MINIMALLY INVASIVE MITRAL SURGERY

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In the mid-1990s, the first minimally invasive mitral valve procedure was described separately by Navia and Cosgrove,[1] followed by Cohn et al.[2] After these descriptions, various methods were developed, including parasternal, hemisternotomy, right mini-thoracotomy, and total endoscopic approaches, which were demonstrated to be suitable alternatives to the traditional full sternotomy approach. Many studies have reported excellent clinical outcomes with low perioperative morbidity and mortality. As a result, minimally invasive mitral valve surgery has been increasingly used as a routine procedure worldwide.

The main advantages of minimally invasive mitral valve surgery are as follows:

- It reduces surgical trauma by minimizing incision size;
- It reduces the need for blood products;
- It reduces postoperative atrial fibrillation;
- It reduces pain;
- It allows for faster mobility and shortens hospital stay;
- It provides better cosmetic outcomes compared to traditional median sternotomy surgery.

However, along with these advantages, there are certain limitations, as well. It is technically more complex and requires a separate learning curve, which is significantly associated with longer cardiopulmonary bypass (CPB) and cross-clamp times.

SETUP FOR VIDEO-ASSISTED SURGERY

Minimally invasive techniques require additional considerations in terms of anesthesia, ventilation, and monitoring.

To access the mitral valve via a right mini-thoracotomy approach, the right lung needs to be collapsed. Various options are available, but double-lumen tubes are usually preferred for single-lung ventilation. Alternatively, an endobronchial blocker can be used to isolate the right lung. Recently, some surgeons have reported using a single-lumen endotracheal tube and collapsing both lungs with CPB to provide an adequate surgical field.

As defibrillator paddles cannot be used through the incision of a right mini-thoracotomy, external defibrillator pads are placed on the patient.

Transesophageal echocardiography (TEE) is necessary in almost all patients before surgery to confirm heart and valve function, as well as to provide specific additional assessment and guidance on access and cannulation techniques for mitral valve in minimally invasive surgery.

Videoendoscopic-assisted techniques can be used to further reduce surgical entry trauma in minimally invasive mitral valve procedures. To use this technique, a video endoscopy unit consisting of a monitor, camera control unit, camera head, cold light source, fiber-optic light cable, telescope, and documentation and archiving section is required.

i. Positioning of the patient (including cannulation)

After anesthesia preparations, the patient is typically positioned in a lateral decubitus position, with the right side of the chest elevated to approximately 30 to 45 degrees while ensuring that the pelvis of the supine patient remains almost flat (Photo 16.1).

Due to the limited surgical field in the right mini-thoracotomy incision, peripheral cannulation is usually performed for CPB. Therefore, cannulation is often applied before making the mini-thoracotomy incision and, then, the incision is made. Various approaches are available for cannulation.

Arterial access is usually obtained through femoral artery cannulation. Alternatively, axillary artery cannulation can be used. In femoral arterial cannulation, there is a concern about retrograde aortic embolization, which can lead to cerebrovascular events. Preoperative vascular assessment is essential for this condition.

For venous drainage, a multi-stage venous cannula can be advanced from the femoral vein to the superior vena cava. In patients with a high body mass index, a single venous cannula may be insufficient for venous drainage; therefore, a second venous cannulation can be performed via the internal jugular vein. The cannula extending from the femoral vein to the superior vena cava passes through the right atrium, and if present during the operation, it may negatively affect the exposure to the mitral valve with left atriotomy, so two different venous cannulas may be preferred. With this approach, the venous cannulas placed from the femoral vein and right internal jugular vein are advanced to where the inferior vena cava and superior vena cava drain into the right atrium, allowing easier exposure during the

Photo 16.1. Determination of patient position and surgical incision area.

