deal with aortic valve-preserving surgery.

**Keywords:** Aortic valve repair; annuloplasty; central plication

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## Introduction

The treatment of aortic valve disease, either valve stenosis or valve insufficiency, is usually the implantation of aortic valve prostheses, which work excellently improving prognosis and quality of life (1). The option of repairing a stenotic aortic valve in adults is not an appropriate option and valvular implant is the first choice. However, valvular repair, in the treatment of aortic regurgitation (AR), offers an alternative to the prosthetic implant, and this allows to avoid possible complications related to prosthetic valve, both mechanical and biological, that reach an incidence of 3% to 5% per year (2) with a cumulative risk of complications of 50% at 10 years (2,3). Survival after aortic valve replacement is also reduced, being only 50% at 10 years (3,4) by some authors.

AR may be due to several mechanisms (5) on which it is possible to act before proposing prosthesis replacement as a first option. If AR is due to root dilatation, procedures on this specific part such as reimplantation (6) and remodeling (7) have shown a 10-year survival rate of 85% (2,8,9) and free from reoperation over 90% at 10 years (2,8,9), with an incidence of complications related to valves of 1.6% (8). AR without dilatation of the root, by mechanisms such as annulus dilatation, leaflet prolapse, leaflet defect or sinotubular junction dilatation are causes that can be repaired surgically. For annulus dilatation some techniques have been described for years, for example the subcommissural plicature by Cabrol *et al.* (10), others are more recent such as annuloplasty with suture (11) or with ring (12). In addition, the extension with pericardium (13)

 


**Figure 1** Techniques on the aortic annulus (18).
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to correct the defect of the leaflets, the central plication (14) or the leaflet resuspension with polytetrafluoroethylene (PTFE) (15) for the treatment of valvular prolapse and remodeling of the sinotubular junction (16) are techniques that employed together allow good results by remaining above 80% free of reoperation at 5 years (16,17).

Patients with AR and aortic root dilatation will be treated with valve remodeling or reimplantation techniques, which can and should be associated with other repair techniques (on leaflets and aortic annulus) to achieve an optimal result. In this report, we will focus on the description of these procedures on leaflets and annulus, without addressing the techniques of aortic remodeling or valvular reimplantation. Our purpose is to explain through description in text and video images the different techniques that, in isolation or combined, can be applied in aortic valve repair.

## Operative techniques

AR may be due to several mechanisms (5) depending on the anatomical alterations that we find. The leaflets can be normal, or can present: excess of movement (prolapse), reduction of movement (restriction) or perforation. Dilatation can affect: only the annulus and aortic root, only the sinotubular junction and ascending aorta with normal root, or all structures (annulus, root and ascending aorta). We will apply the repair techniques after a thorough analysis of the anatomy of the aortic valve, aortic root and ascending aorta, first with the examination of imaging tests such as transesophageal echocardiography (ECO-TE) and computerized tomography (CT) and later with the direct visual examination in the own operating room. We will describe individually the techniques on the different parts of the aortic valve anatomy, but we usually have to apply them together or with root procedures to achieve a good result.

The interventions presented in the videos were performed under general anaesthesia, under ECO-TE control, through a mean sternotomy in all patients. Extracorporeal circulation (ECC) was established through cannulation in the ascending aorta and right atrium. Under mild hypothermia, cardiac arrest was performed by infusion of crystalloid cardioplegia Celsior© (Genzyme Corp., Boston, MA, USA) via retrograde (cannula in the coronary sinus) and via anterograde direct into coronary ostia.

