AORTIC VALVE REPAIR TECHNIQUES

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Aortic valve replacement is the most commonly used method in the surgical treatment of symptomatic and severe aortic valve disease. Concerns about the complexity of valve repair, surgical techniques and durability of the repair have led to widespread use of prosthetic valves in the surgical treatment of aortic valve regurgitation. However, in addition to structural deterioration, infection, bleeding and thromboembolic complications in prosthetic valves, their inability to provide hemodynamic function similar to the natural valve has increased interest in aortic valve repair methods in recent years, and it has been used widely in experienced surgeons and centers. Additionally, advances in cardiac imaging methods and a better understanding of the functional anatomy of the aortic valve have further increased interest in aortic valve repair. Aortic valve repair in aortic valve insufficiency can be done successfully, when performed by competent surgeons in a high-volume center with sufficient expertise.

Repair methods applied by preserving the normal anatomy and physiology of the aortic valve functional unit have become a reasonable alternative to prevent valve replacement complications. To perform a successful aortic valve repair, in addition to knowing the surgical anatomy, it is necessary to be well aware that the aortic root complex is a functional unit that works together. The aortic root mainly consists of four parts: aortic annulus, aortic valves, aortic sinuses of Valsalva, and sinotubular junction (STJ) (Figure 10.1). The repair of aortic insufficiency which develops as a result of a change in any of these four components will also be different than the other.

Once aortic valve repair is decided, it is essential to carefully examine the measurements of the aortic root, sinus of Valsalva, STJ, and ascending aorta with transthoracic and/or transesophageal echocardiography and computed tomography (CT) angiography. These measurements are useful to reveal both the cause of the deficiency and help which repair method must be chosen.

OPERATION

Since a good surgical view is extremely important in aortic valve repairs, median sternotomy is still recommended first for a successful repair of

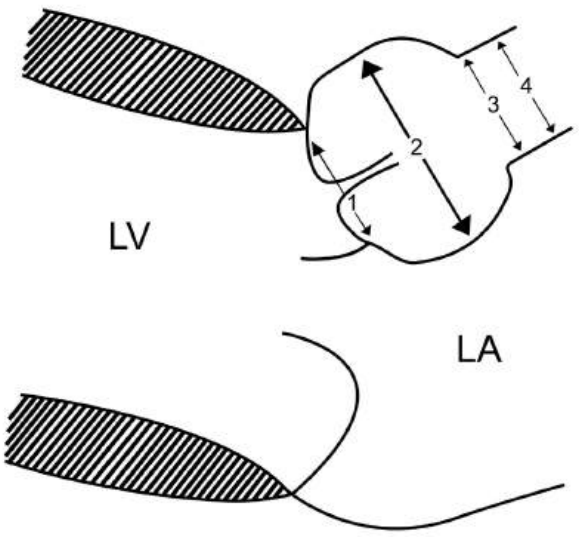

Figure 10.1. Aortic root and components: Aortic annulus (1), leaflets, sinus of Valsalva (2), Sinotubular junction (3), Ascending aorta (4).

the aortic valve and its components. Myocardial protection should be done through the antegrade coronary buttons and retrograde cardioplegia should be applied. While performing a standard transverse aortotomy, it may be necessary to transect the aorta in attempts to repair the aortic root.

Aortic root components should be evaluated carefully. The structure, geometry, thickness, flexibility, and integrity of the valves should be reviewed. Leaflet examination can be performed with the help of 4-0 sutures with pledgets passed through the tops of the aortic commissures. The length of the free edges of the aortic cusp should be evaluated gently with the forceps to visualize if there is any prolapse (Figure 10.2).

When the valve structure is severely destructed due to calcification or a severe damage of a rheumatic heart disease, these cases are not considered very suitable for repair.

If the aortic valve structure and movements are normal, but there is a central aortic valve insufficiency due to the dilatation of the ascending aorta, it is recommended to replace the ascending aorta with a graft and reconstruct the STJ (Figure 10.3). The decision to determine the graft diameter in such cases is based on the diameter of the imaginary circle at the optimal location for cuspid coaptation, after aortotomy is performed 5 mm above the STJ. David et al.[1] recommend that the diameter of the graft must be 10 to 15% less than the length of the free edge of the aortic leaflets (or approximately twice the height of the leaflets). The graft size is another issue to be considered. The patient's body surface area should also be taken into consideration while choosing a graft. A small graft may increase

