EXPOSURE OF THE MITRAL VALVE

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Mitral Valve Replacement

1- SURGICAL ANATOMY

The mitral valve is the most commonly repaired valve worldwide, and it is the second most frequently replaced valve after the aortic valve. Successful repair or replacement requires a thorough understanding of anatomy.

Before delving into surgical approaches to the mitral valve, as with any surgical procedure, it is essential to have a good grasp of the anatomy of the operative area. The mitral valve consists of two leaflets: anterior and posterior. The anatomical structures and their relationships are crucial. The circumflex (Cx) coronary artery passes posteriorly within the atrioventricular (AV) groove along the lateral edge of the annulus. The coronary sinus is more medial within the AV groove. The AV nodal artery, usually a branch of the right coronary artery (RCA), runs parallel to the anterior leaflet, near the posterior medial commissure. The aortic valve non-coronary and left coronary cusps lie between the anterior and posterior fibrous trigones. The His bundle is just posterior to the right trigone (Figure 13.1). Knowledge of regional anteroposterior leaflet classification is essential for valve replacement, particularly for valve repairs (Figure 13.2).

The mitral valve is oriented vertically-obliquely between the left atrium and left ventricle. For proper exposure from the surgical position, the heart's apex needs to rotate vertically cranially, posteriorly in the sagittal plane, and to the left in the transverse plane. In common practice, while placing pericardial sutures, tight tying of the sutures on the right side to turn the apex to the left and posteriorly is done, while no sutures are placed on the left side of the pericardium. In cases where adequate exposure is not achieved, particularly in reoperations where the apex is adherent, opening the left pleura to let the heart fall to the left can be helpful. Vertical orientation is achieved during valve stitching by pulling the stitches.

2- INCISIONS AND APPROACHES

2.1 Left Atrial Incision

A left atrial incision is a frequently chosen approach for isolated mitral valve surgery. It can also be preferred as a second incision in cases where there are additional pathologies requiring opening of the right atrium. Following arterial cannulation from the aorta and bicaval venous cannulation, a parallel incision is made over the pulmonary veins, anterior to the right superior pulmonary vein, and posterior to the interatrial groove (Sondergaard's sulcus) (Figure 13.3). Confirming our location in the left atrium is done, when air coming from the pulmonary vein is visualized. Then, the incision is extended superiorly and inferiorly. Care should be taken, particularly during the inferior incision, to avoid opening the right atrium. Additionally, the left atrial incision can be made through the interatrial groove (Sondergaard's sulcus). In this incision, the left atrium is separated from the right atrium. This allows the surgeon to approach the mitral valve from a closer plane with a 2 to 4 cm left atrial incision in the medial region (Figure 13.4). Sondergaard's