### *Techniques on the aortic annulus (Figure 1)*

The dilation of the aortic annulus or aorto-ventricular junction (AVJ) is a cause of AR because it promotes the lack of coaptation of the leaflets. It is usually associated with dilatation of the aortic root. The annulus stabilization is critical to the durability of the repair. In cases of aortic root and AVJ dilatation, root correction through reimplantation or remodeling procedures must be performed. When the aortic annulus is ≥29 mm the classically recommended treatment is aortic valve reimplantation (6). This consideration is due to the fact that the initial description of the remodeling surgery did not act on the aortic annulus, and the dilation of the AVJ is the cause of recurrence of AR in these patients (19). Reimplantation surgery is associated with AVJ stabilization, but there are alternative ways to achieve this stabilization, such as the implantation of an external ring (20) or annuloplasty with suture (Gore-Tex CV-0; WL Gore and Associates, Munchen, Germany) (11). The reimplantation technique or the use of the external ring may clash with anatomical problems, because in the right coronary sinus the basal ring and the AVJ are very distant in 20–30% of cases (11). The use of the annuloplasty with suture avoids these anatomical problems.

The stabilization of AVJ is essential in aortic repairs, with or without aortic root treatment, and we can provide it by annuloplasty with suture in a simple way compared to other procedures.

In *Figure 1*, we will focus on the technique of annuloplasty with suture, because we consider that its knowledge is basic in aortic repair since it can be applied in multiple circumstances. In order to perform the annuloplasty, a Gore-Tex CV-0 suture with a 36 mm needle is used; the aim is to pass through the nadirs of the three coronary sinus (LC: left coronary sinus; RC: right coronary sinus; NC: non-coronary sinus):

 

(I) We start from the right sinus below the right ostium, deepening until we reach the nadir of the right leaflet, coming out near the RC-LC commissure;
(II) We continue inserting the needle through the RC-LC commissure, deepening to the left leaflet nadir, out by the LC-NC commissure;
(III) We carry on through the LC-NC commissure until NC nadir;
(IV) With the other end of the suture we passed around the RC-NC commissure, deepening the right ventricle to move away from the membranous septum and the possibility of producing an atrioventricular block;
(V) We continue along the RC-NC commissure until we reach the nadir of NC;
(VI) With a Hegar stem or a caliper of the desired size within the light, we proceed to knot in the nadir of NC.

We must know that the 36 mm needle offers enough resistance to the passage through the fibrous areas of the AVJ and will be careful not to enter into the lumen of the AVJ. It is necessary to make lots of knots and posterior fixation with hemoclips for the tendency to get rid of this type of suture.

In the *Figure 1* we present three cases with peculiarities that we will comment:

(I) Annuloplasty in a patient with unicuspid valve prior to remodeling technique. Annuloplasty with suture associated with the remodeling technique is easier to perform because dissection of the tissues and coronary ostia has already been performed previously. In the *Figure 1*, we verified that the AVJ measures 27–28 mm and after reduction it is left in 23–24 mm. It is advisable to perform the annuloplasty in this type of valves before proceeding to the repair of the aortic leaflets;
(II) Annuloplasty in a patient with isolated aortic plasty by leaflet prolapse without root remodeling. The patient in this case does not require aortic root remodeling, although it needs replacement of the ascending aorta. Coronary ostia have been identified to avoid injury. Annuloplasty is performed as described. At the end we check the measure of the AVJ that we have left (23–24 mm);
(III) Annuloplasty in a patient with a quadricuspid valve. In this patient only isolated aortic plasty is performed and we will work on the leaflets and the AVJ to stabilize it. However, to perform the annuloplasty we must dissect the structures almost to the ring, to be able to comfortably perform the annuloplasty, and identify the coronary ostia to avoid injury, as shown in the *Figure 1*. With annuloplasty we reduced the AVJ from 25–26 to 21–22 mm.

### *Techniques on the leaflets*

The aortic leaflets may present insufficiency for four reasons: leaflets with normal movement, excess of movement (prolapse), reduction of movement (retraction) or perforation. The objective of the techniques on the leaflets is to achieve good morphology, adequate effective height (≥8 mm) (21) and adequate coaptation surface (≥4 mm).