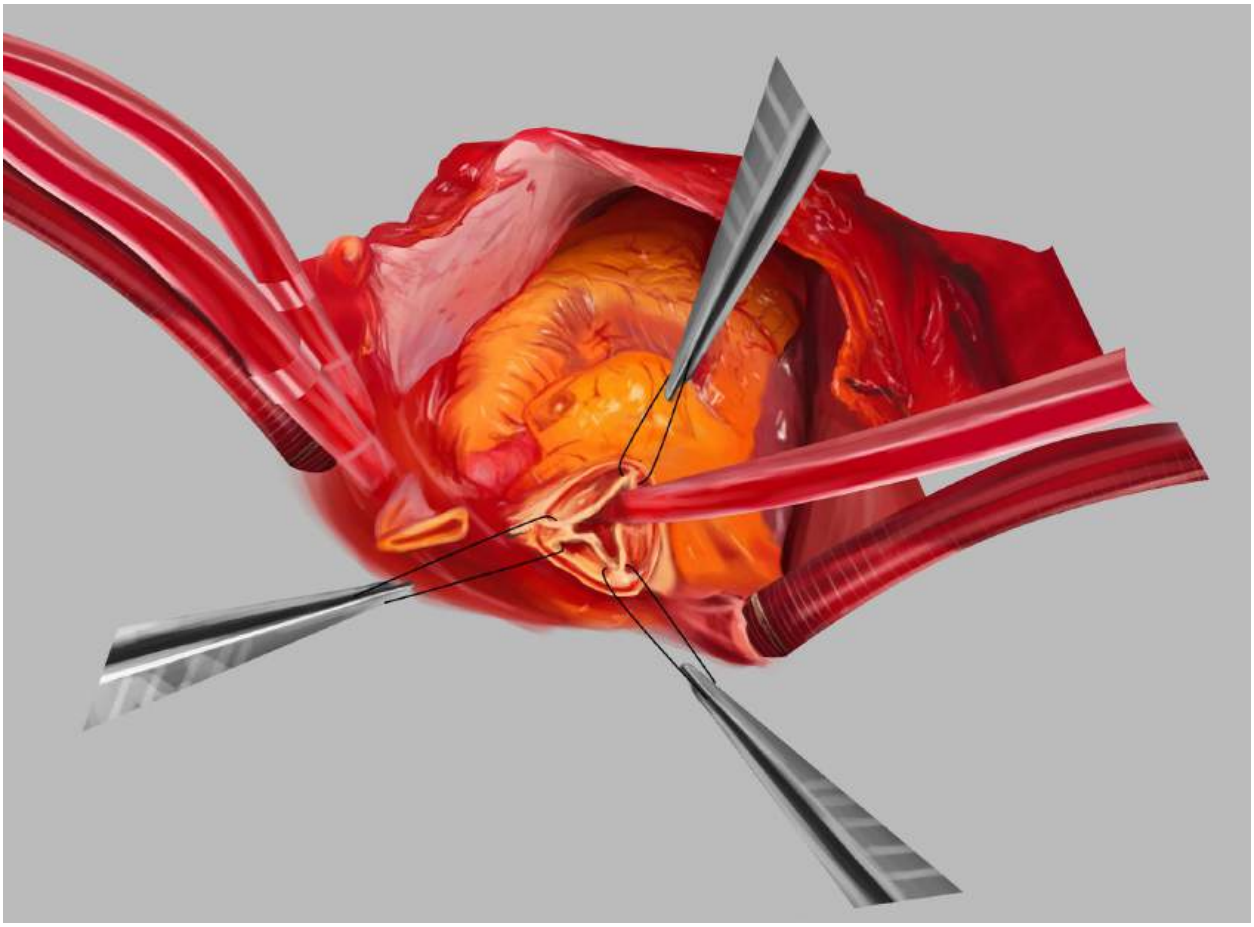

Figure 10.2. Cardiac arrest is achieved under cardiopulmonary bypass and the aorta is transected. The valve components are evaluated with 4-0 sutures with pledgets placed through the tops of the aortic commissures.

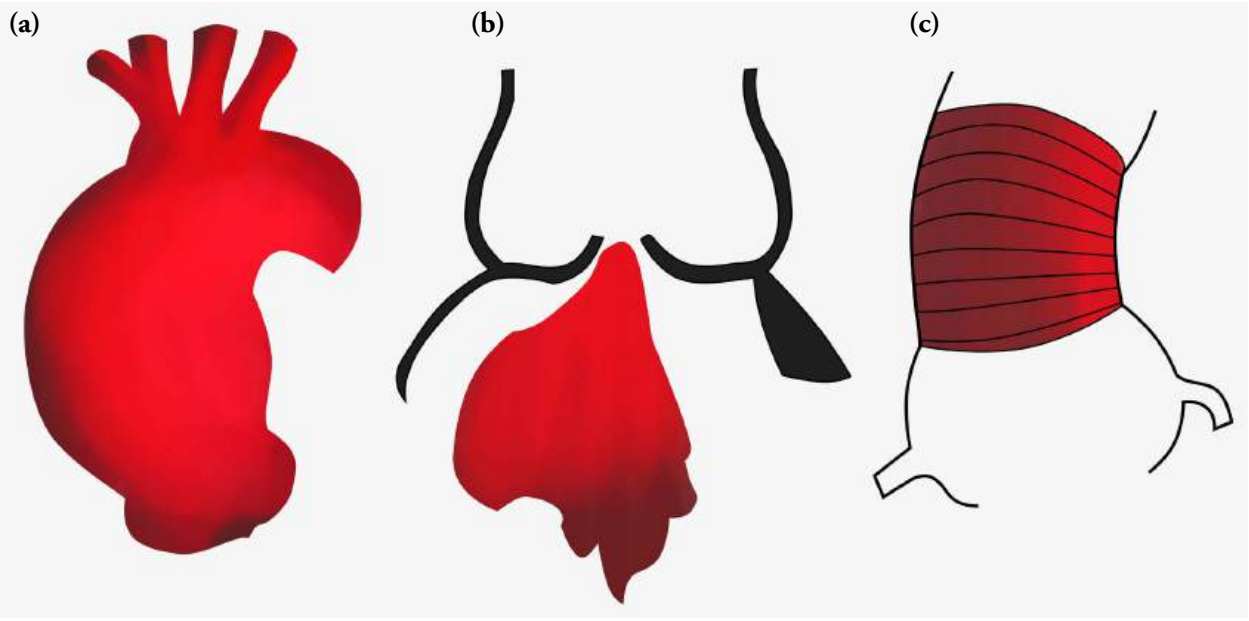

Figure 10.3. **(a)** Ascending aortic aneurysm, **(b)** Central aortic insufficiency, **(c)** Replacement with ascending aortic graft.

left ventricular afterload. Grafts smaller than 26 mm should be avoided in patients with higher body surface area.

In cases of aortic insufficiency caused by other elements of the functional unit we defined other than the valves, the insufficiency is always central. In cases related to perforation, prolapse and movement restriction of the valves, the insufficiency is mostly observed in the eccentric type. In addition, it should be kept in mind that both central and eccentric failure may occur due to different pathologies simultaneously in the same patient. In patients with Marfan syndrome, dilatation of the aortic annulus and ventriculoaortic junction; in simple words, annuloaortic ectasia develops due to a degeneration in the media layer. In patients with bicuspid aortic valve, ascending aortic aneurysm and root dilatation may be either together or separately, depending on the phenotype. In addition, valve prolapse may also cause failure. In Type A aortic dissection, aortic root dilatation and ascending aortic aneurysm may be in the background, as well as a coaptation defect caused by the separation of the commissures due to the intimal tear. Briefly, considering the pathophysiology of aortic insufficiency, the extent of the process in the aortic unit determines the degree of insufficiency, its form and treatment options.

Most failures of valve-sparing procedures are due to residual valve prolapse. This situation is triggered by root reconstruction. For a successful repair process, a systematic and physiological approach based on the reduction of the enlarged aortic root ensuring the effective height of the cusp through resuspension with the respect for root dynamics is needed.

If there is an ascending aorta enlargement with the dilatation of one or more of its components, it would be appropriate to make a decision based on the diameter of sinus of Valsalva and annulus. In cases where the sinus of Valsalva is over 45 mm and the aortic annulus is over 25 mm, supracoronary aortic replacement alone may not be sufficient in the long term and the patient can be a candidate for reoperation (Figure 10.4).