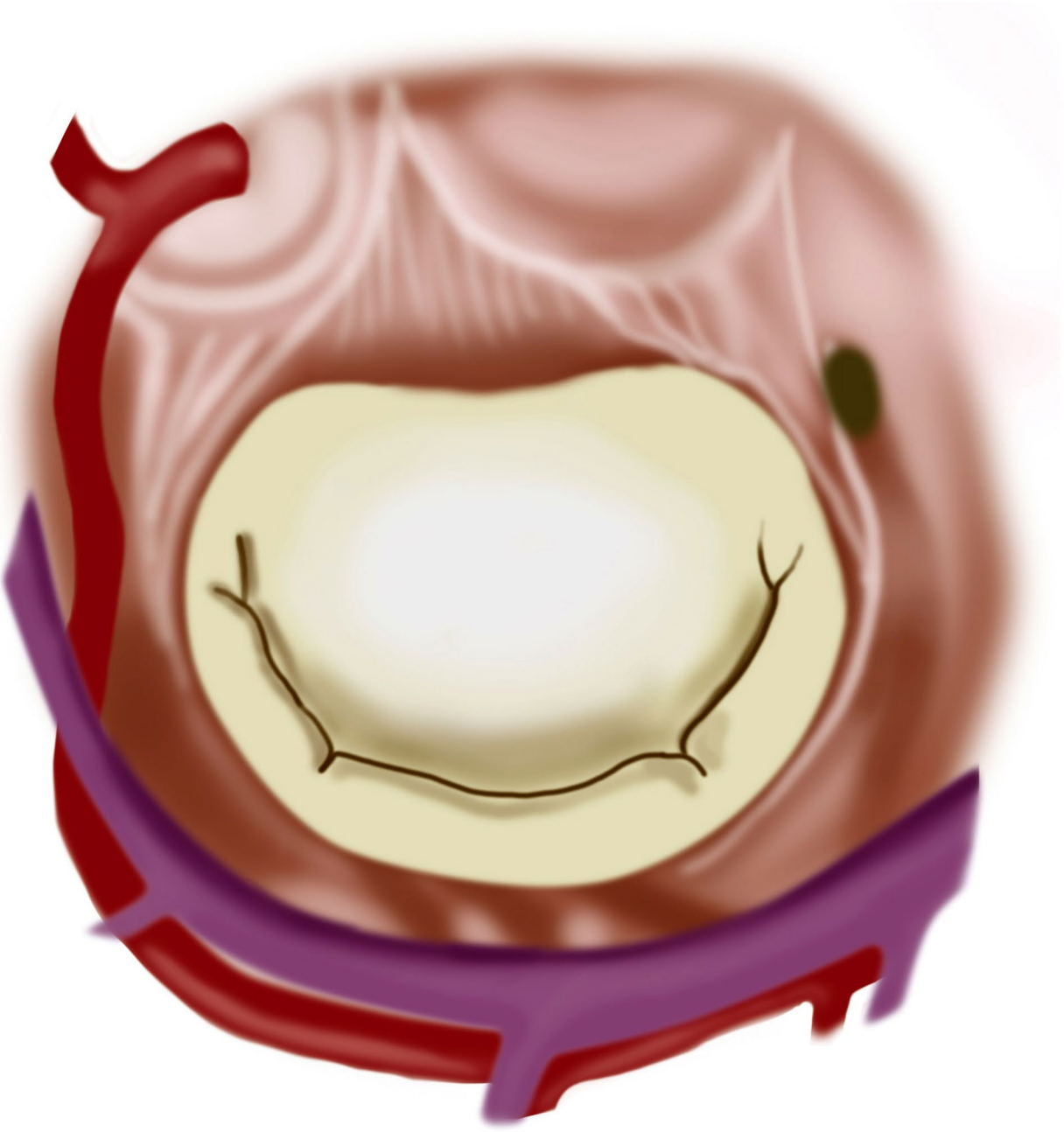

Figure 13.1. The circumflex coronary artery (red) passes posteriorly within the atrioventricular groove along the lateral edge of the annulus. The coronary sinus (purple) is more medial within the atrioventricular groove. The atrioventricular nodal artery, usually a branch of the right coronary artery, runs parallel to the anterior leaflet, near the posterior medial commissure. The aortic valve non-coronary and left coronary cusps lie between the anterior and posterior fibrous trigones. The His bundle (green) is just posterior to the right trigone.

sulcus incision should not be preferred in cases where the left atrial wall is thin and fragile. In surgical procedures performed through a left atrial incision, difficulty in reaching the mitral valve may be encountered, if the volume of the left atrium is small.

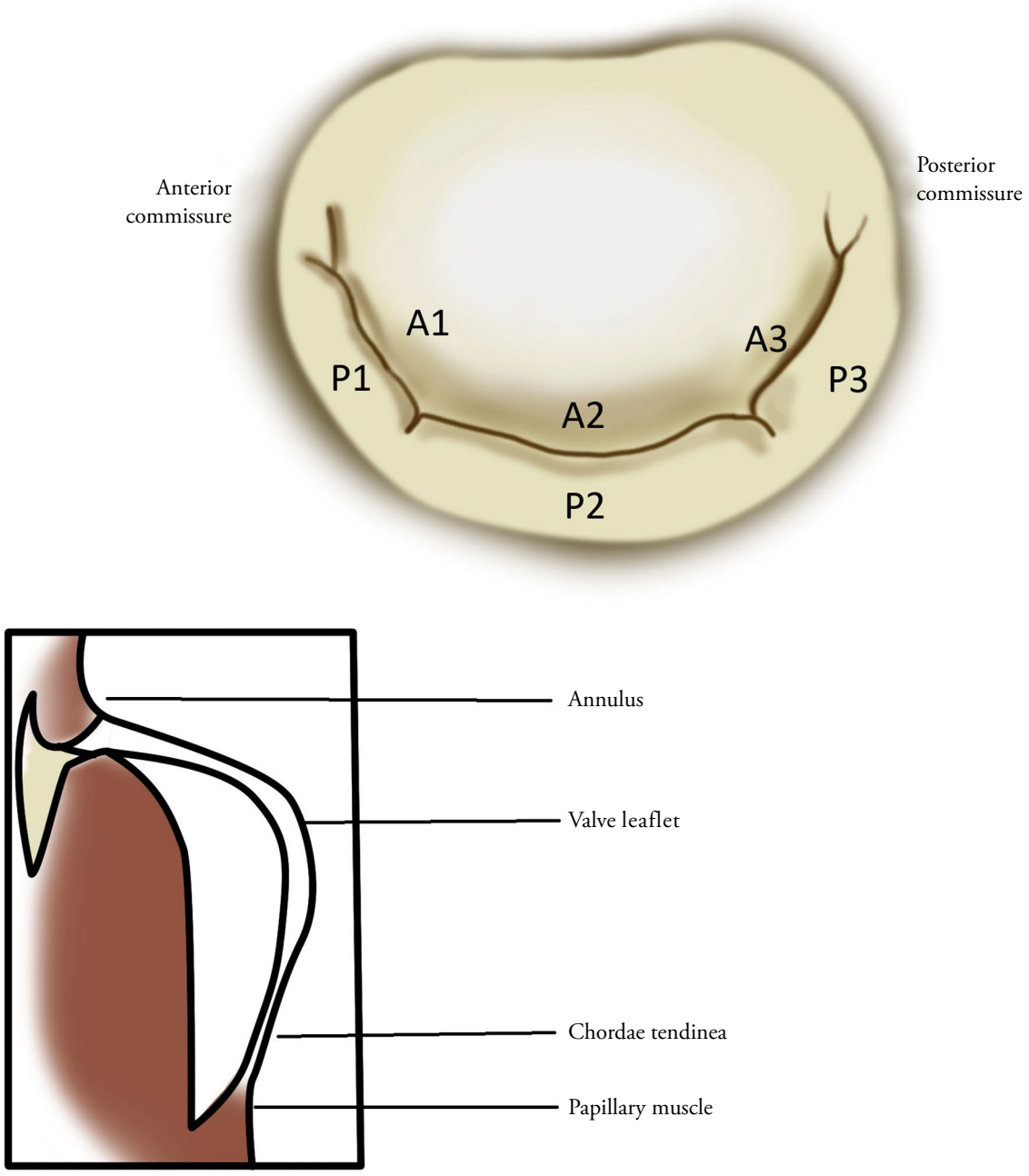

Figure 13.2. Regional anteroposterior leaflet classification.