The main problem of movement retraction or perforation is the absence of tissue, it will be necessary to use external material, usually heterologous pericardium (13).

The prolapse is corrected with two fundamental techniques, central plication (14) or leaflet resuspension with PTFE (15).

AR in the presence of normal leaflets is mainly due to aortic root dilatation, but when this is corrected, the root dimensions and the relationships between its components are changed, so it is common to produce a leaflets prolapse after valve-preserving surgery (21,22). It will be necessary to apply some technique on them to recover an adequate morphology with good effective height and coaptation surface.

The techniques on the leaflets can be seen in *Figures 2,3*.

(I) Use of heterologous pericardium (*Figure 2*):
  (i) Fenestration closure: during aortic repair surgeries, it's common to find fenestrations in the leaflets near the commissures usually produced by stress. The persistence of the same ones after the repair can be the cause of an insufficiency in the echocardiographic control, reason why it is advisable to close them maintaining a suitable morphology of the aortic leaflet. As shown in the *Figure 2*, the valve has a large fenestration in the left leaflet that will be corrected using heterologous pericardium cut to size of fenestration and sutured with PTFE (Gore-tex CV-6). We started at the base of the annulus toward the commissure, and then proceed from annulus to edge of leaflet and by the edge towards the commissure knotting on

 


**Figure 2** Use of heterologous pericardium (23).
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**Figure 3** Valvular prolapsed correction (24).
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the outside of the aortic wall.

(ii) Valvular reconstruction: the cause of regurgitation may be a dysplastic valve with retracted tissue that can be replaced by heterologous pericardium. We show in the *Figure 2* the case of a unicuspid aortic valve, where a resection of the dysplastic tissue is performed, after which the valve is reconstructed with bicuspid morphology creating a new commissure with pericardium sutured in both leaflets until reaching a suitable height and valve morphology. The suture of the pericardium was done with PTFE (Gore-tex CV6). The beginning of the suture is always by the annulus to have a solid anchorage. The sutures are made by the three parts of the triangular shaped patch. At the free edge a continuous suture is performed without tension to give consistency. An excess of tension can produce an unnecessary shortening of the length of the leaflet. In the area of the new commissure we crossed the thread to later tie on the outside of the aortic wall; with this we avoided to pucker the edge of the leaflet.

(II) Valvular prolapsed correction (*Figure 3*):

(i) Central plication: the introduction of the central plication (25) was an improvement in restorative surgery. It is a simple and fast technique, with good results. It has to be performed in the central area because it´s the most resistant of the aortic leaflets. We use polypropylene 6/0 or 5/0 depending on the thickness of the tissue. First we must provide tension at the commissures to have a fixed frame and to reproduce the tension that the leaflets receive in diastole; we proceed to suture commissures to the pericardium. Secondly, we must know what the prolapsing leaflet is; for it, to use a central point in which we join the three leaflets is essential. Pulling from this central point to each commissure we check that the edges are parallel; if there is a longer one, it will be the one that prolapses.

In the *Figure 3* we show four examples of central plication:

- ❖ The valve has a right leaflet prolapse. After correction of a rupture at the commissure an excess of tissue is maintained and corrected with the central plication.
- ❖ A quadricuspid valve that, after converting it into a tricuspid valve, presents excess tissue in the right leaflet that is corrected with the central plication.
- ❖ A tricuspid valve with a right leaflet prolapse that is corrected before performing the aortic valve reimplantation.
- ❖ A bicuspid valve with prolapse and retraction of fused leaflet, in this case the right and non-coronary leaflets. We pull the commissures at 180°. We perform central plication in left leaflet. We compared the fused leaflet with the left leaflet, we used for reference. Several plications are made in the fused leaflet until the two lengths at the edges are equal.