Aortic Remodeling

With one of the valve-sparing procedures, physiological movement of the cusps within the three new sinuses are reconstructed by the aortic remodeling technique, while preserving root extensibility through the fibrous skeleton. If there is dilatation in one or more aortic sinuses, replacement should be performed with a properly prepared tubular Dacron® graft. The aortic root is dissected circularly

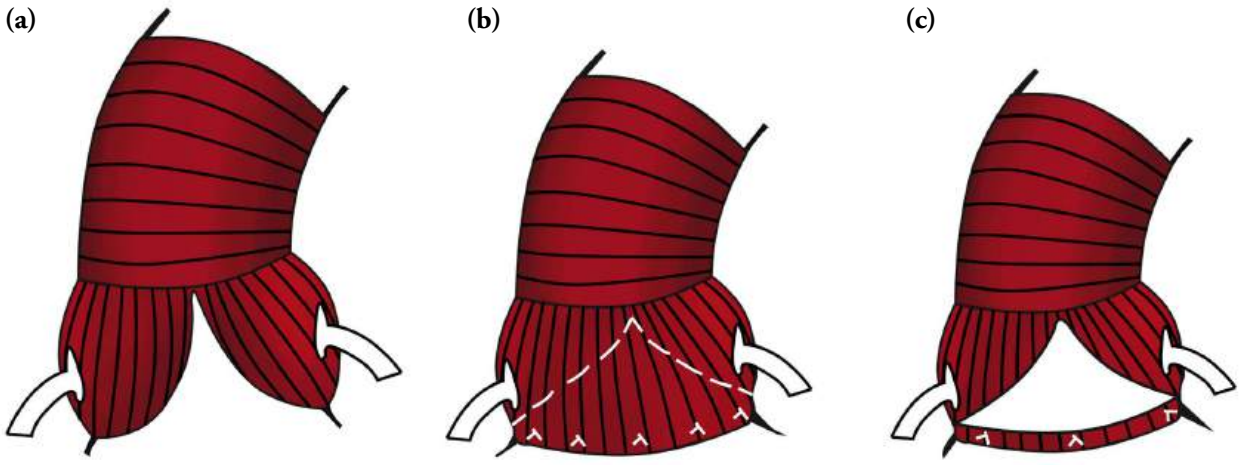

Figure 10.4. In the presence of a dilated aortic root, **(a)** valve-sparing replacement if sinus of Valsalva is ≥45 mm and aortic annulus is <5 mm, **(b)** and **(c)** aortic annulus is ≥25 mm plus subvalvular aortic annuloplasty.

below the aortic annulus. Coronary buttons are prepared leaving a rim around the sinuses. Aortic sinuses are resected leaving 4 to 8 mm of tissue adjacent to the annulus. Semicircular neoaortic sinuses are created with three longitudinal incisions made in the selected graft. Aortic valve commissures are fixed to the upper part of the new aortic sinuses with 4/0 prolene sutures passed from inside to outside. New aortic sinuses are reconstructed on the aortic annulus and the adjacent artery wall using the continuous suture technique. Then, the coronary buttons are anastomosed to the new ostia opened to the graft (Figure 10.5).

Aortic Re-implantation

In the re-implantation technique, annuloplasty is performed with a suture line passing proximal to the prosthetic graft extending to the subvalvular region. This technique may be preferred in cases of annuloaortic ectasia, such as Marfan syndrome and acute type A aortic dissection. The graft contains the sinuses of Valsalva and the triangles between

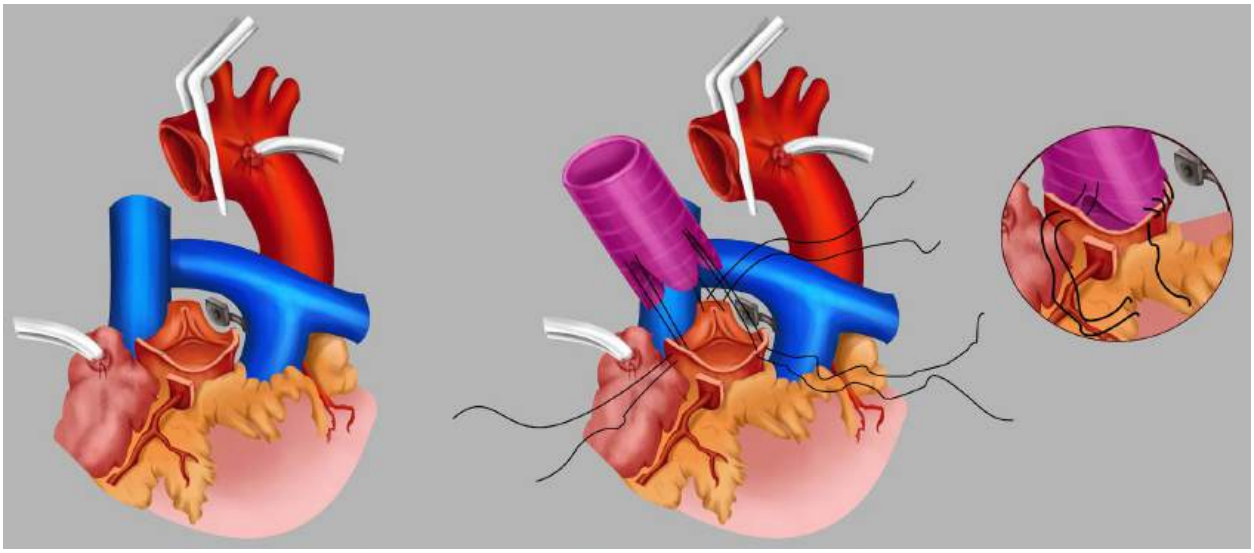

Figure 10.5. Aortic remodeling technique.

the leaflets. This situation within the graft affects the root dynamics. As in the remodeling technique, the aortic sinuses are excised. Afterwards, 3/0 or 4/0 horizontal mattress sutures are placed in the left ventricular outflow tract from the inside to the outside. These sutures should be placed in a single horizontal plane along the fibrous components of the outflow tract and follow the aortic annulus along the muscular ventricular septum. If the fibrous component is thin, Teflon felt should be used. The tube graft to be selected, should be 2 to 4 mm larger in diameter than the average length of the free edges of the aortic valve leaflets. Three equal sections are created by making three equidistant marks at the proximal end of the graft. A triangular excision of 8 to 10 mm is made in one-third, corresponding to the commissure supported by the muscular septum. Three plication sutures are put between the marked spaces to align the commissures to reduce the diameter of the graft by 2 to 4 mm. Sutures passed through the left ventricular outflow tract are then passed from the inside to the outside of the tip of the graft. It is of utmost importance that these sutures are evenly distributed, particularly along the muscular septum. Most of the reduction in aortic annulus diameter should occur on the non-coronary side. After the graft is placed, all sutures coming out of the graft are tied. The three commissures are, then, resuspended and fixed within the graft using 4/0 polypropylene horizontal mattress sutures with pledgets. These sutures are used to secure the aortic wall and aortic annulus to the graft. Next, the coronary arteries are anastomosed to their new openings on the graft (Figure 10.6).