2.2 Transseptal Approach

The transseptal approach is a preferred method, particularly in cases where the left atrium is small or when intervention on the tricuspid valve is planned, and it can also be routinely preferred based on the surgeon's experience. After positioning the heart as described above for ideal exposure, total cardiopulmonary bypass (CPB) is initiated when the right atrium is opened to prevent air from entering through the cannulas and to cut off blood flow to the atrium. Theoretically, total CPB ensures the drainage of all the blood returning to the heart through the cannulas. To achieve this, the areas

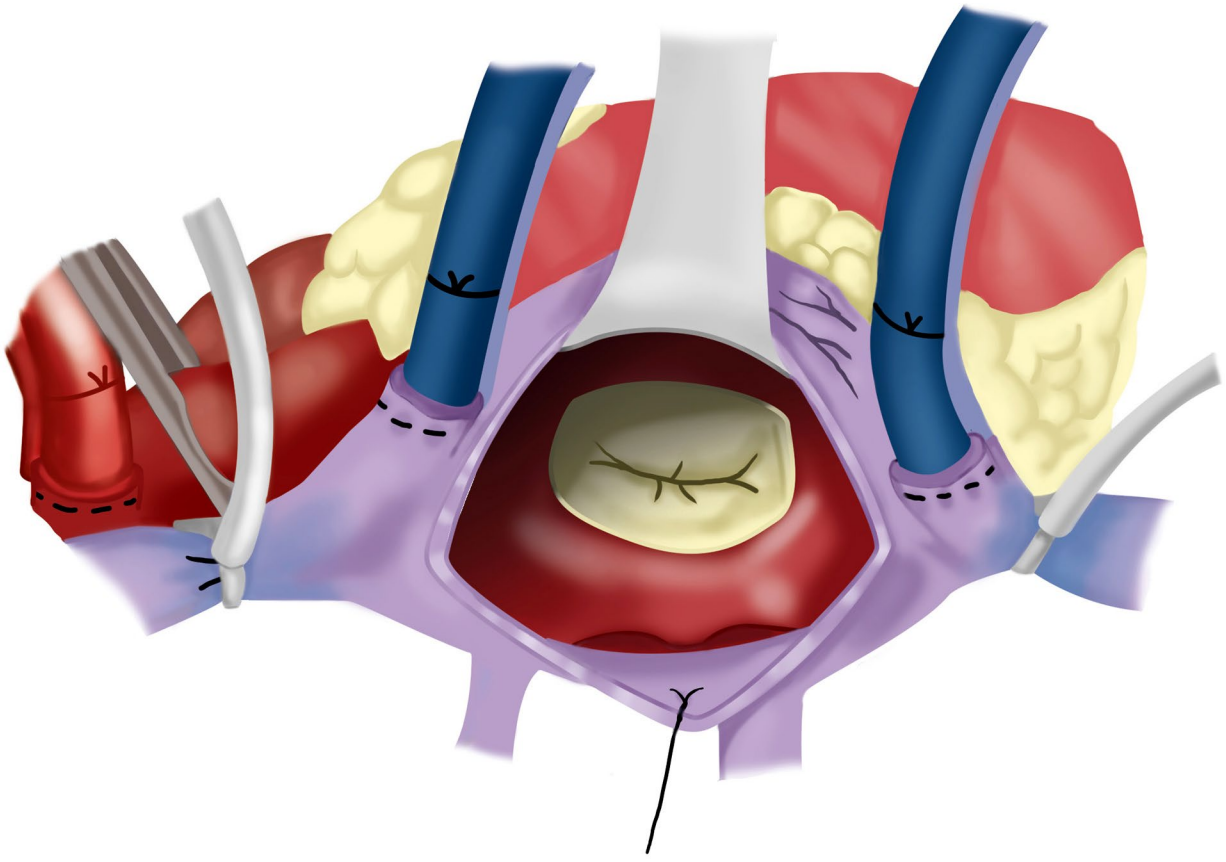

Figure 13.3. Classical left atrial incision to perform mitral valve surgery.

around the superior vena cava and inferior vena cava cannulas need to be encircled and compressed with a tourniquet. Encircling the inferior vena cava with a nylon tape is a relatively easy process in practice, achieved by passing through the diaphragmatic border of the inferior vena cava with Cooley vascular clamps. Dissecting the surrounding tissues with blunt finger dissection to prevent injury to the inferior vena cava can make this process safer. While encircling the superior vena cava, a small incision is made with scissors at its proximity to the right pulmonary artery, and dissection is performed with a blunt-tipped large right-angle clamp from the lateral border of the right atrium and the incision. Then, a nylon tape is passed through, and after encircling with the nylon tape, the procedure is completed by passing the tape through a thick tourniquet. It is of utmost importance that the nylon tapes are positioned distal to the cannulas and encircle the cannula. Total CPB is completed by tightening the tourniquets.