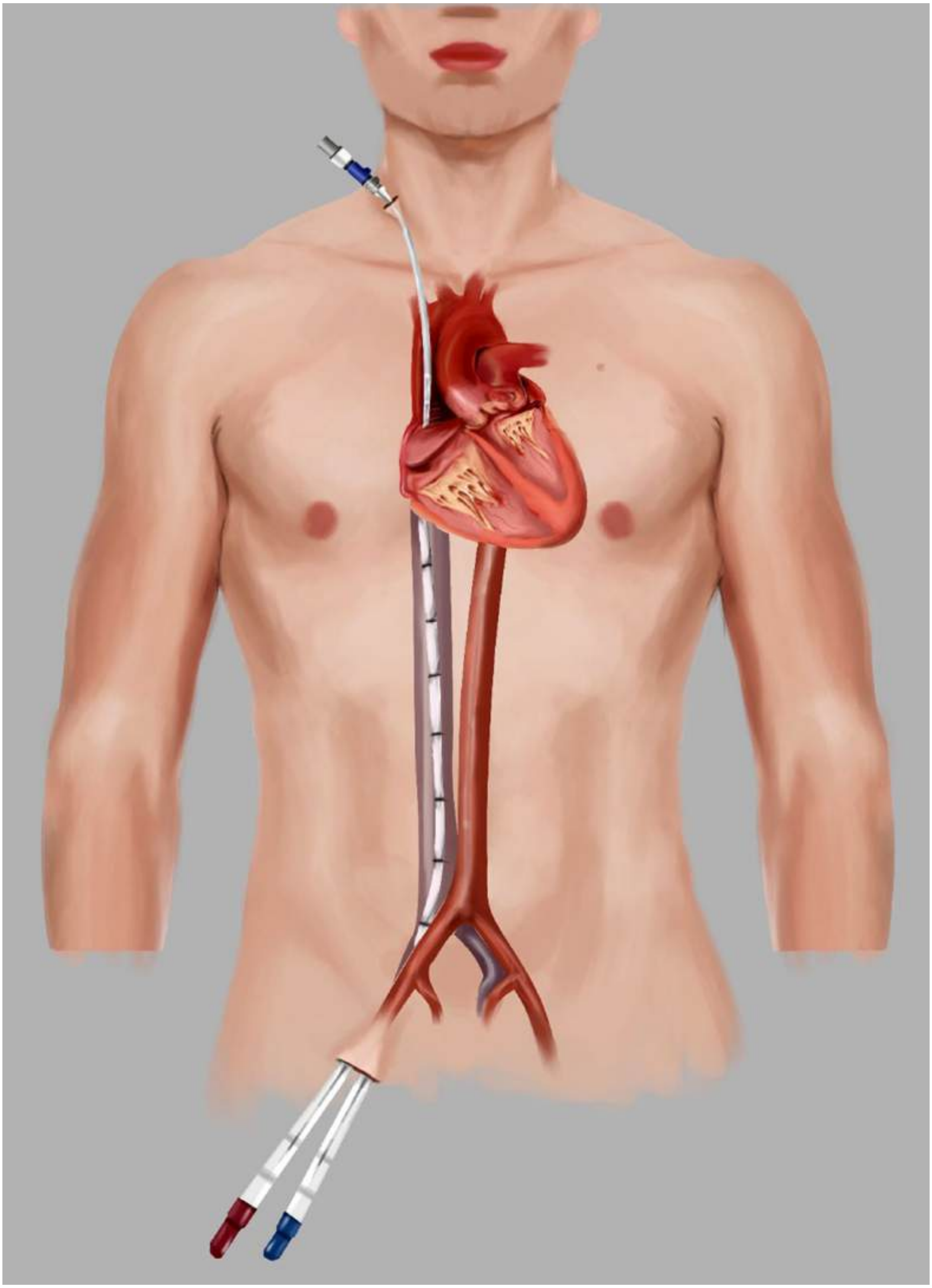

Figure 16.1. Femoral arterial-venous and jugular venous cannulation.

operation as there are no cannulas inside the right atrium. The TEE can be helpful in adjusting the localization of the venous cannulas (Figure 16.1).

Less frequently, some surgeons prefer central cannulation. After making the right mini-thoracotomy and opening the pericardium, the aortic cannula can be placed directly into the aorta through a small incision made over the second intercostal space, and the two-stage venous cannula can be placed directly into the right atrium through an incision made over the fourth intercostal space.

ii. Incision (anatomical landmarks, size of the incision)

Following the use of the right parasternal incision in the initial cases of minimally invasive mitral valve surgery, hemi-sternotomy became a common approach. The first minimally invasive mitral valve surgery via a right mini-thoracotomy was performed by Carpentier et al.[15] in 1996. Subsequently, after the presentation of clinical results of video-assisted mitral valve surgeries using a transthoracic aortic clamp by Chitwood et al.[16] and the reporting of cases of video-assisted minimally invasive mitral valve surgeries with port access technology based on endoaortic balloon clamping by the Leipzig group, relevant technologies such as long shaft surgical instruments, high-resolution endoscopy, and peripheral access CPB systems rapidly developed. Following these developments, right mini-thoracotomy became the most common approach for minimally invasive mitral valve surgery.

In the anterolateral right mini-thoracotomy, access to the thorax is achieved through a 4 to 6 cm incision made from the inframammary fold into the fourth or fifth intercostal space. While a more medial incision may provide proximity to cardiac structures, a more lateral incision may provide better exposure of the mitral valve despite the increased distance. After reaching the pleural cavity, good exposure can be achieved using soft tissue retractors and mini-thoracic spreaders (Photo 16.2).