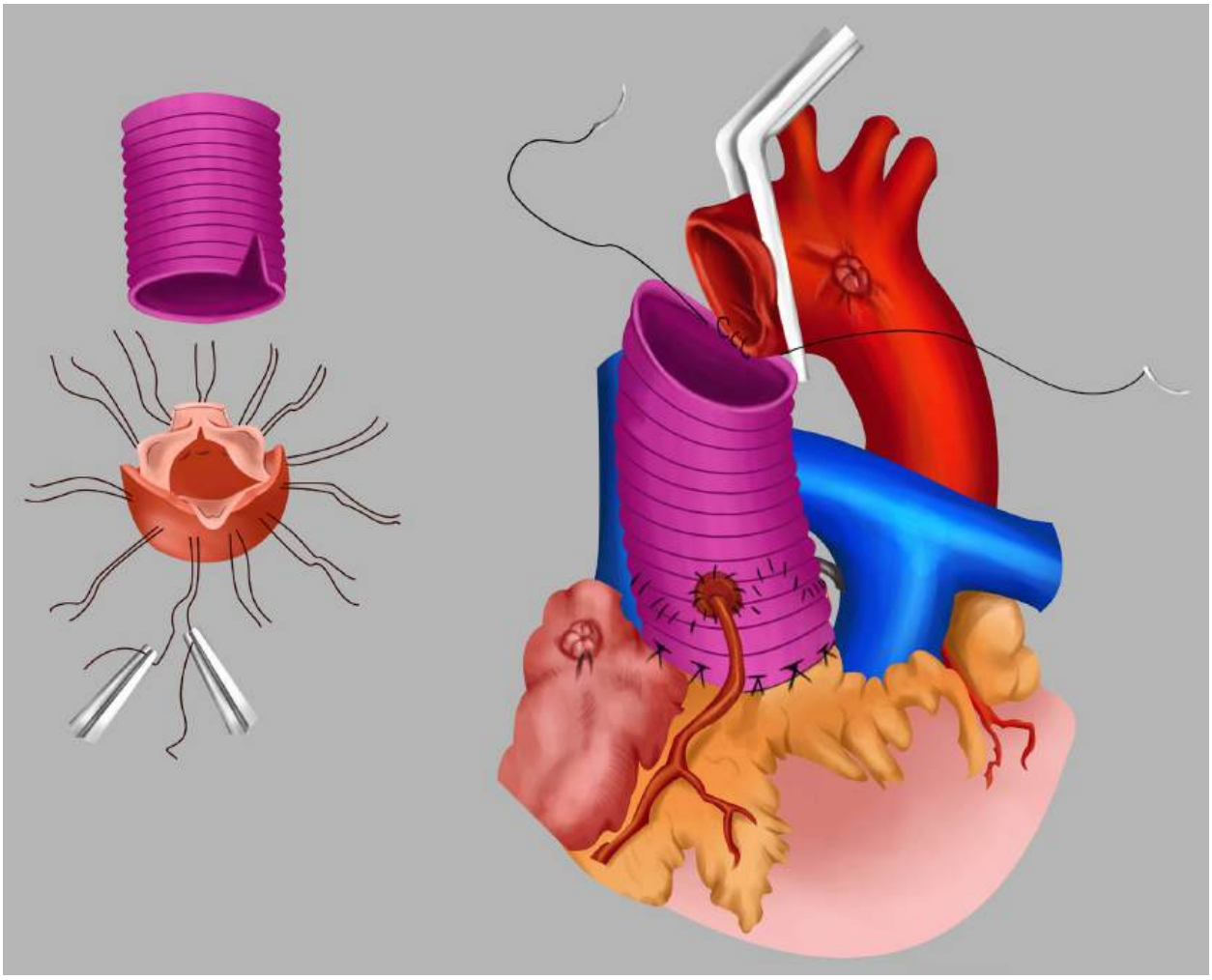

Figure 10.6. Aortic re-implantation technique.

TIPS & PITFALLS

While performing aortic valve repair, it is essential to evaluate the valve with transesophageal echocardiography before and after the operation in the operating room. It should be kept in mind that, in failed cases, the valve should be replaced with a prosthetic valve.

I. VALVE REPAIR TECHNIQUES

A. COMMISSURAL SUSPENSION

It is a method performed in cases where the aortic commissures cannot coapt adequately as a result of loosening. It is the process of almost reshaping the valve by fixing the free edges of the cups. Before this process, the anatomy, elasticity and coaptation of the cusps are evaluated with water test and, if this process will be beneficial, mutual fixation is done with the help of polytetrafluoroethylene (PTFE) pledgets. It effectively reduces the size of the aortic root at the level of the commissure and shortens the free margin. The commissures are joined with horizontal sutures with PTFE pledgets (Figure 10.7) (Photo 10.1). In commissuroplasty repair technique, central plication can be performed simultaneously. Alternatively, asymmetric commissuroplasty can be performed by making the plication toward one of the commissures and realigning the free edge of the overhanging process.