The superior vena cava cannula is positioned cranially, and the inferior cannula is positioned caudally and secured. Then, a cut is made from the anterior surface of the right atrium parallel to the AV groove, leaving a safe distance from the inferior vena cava up to the appendix (about 1 cm away and anteriorly). If necessary, making a cut toward the anterior of the appendix for superior transseptal access facilitates reaching the superior wall of the right atrium. After opening the right atrium, placing two sutures on the upper edge and one on the lower edge provides an ideal view. In general, 5/0 prolene sutures are preferred for suturing. While placing the lower edge sutures, passing superficially through the crista terminalis can provide better exposure. Check for air entry through the cannulas and the presence of blood flow in the surgical field.

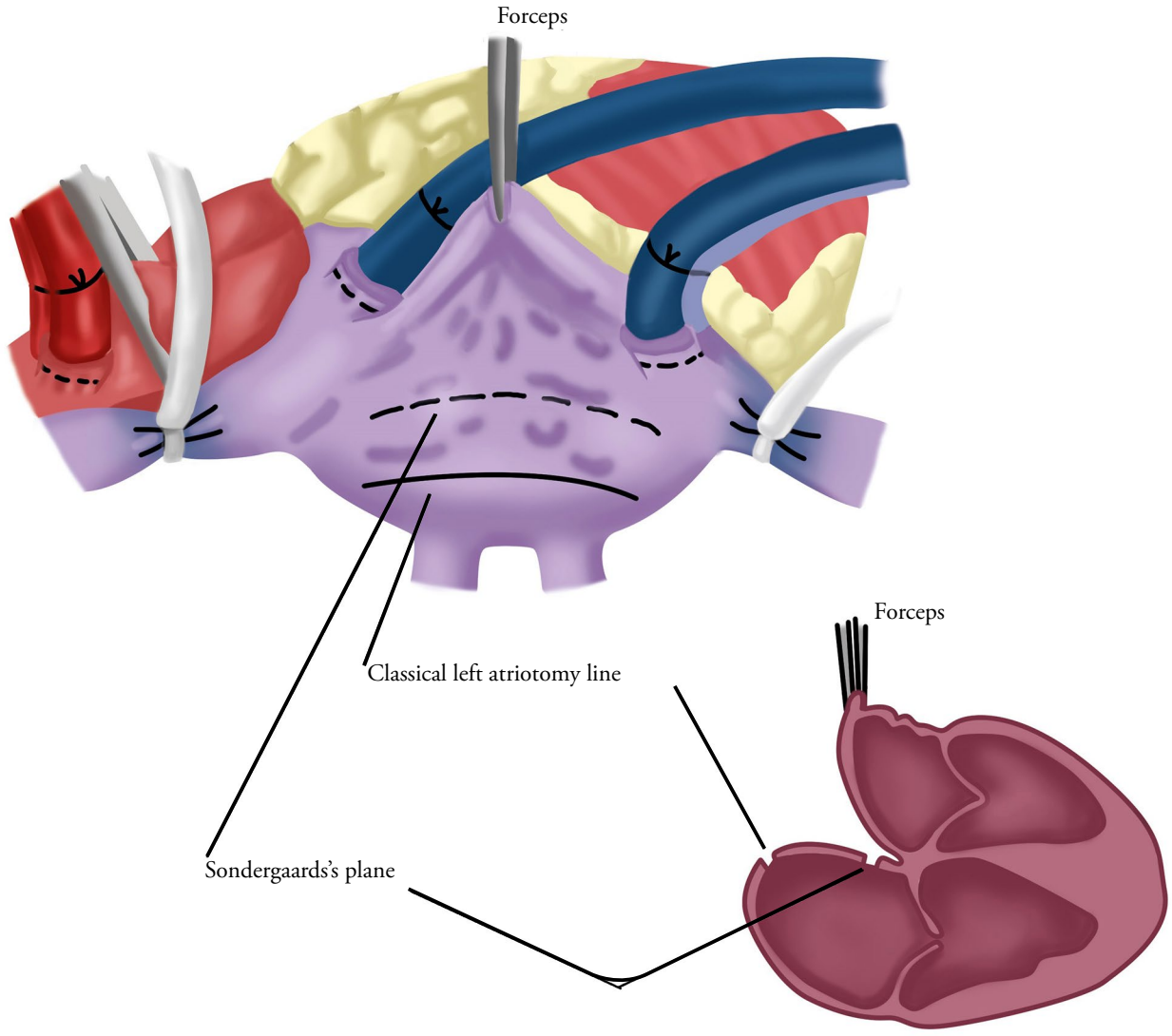

Figure 13.4. The Sondergaard's plane; the left atrium is separated from the right atrium. This allows the surgeon to approach the mitral valve from a closer plane with a 2 to 4 cm left atrial incision in the medial region.

If necessary, tightening the tourniquets firmly will prevent air and blood flow. Nevertheless, in cases of air entry into the cannulas or blood flow hindering exposure, a clamp may need to be placed proximally to the cannula. Placing the tourniquets toward the left side of the patient can help the heart turn to the left.