(ii) PTFE leaflet resuspension: prolapse correction using this technique is more complicated and its use is less. The difficulty lies in adjusting

 

the tension of the suture in static, because an excess of tension can suppose a restriction of the movement of the leaflet with the heart beating. Usually reserved for cases where we want to give a more resistant support at the edge of the leaflet. We can see it in *Figure 3*, where we made a resuspension of the leaflet with PTFE (Gore-Tex CV-6) in a bicuspid valve. We start at one commissure; we go through the edge continuously without applying tension to the thread so as not to pucker in excess. Before tying on the outside of the aortic wall we cross the suture to block excess tension when knotting. In this case, we resuspend the other leaflet to provide resistance; we introduce the PTFE-thread into the aortic lumen and a suture is made at the border continuously to the opposite commissure, where the thread is crossed before going across the aortic wall to knot on the outside.

## Comments

Aortic valve repair has been incorporated for many years into the therapeutic arsenal we can provide to patients with aortic regurgitation. It reduces the risk of complications associated with prosthetic valves from 3–5% (2) to 1.6% (8), but the application of these techniques requires a learning curve. In order to try to explain the repair techniques we have considered two major groups, procedures to treat the aortic root and procedures on the rest of components, and in this article we will focus on the latter (aortic annulus and leaflets).

Stabilization of the aortic annulus is essential for the durability of the repair. This can be achieved with three techniques, subcommissural plicature (10), ring annuloplasty (12) and annuloplasty with suture (11). The subcommissural plicature is the simplest to perform and consists of three points supported on Teflon that are applied in the annulus closing the intercommissural triangles in its superior half. This technique has utility and some authors (26) have obtained good results, but in our experience we haven't had the expected results and we consider that it is less stable in the time. External ring annuloplasty offers good long-term results (12), but presents more difficulties in implantation (the stitches are similar to those made when performing the reimplantation technique); and is a prosthetic material that can raise the cost of repair, although in some centers without availability it is replaced by a segment of Dacron tube. In the *Figure 1*, we show three cases with PTFE-suture annuloplasty (11), it is the technique we do in our group because we believe that combines durability, ease of performance, and can be used as an adjunct to aortic remodeling surgery and isolated aortic repair procedures.

Leaflets repair is another critical part of aortic valve-preserving surgery. Achieving suitable cusp geometry has a direct impact on durability. The parameter "effective height" (EH) described by Schäfers (21) is one of the few standardization in aortic valve-preserving surgery. A patient with an aortic repair who has grade I insufficiency in the postoperative period and an EH ≥8 mm will have a very good durability. The techniques on the leaflets are fundamental to obtain these parameters.

We do not always have enough tissue in the cusps. In the *Figure 2*, we show two cases in which to obtain cusps with suitable form we have to use external material, heterologous pericardium. This material is really useful, and although others have been described as autologous pericardium (13) or PTFE, our experience has focused on the heterologous pericardium with which we have obtained good results. However, we must know that the repair procedures that require adding external material have less durability over time (2); in our experience we do not usually start a valvular repair if we have to supply more than 50% of external tissue.

In *Figure 3*, we show two ways of correcting valvular prolapse, central plication (14) or leaflet resuspension with PTFE (15). Between the two options, the fastest, simplest and with good results in durability is the central plication. This must be done in the central area, if it is performed in the area adjacent to the commissure there is a risk of rupture. Leaflet resuspension with suture at the edge takes longer and it is more complicated to know how much we reduce or lift the cusp, this usually translates into a restriction of the movement of the cusp with the beating heart. In contrast, it can offer a plus of resistance and is the main reason why our group uses resuspension technique.

In this article we present videos that try to illustrate and communicate a part of the aortic valve-preserving techniques. We have not included aortic root procedures because we believe they need special treatment. We consider that the techniques that we show are a useful tool and whose knowledge is basic to start an aortic repair program.

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## Footnote

*Conflicts of Interest*: The author has no conflicts of interest to declare.

*Informed Consent:* The corresponding author states that he has received a signed release form from each patient recorded on the submitted video authorizing the recording.

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