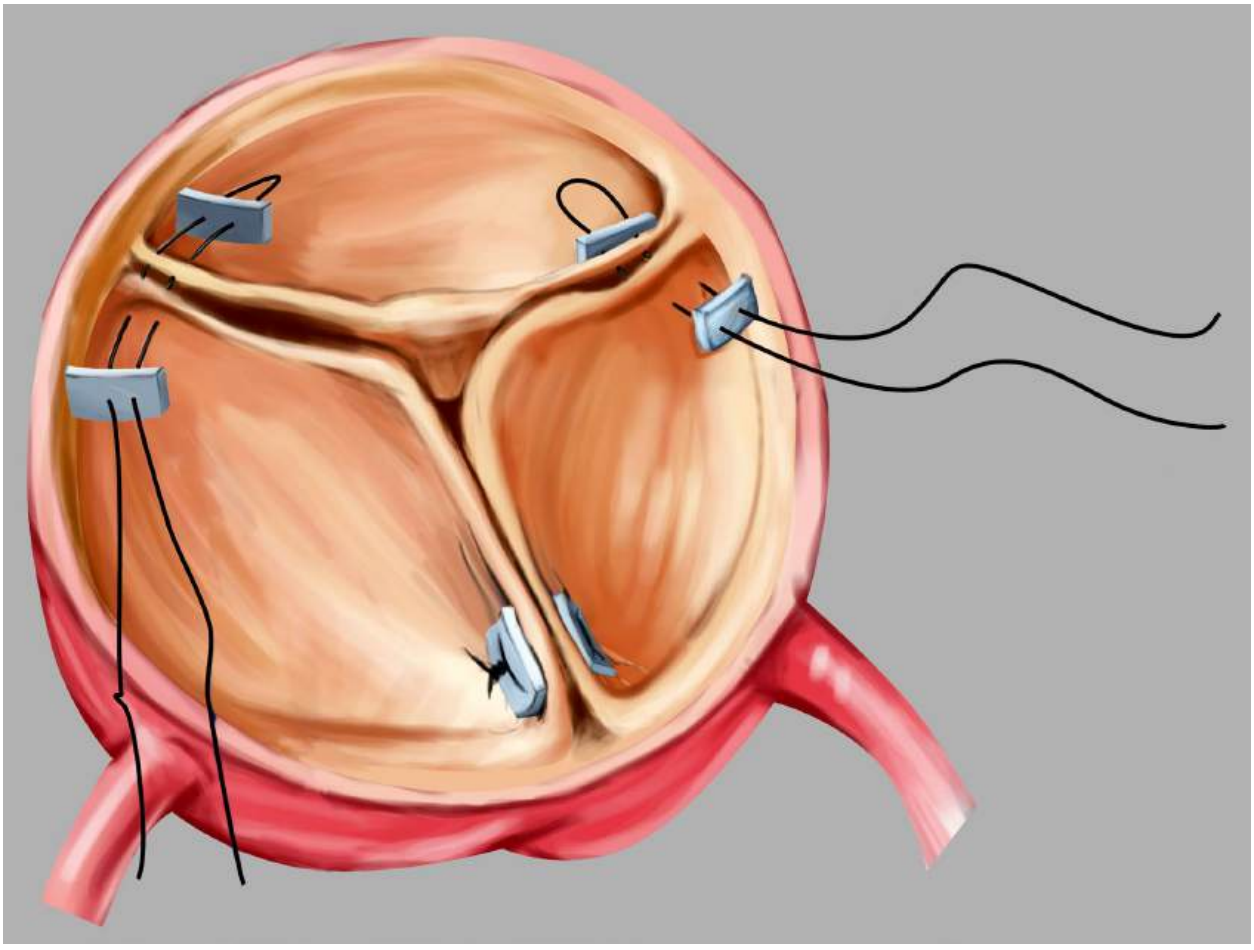

Figure 10.7. Commissuroplasty repair technique.

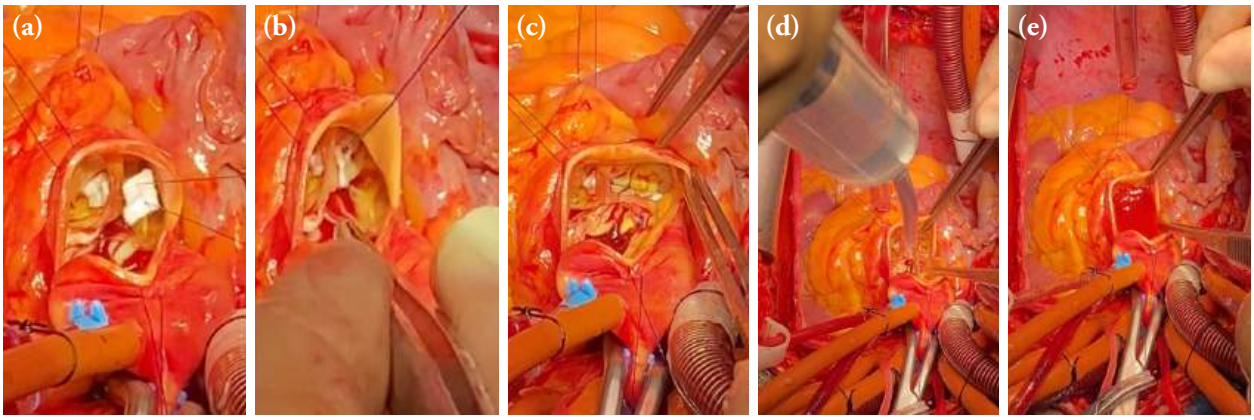

Photo 10.1. **(a)** Pledgeted sutures passed from the right commissure, **(b)** suture tied, **(c)** all three commissures completed, **(d)** saline test performed, **(e)** total coaptation succeeded.

B. FREE EDGE RESUSPENSION

The resuspension technique of the free edge eliminates the excess tissue on the tip of the leaflet and makes the coaptation surfaces on the same level to reestablish valve adequacy (Figure 10.8). This technique is particularly useful, when the overhanging ridge has a fragile free edge or fenestration. The pericardial patch used for valve augmentation can also be repositioned using this technique. Non-prolapsed protrusions are aligned side by side with 7/0 prolene sutures. A double-needle 6/0 PTFE suture is, then, placed over the free edge of the overhanging protrusion. The free edge length can be adjusted by applying gentle tug on each arm of the stitch, until the same free edge length is achieved compared to the reference peak point. The sutures can then be tied to the commissures.

C. CENTRAL PARACENTRAL PLICATION

If necessary, the central plication method can also be applied. This method is applied to arantius nodules that are worn out due to excessive exposure to dynamic stress. For successful plication, it is critical to ensure the height, taking into account other intact leaflets. Therefore, a 7-0 polypropylene suture is passed through the nodules of the non-prolapsed leaflet processes and a reference length is created by combining the leaflets. Then, to estimate the length of the free folded part of the leaflet to be intervened, the overhanging protrusion is aligned and sutured with 6/0 polypropylene sutures starting from the center point, with the smooth part remaining in the inner part, to eliminate the prolapsed part. If the problem is in the paracentral area, that part is

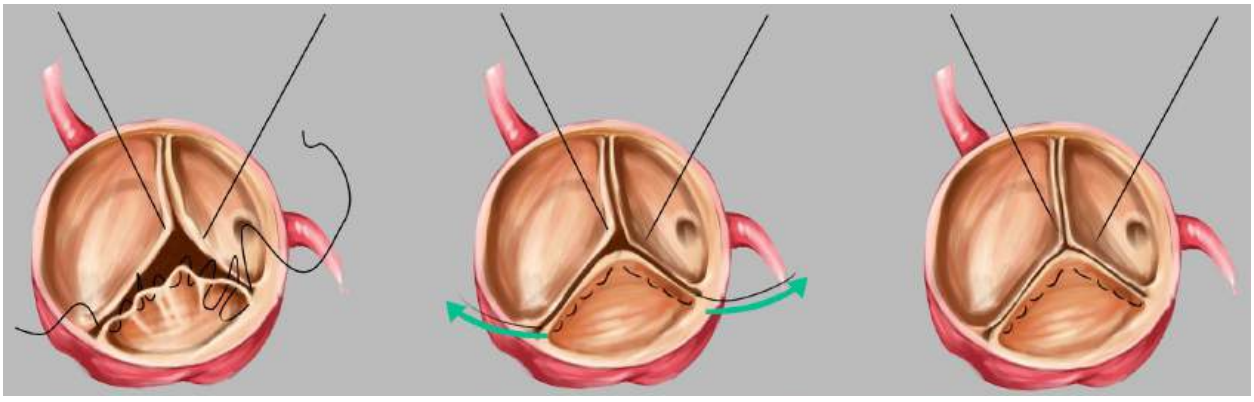

Figure 10.8. Free edge resuspension technique.

aligned and sutured from top to the bottom where sufficient coaptation is formed (Figure 10.9).