After the right atrium is opened and adequate exposure of the septum is achieved, the incision is made on the septum. The septal incision should preserve the coronary sinus ostium inferiorly and the left atrial roof superiorly. The incision progresses down and up from the center of the fossa ovalis parallel to the atriotomy (Figure 13.5). A cut of about 3 cm will provide the necessary space for intervention. In cases of small left atrium, extending the lower part of the incision anteriorly to preserve the coronary sinus can provide additional space. Care should be taken to avoid opening the left atrial roof at the upper border. After the septal incision, the left atrium is reached using palpable retractors or atriotomy retractors. In mitral valve surgery,

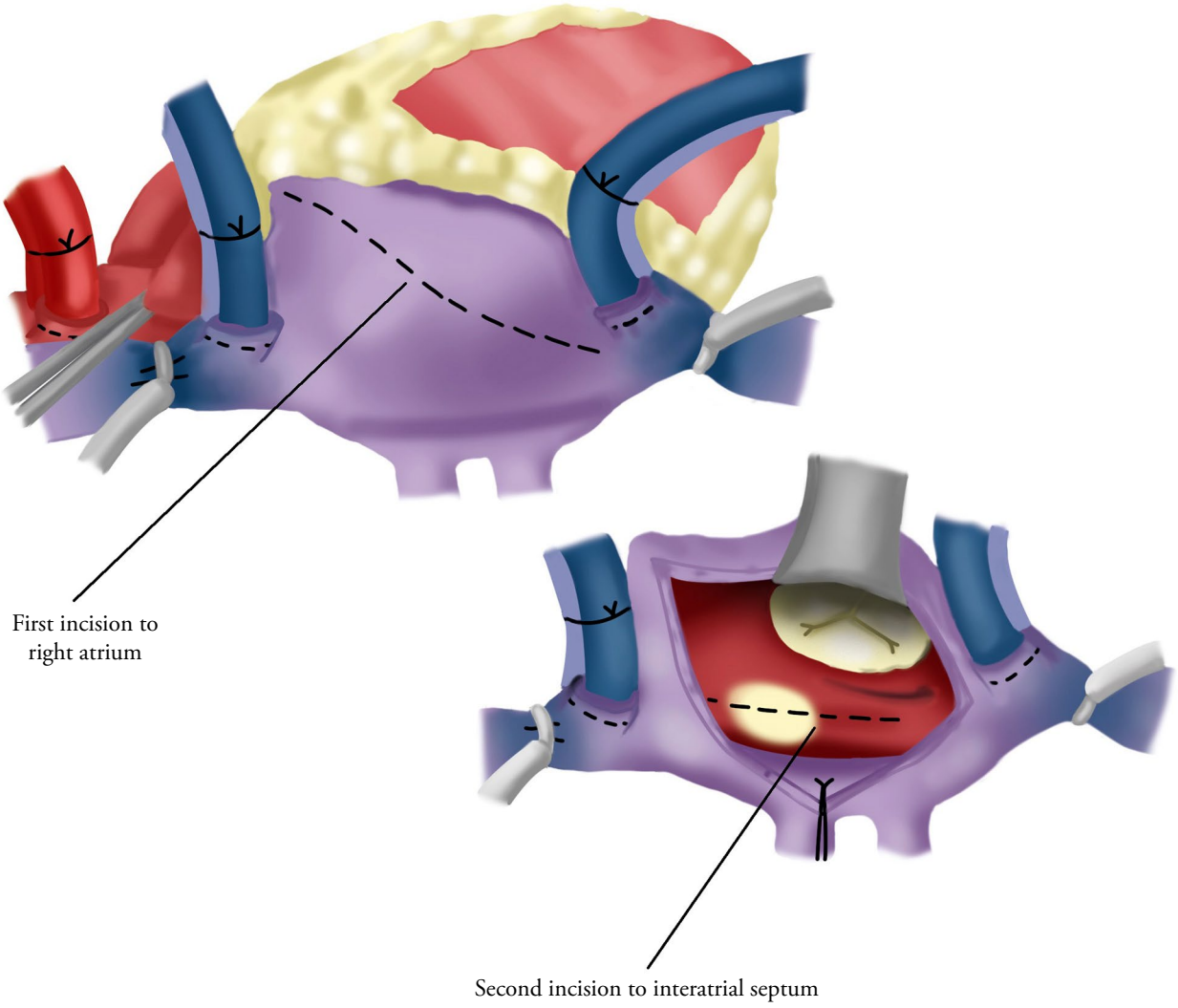

Figure 13.5. Firstly, the right atrium is opened and adequate exposure of the septum is achieved, then the second incision is made on the septum to gain access to left atrium.

the suture usually guides the sample from the transseptal incision to the apex of the left atrium. A detailed examination of the mitral valve leaflets, mitral annulus, commissures, chords, and papillary muscles is performed. This is done by passing through the chordae tendineae between the leaflets with a hook to evaluate leaflet structure, length, thickness, prolapse, chordal rupture, elongation, fusion, subvalvular masses, and calcifications. In particular, in elderly patients, the mitral annulus should be carefully examined for mitral annular calcification.

Following evaluation, leaflet resection for replacement is performed. Depending on the case, complete leaflet resection, posterior leaflet sparing resection, or bileaflet sparing leaflet preparation is performed. In complete resection, both leaflets are resected, leaving 2 to 3 mm of tissue at the annulus level, usually starting from the center of the anterior leaflet. At the anterolateral commissure level, 4 to 5 mm of tissue can be left due to proximity to the circumflex artery. In posterior leaflet sparing resection, while the anterior leaflet is resected, the posterior leaflet is entirely or partially preserved. In

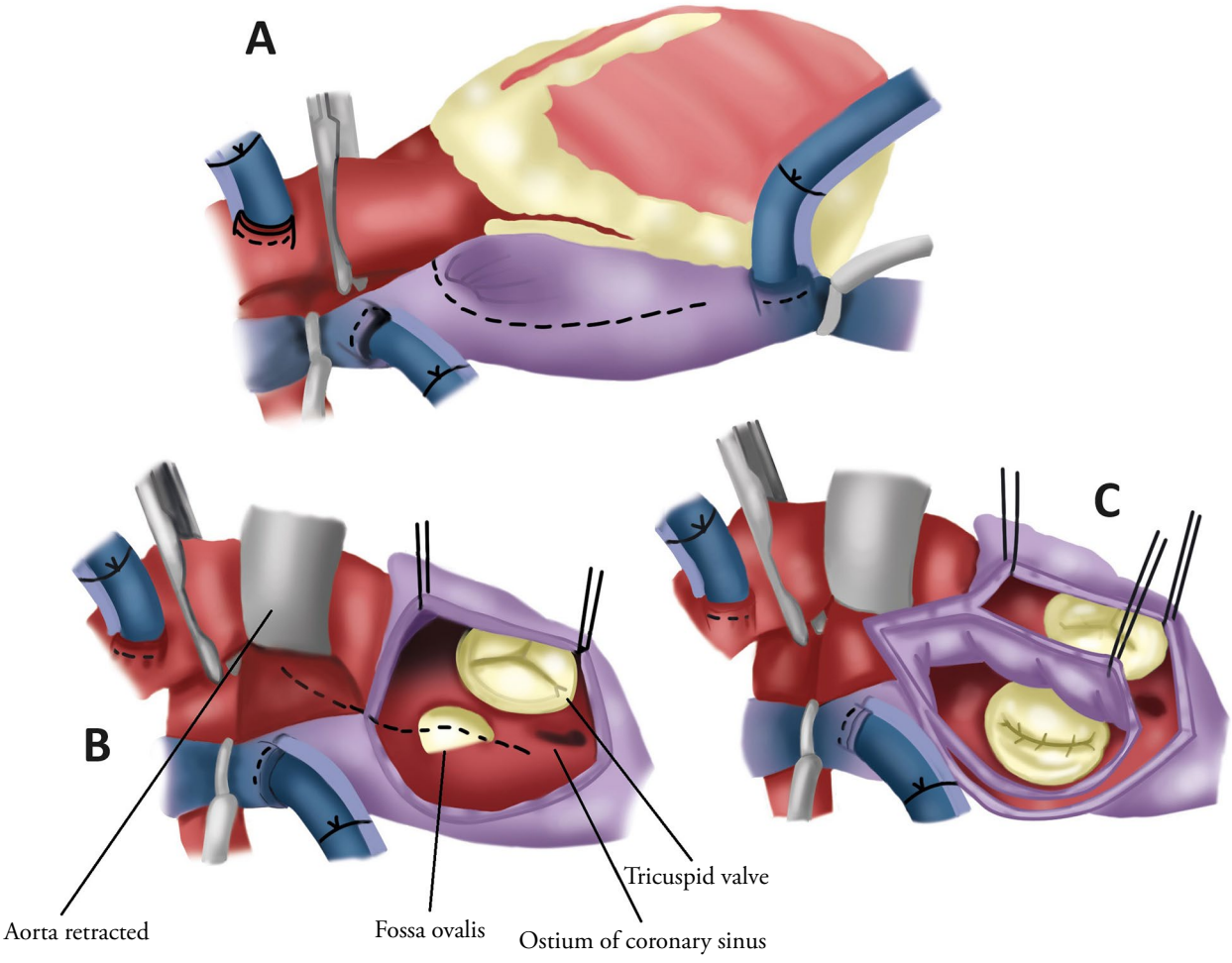

Figure 13.6. **(a)** A longitudinal (vertical) right atriotomy is performed longitudinally in the anterior aspect of the sulcus terminalis. **(b)** To reach the atrial septum, the incision is expanded either around the upper base of the atrial extension or directly through the extension. Care should be taken to avoid the sinoatrial node. However, the incision should be made 1 to 2 cm away from the right ventricle to allow for secure closure. **(c)** The septum is cut vertically along the fossa ovalis, just below and parallel to the right atriotomy. The incision is extended toward the upper tip of the right atriotomy. These two incisions are, then, joined toward the dome of the left atrium.

complete preservation, the posterior leaflet is left uncut from the commissures. In partial preservation, usually, a resection is made from the middle of the leaflet, preserving secondary and tertiary chordae. In bileaflet preservation, similarly, the anterior leaflet is partially resected or preserved without resection. Care should be taken to ensure that the thickness and size of the leaflet do not obstruct the movement of the prosthesis. Resection usually starts from the center of the anterior leaflet. After resection, measurement for the prosthesis is performed. In cases of partial resection or unresected cases, measurement may be preferred after placing the valve sutures. While measuring, the gauge should pass through the same plane as the annulus depending on the position of the valve. Measuring at an angle may lead to incorrect selection of a larger valve. It is important that the gauge does not pass through the annulus too easily or with difficulty. Simultaneously, in cases where aortic valve replacement will also be performed, using a valve one size smaller than the measurement is a widely accepted technique.