TIPS & PITFALLS

Since a good surgical view is extremely important in aortic valve repairs, median sternotomy is still recommended first for a successful repair of the aortic valve and its components. While standard transverse aortotomy is performed, it may be necessary to transect the aorta in aortic root interventions. The commissures are fixed mutually with the help of polypropylene 4/0 sutures with PTFE pledgets, and the non-prolapsed protrusions are aligned side by side with 7/0 prolene sutures.

D. LEAFLET REPAIR

1. Perforation repair

Patching with an autologous or bovine pericardium is recommended in cases of aortic insufficiency, due to a perforation occurring

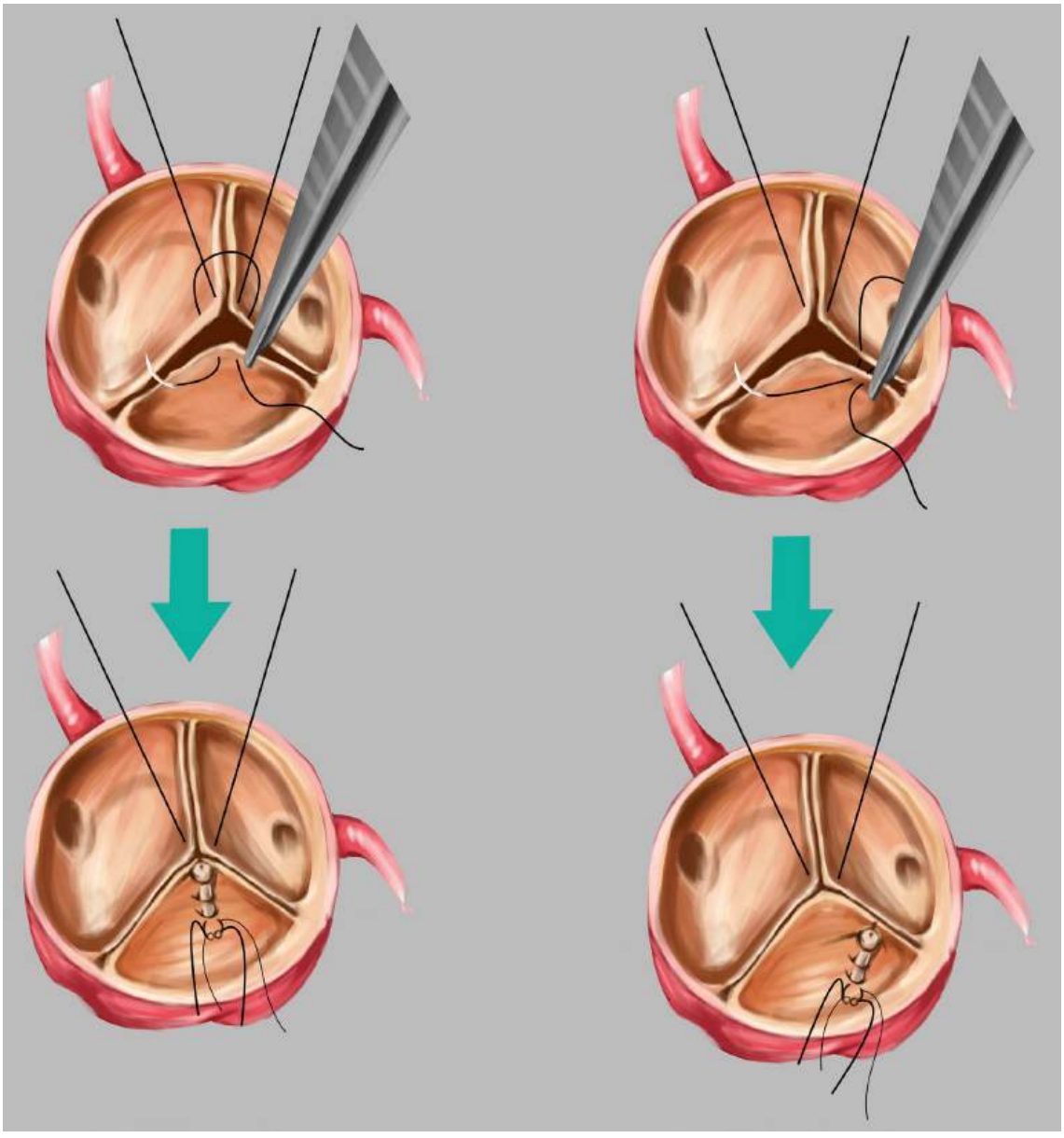

Figure 10.9. Central and paracentral plication.

for various reasons in the leaflets where valve movements are normal. Care should be taken to ensure that the patch is used in the appropriate shape and that it does not cause looseness and serious failure and/or narrowing (Figure 10.10).

2. Leaflet decalcification

It is possible to remove the calcified part of the leaflet and repair it close to the real anatomy with a pericardial patch we commonly use. Although the use of devices such as an ultrasonic surgical aspirator is a potential approach, we prefer to use sharp dissection. Calcified leaflet fusion restricts the mobility of the entire fused process. In this case, triangular resection should be performed. This can be achieved by cutting off the middle part of the leaflet and, then, sewing the edges back together. Continuous suturing is the preferred over interrupted sutures, since it reduces the risk of thrombosis and residual aortic regurgitation (Figure 10.11).