Teflon pledgeted sutures are usually preferred for mitral valve replacement. Needle size is determined based on the annulus or exposure. Instead of pre-made pledgeted sutures, Teflon pieces of 1.5×2.5 mm size can also be cut and used. Before passing the sutures, the area is preferably covered with a perforated green drape, and suture guides are fixed in a U or triangular shape. Suture guides are very useful tools for preventing the tangling of threads and for using the threads as a suspension. While passing the valve sutures, starting from the center of the posterior annulus and progressing clockwise usually allows the valve to approach the surgeon and provides better visibility of the anterior annulus. Pledgets are passed through the annulus, exiting under the leaflets to remain on the atrial side. Care should be taken to ensure that there is not more than 1 to 2 mm distance between the pledgets. Due to the proximity of the circumflex artery in the anterolateral commissure area, the sutures should not penetrate deeper than the annular tissue. Similarly, the proximity of the coronary sinus to the posterior annulus should be kept in mind. While passing the sutures, reaching the medial half of the anterior annulus can be achieved by pulling both threads of the previous or passed stitch. It should be kept in mind that the aortic valve is located anteriorly on the front side of the anterior annulus. After encircling the annulus with sutures, it is recommended to check again with the valve gauge.

Once the type (mechanical, bioprosthesis) and appropriate size of the valve are determined, the sutures taken from the guides are passed through the valve ring one by one. The total number of stitches is distributed symmetrically and equal to the prosthetic ring. In mechanical valves, the position of the leaflets can be adjusted symmetrically (anti-anatomic) or perpendicular (anatomic) to the septum. In small and hypertrophic ventricles, the valve opening should be controlled to position the prosthesis. There is a special consideration for bioprosthetic valves at this stage. The positions of the three struts, also called horns, of the bioprosthesis in the ventricle are important. If the struts remain in the middle of the anterior annulus, particularly in patients with small ventricles, it can lead to obstruction of the left ventricular outflow tract. Positioning the struts at 10-14-18 positions on the clock dial can prevent this. Care should be taken to ensure that two pledgeted sutures are side by side while passing the stitches. Then, with the sutures taut, they are wetted and passed through the septal incision and then through the annulus using a valve holder, and finally secured. While passing through the septum, the anterior part of the valve is passed first and, then, pushed toward the annulus. Once the valve is seated, it is checked thoroughly with fingers to ensure that all pledgets are on top. The threads of the valve holder are cut and removed, and the sutures are tied sequentially 5 to 6 times. It is of utmost importance not to pull excessively, particularly while tying the posterior stitches. After tying the stitches, the opening and closing of the valve are checked, and it is confirmed that there is no tissue that could cause entrapment under the valve. Once the valve implantation is completed, the interatrial septum is closed with a double-layer suture. Before tying, saline is used to fill the left atrium for air escape. Then the right atriotomy is closed according to the surgeon's preference, either double-layered, single-layered, or inverted.

2.3 Superior Septal Approach

In some cases where the volume of both atria is within normal limits, it may not be possible to reach the mitral valve through either a left atriotomy or a transseptal approach. In such situations, combining incisions can provide a more visualized surgical field. A longitudinal (vertical) right atriotomy is performed longitudinally in the anterior aspect of the sulcus terminalis. To reach the atrial septum, the incision is expanded either around the upper base of the atrial extension or directly through the extension. Care should be taken to avoid the sinoatrial node. However, the incision should be made 1 to 2 cm away from the right ventricle to allow for secure closure. The septum is cut vertically along the fossa ovalis, just below and parallel to the right atriotomy. The incision is extended toward the upper tip of the right atriotomy. These two incisions are, then, joined toward the dome of the left atrium (Figure 13.6). Hold these three incisions away from the thin tissue at the base of the left atrium near the aorta and left pulmonary artery, and away from the back of the aorta near the left coronary artery. Marking or labeling the junction of these three incisions facilitates re-approximation and closure later on. Atrial septal eversion should be performed gently to prevent damage to the AV node.

The superior septal incision provides a wide surgical approach to the mitral valve. However, it can lead to atrial dysrhythmias due to injury to the

sinoatrial nodal artery. Therefore, knowledge of the course of the sinoatrial nodal artery is important for this incision. Another drawback of this incision is that, due to the opening of the atrial roof, it can cause significant bleeding, particularly in fragile atrial structures.

3. MITRAL VALVE SURGERY COMPLICATIONS

3.1 Myocardial Rupture

Myocardial rupture typically occurs due to excessive tension or cutting of papillary muscles in fragile myocardium. It is the most lethal complication of mitral valve surgery. The tear may result from excessive cleaning of the calcified annulus, excessive resection of the posterior leaflet, or the use of a large prosthesis.