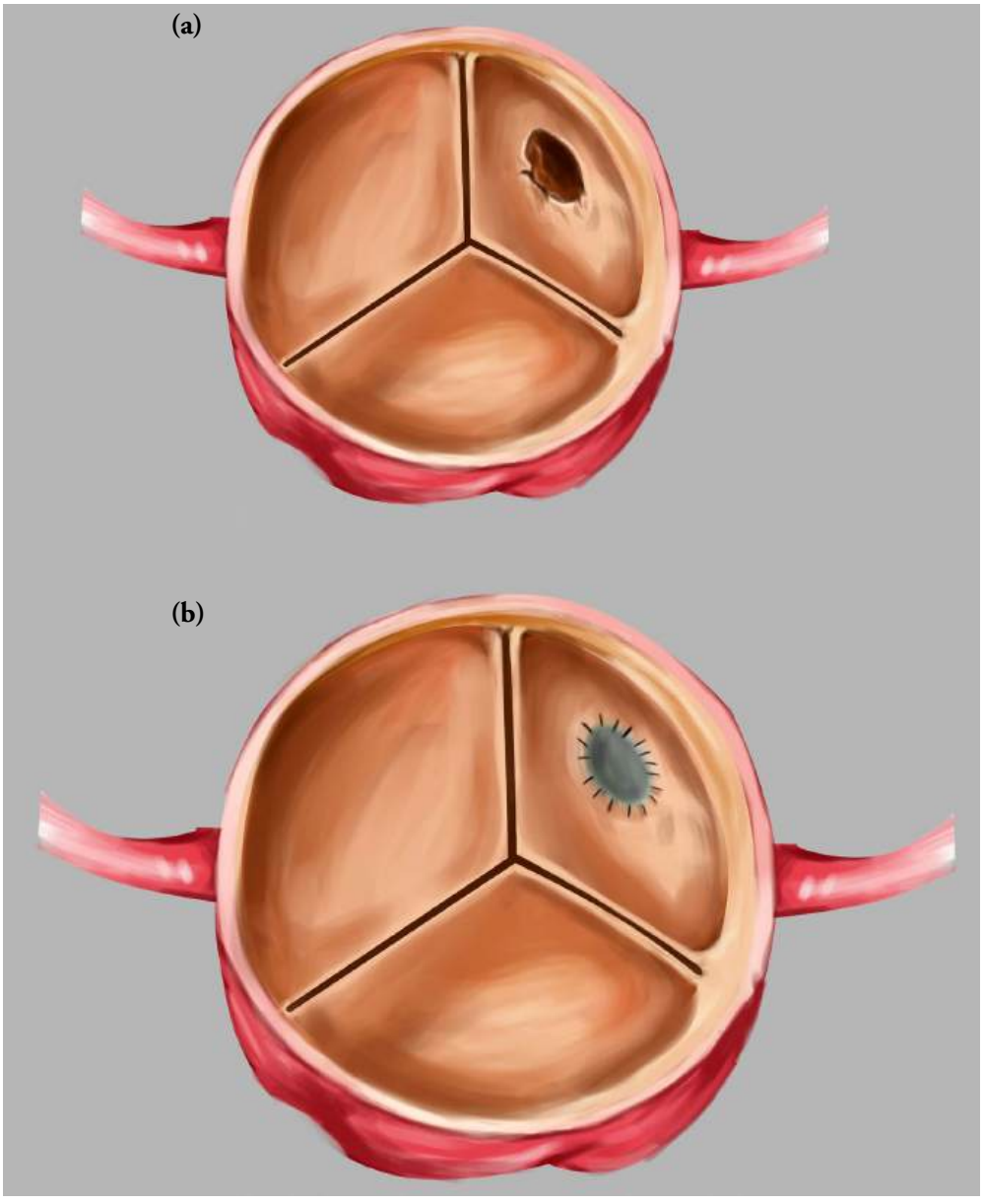

Figure 10.10. (a) Defect in the right coronary cusp, **(b)** defect repaired with a pericardial patch.

3. Pericardial Reconstruction and Augmentation

In case of a large leaflet resection, it can be reconstructed with a pericardial patch. In this technique, an oval-shaped autologous or bovine pericardial patch, slightly larger than the defect on the leaflet is prepared. As in Ozaki procedure, the entire aortic valve can be replaced with pericardium, but this is considered as the replacement of the valve. The use of a pericardial patch should depend on the size and location of the defect and its effect on valve motion, hemodynamics, and coaptation. The pericardial patch is sutured to the defect on the leaflet using a PTFE suture. Alternatively, a pericardial patch can be used for leaflet augmentation, when insufficient valve tissue remains. This valve lengthening technique is completed by suturing the pericardial strip to the free edge of the protrusion to recreate the coaptation surface.

Regardless of the repair method used for the aortic valve, the function of the valve should be re-evaluated with TEE in the operating room at the end of the operation, after weaning from cardiopulmonary bypass. Replacement should be

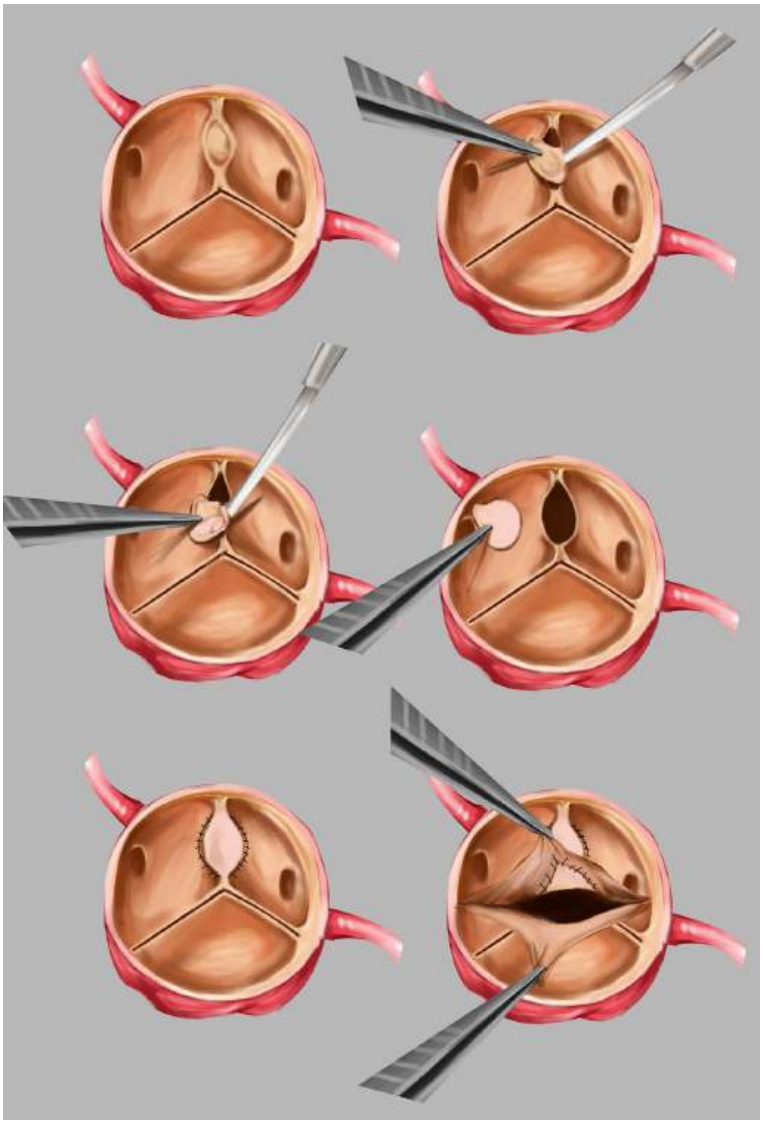

Figure 10.11. Decalcification and repair with a pericardial patch.

considered in cases that will cause problems in the near future and require reoperation in the short term.