3.2 Atrioventricular Groove Rupture

Another serious complication is the rupture of the AV groove. Excessive resection of the posterior leaflet, particularly in the presence of a calcified annulus, predisposes to this complication. Also, taking the sutures too deep from the myocardium is dangerous. To prevent this complication, posterior leaflet preservation can be preferred, or sutures can be taken from the left atrium. If calcifications are to be left, Teflon strip-reinforced sutures can be used. If all calcifications are to be removed, the area is closed with a pericardial patch, and the valve is sutured onto the patch.

3.3 Circumflex Artery Injury

Injury to the circumflex artery can occur due to the deep placement of sutures passing through the AV groove level. The reason is the excessive resection of the posterior annulus, leaving no place for sutures. Therefore, leaving at least 3 to 4 mm of tissue in the posterior leaflet can prevent circumflex artery injury.

3.4 Aortic Valve Non-Coronary Cusp Dysfunction

Excessive resection of the anterior leaflet may lead to dysfunction of the aortic non-coronary cusp, resulting from a technical error. The non-coronary cusp is very close to the mitral annulus near the anterolateral commissure at approximately 10 to 12 o'clock. Leaving 4 to 5 mm of the anterior leaflet in this area does not require deep suturing and prevents the development of this complication. Otherwise, acute aortic insufficiency may develop after mitral valve surgery.

TIPS & PITFALLS

1. A good visual field is crucial for a successful mitral valve surgery. The approach should be tailored to the patient's anatomical features and the most suitable procedure.
2. In cases with small atria, the superior transseptal approach can be life-saving. Therefore, it should be part of training and developed through elective procedures.
3. For an ideal visual field, pericardial sutures should be tense on the right and loose or absent on the left.
4. Opening the left pleural space can increase visibility when there is insufficient heart rotation.
5. While making the incision in the right atrium, extending it slightly anteriorly to the inferior vena cava cannula can facilitate closure.
6. While performing a transseptal incision, attention should be paid to the coronary sinus ostium inferiorly and the incision should be extended superiorly toward the superior vena cava.
7. Placing a superficial suture on the inferior aspect of the crista terminalis can improve visibility.
8. Leaving about 2 mm of tissue during valve resection can enhance replacement safety.
9. Passing the valve sutures first through the middle part of the posterior annulus and then pulling these sutures can facilitate visualization of the anterior part of the annulus.
10. The circumflex artery approaches the mitral annulus most closely at the lateral commissure level. Care should be taken while passing sutures from this area.
11. The His bundle is adjacent to the medial commissure. Passing sutures close to the annulus and more superficially can prevent injury.

12. The posterior mitral annulus is adjacent to both the circumflex artery and the coronary sinus. Therefore, care should be taken to stay within the annular tissue and avoid entering the muscle.
13. Calcification in the posterior mitral annulus can be a significant issue in some patients. Solutions to this problem are discussed in the section on complications.
14. After completion of replacement, the movements of the prosthetic valve should be checked, particularly to ensure that no tissue is trapped, if leaflet preservation was performed.
15. Leaflet preservation is a technique that requires experience and should not be preferred in initial cases.
16. During the placement of bioprosthetic valve horns, being slow and cautious, passing through the anterior annulus first, and then passing the single horn through the posterior annulus with a wrist movement can facilitate the process.
17. It is recommended to take measurements after placing the sutures. The ideal measurement is one that passes easily through the annulus but leaves no gaps around it.
18. While not as common as with the aortic valve, mismatch between the prosthetic valve and the patient should be watched for in mitral valve surgery, and a prosthesis suitable for the patient's body surface area should be selected.
19. In advanced diseases, very large annuli due to dilated ventricles can pose challenges in selecting the appropriate valve. Larger valve rings may be a good option for these patients.
20. In cases where aortic valve replacement will be performed as an adjunct procedure, selecting a slightly smaller mitral prosthesis can be advantageous for the aortic valve.

TROUBLESHOOTING

Although mitral valve replacement is a common procedure, rare but potentially fatal intraoperative complications can occur. These complications are often related to the individual characteristics of the patient and can be summarized as follows:

Mitral annular calcification: In particular, affecting the posterior annulus, but complete circular calcification can also occur. It may extend beyond the annular tissue into the atrium and ventricular tissues. Total calcification involving valve tissue can also occur. In limited calcifications, decalcification (breaking and removal) may be sufficient, but for large and extensive calcifications, resection and repair with a pericardial patch are preferred. During replacement, care should be taken to avoid tearing the annulus toward the ventricular wall by using sutures passing through the pericardial patch.

Excessive leaflet calcification: In cases of annular calcification affecting leaflet integrity, maximum debridement and, if necessary, consideration of supra-annular placement of the valve may be necessary.

Myocardial or AV groove rupture: This is a highly mortal and challenging complication. It is usually observed after the valve is placed and the heart is functioning. In such cases, immediate cardioplegia is administered, and systemic cooling is provided. The replaced valve is removed, and the rupture is attempted to be repaired internally and externally using Teflon strips. Then, a secure area is found, and re-replacement is performed.

Coronary sinus injury: This is rare. It is repaired using pledgeted sutures and, if necessary, tissue glue, and the pericardium is closed. Repair in an arrested heart is very difficult and dangerous. It is recommended to establish arrest and, then, repair.

Circumflex artery injury: If there is bleeding, the bleeding area is closed, and a distal bypass is performed if necessary. If there is no bleeding, it can be managed by performing a distal bypass.

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