II. ANNULOPLASTY

Aortic valve annuloplasty appears to be an important component of aortic valve repair to normalize the basal plane of the aortic root and is recommended to increase the durability and permanence of the repair.

Annuloplasty Techniques:

The subcommissural suture technique was first performed by Cabrol et al.[2] Its ease of application has enabled its widespread use. Although it has never been standardized, annular plasty has usually been performed with the help of sutures placed between the annulus and commissures. Progressive annular dilatation was observed in this technique over time, and many surgeons abandoned this technique with the belief that subcommissural sutures did not provide adequate and stable annular support.

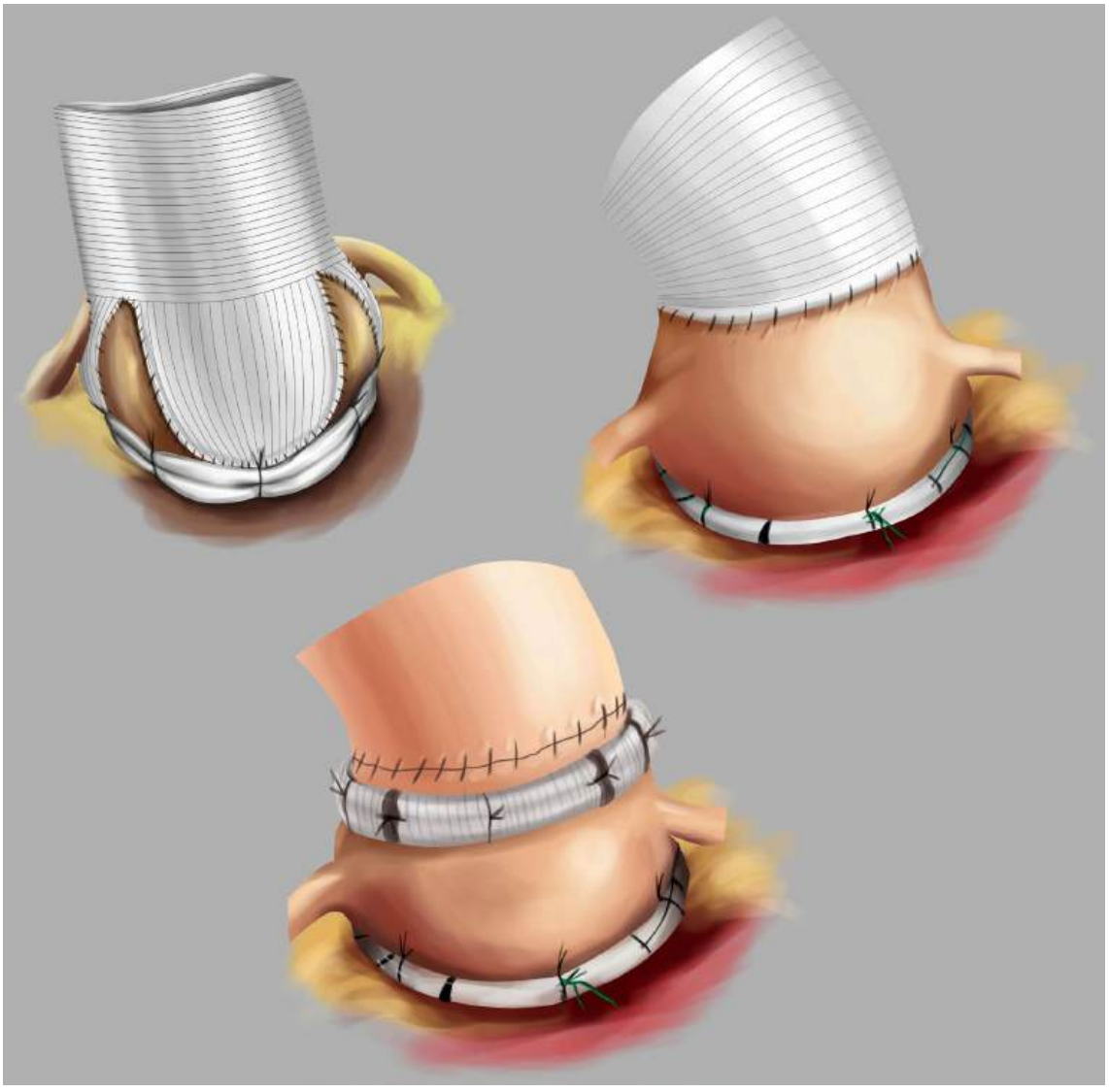

Figure 10.12. Annuloplasty techniques.

External ring annuloplasty was first used by Lansac et al.[3] primarily using an external ring for remodeling. An open ring was produced by cutting a ring from a Dacron® graft to be used in isolated valve repair. Implantation of such an outer ring requires extensive dissection similar to the re-implantation procedure. Furthermore, the incompatibility between the ventriculoaortic junction and the aortic annulus makes this technique difficult to apply. Although it is considered as an effective repair method, its success when used together with other techniques has not been clearly elucidated yet.

Internal ring annuloplasty is a method based on geometric studies of the aortic root in diastole and applied by using an internal ring. The developed ellipsoid rigid ring has structures that extend tight toward the commissures. It is implanted under the lines of the cusps using a suturing technique similar to stented prosthesis implantation.

Combined use of internal and external ring; An internal circular Dacron® ring is implanted just below the annular plane, and a crown-like shaped Dacron® ring is sutured externally to the STJ.

In annuloplasty technique performed by using two external rings; A ring is implanted in the annulus and the other in the STJ. Although STJ implantation seems easy, valve function may deteriorate, if commissural position is not taken into consideration. It is claimed that better results are obtained by using double rings. Apart from the commissural position, attention should also be paid to the to the coronary arteries. In this technique, possible dilatation of the STJ is also prevented (Figure 10.12).

Aortic valve annuloplasty appears to be an important component for aortic valve repair to normalize the functional annulus, that is, the basal plane of the aortic root. An annuloplasty technique performed alone rarely normalizes aortic valve form and function. Prior to this, valve repair is almost always necessary. It still remains to be elucidated which annuloplasty method to choose.

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