As a variation of the standard right lateral mini-thoracotomy, an alternative access route can be provided by making a periareolar incision. This approach requires a small convex incision of about 3 cm along the right areolar border.

In addition to mini-thoracotomy incision, for the use of video assistance, a port is placed through

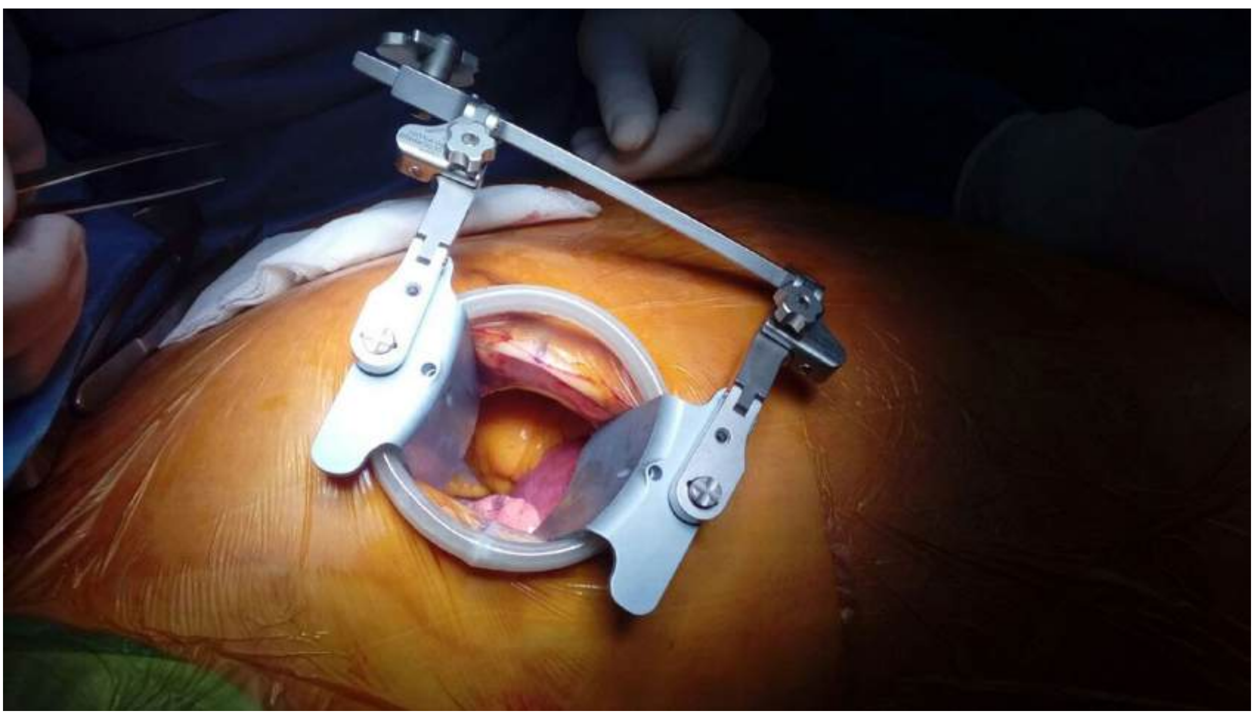

Photo 16.2. Mini-thoracotomy incision.

an approximately 1 cm incision made at the level of the second or third intercostal space on the anterior axillary line, and a camera is inserted through this port.

For the application of transthoracic aortic cross-clamping, an incision of approximately 5 mm is made on the mid-axillary line at the level of the third intercostal space. Through this incision, a Chitwood clamp (Scanlan, Saint Paul, MN, USA) is advanced into the thorax and mediastinum for transthoracic aortic clamping.

In cases where the aortic cross-clamp obstructs the view and movement of the camera, the aortic cross-clamp can be placed through the second intercostal space on the anterior axillary line, and the camera port can be placed through the third or fourth intercostal space on the mid-axillary line. The choice of intervention sites may vary depending on the patient's anatomy and the surgeon's preference (Photo 16.3).

For the placement of an atrial retractor, another 5-mm incision is made parasternally at the level of the fourth or fifth intercostal space, avoiding damage to the right internal thoracic artery.

Finally, a 2 to 3 mm incision can be made at the level of the fifth or sixth intercostal space for the insertion of a left atrial vent.

iii. Instrumentation (Camera, Chitwood, Atrial retractor)

Camera: Following the thoracotomy incision, a high-resolution standard camera is advanced into the chest through a 10-mm port placed at the intercostal space. These cameras come with various scope, tool, and accessory options (two-dimensional, three-dimensional, 00 or 300) and can be selected

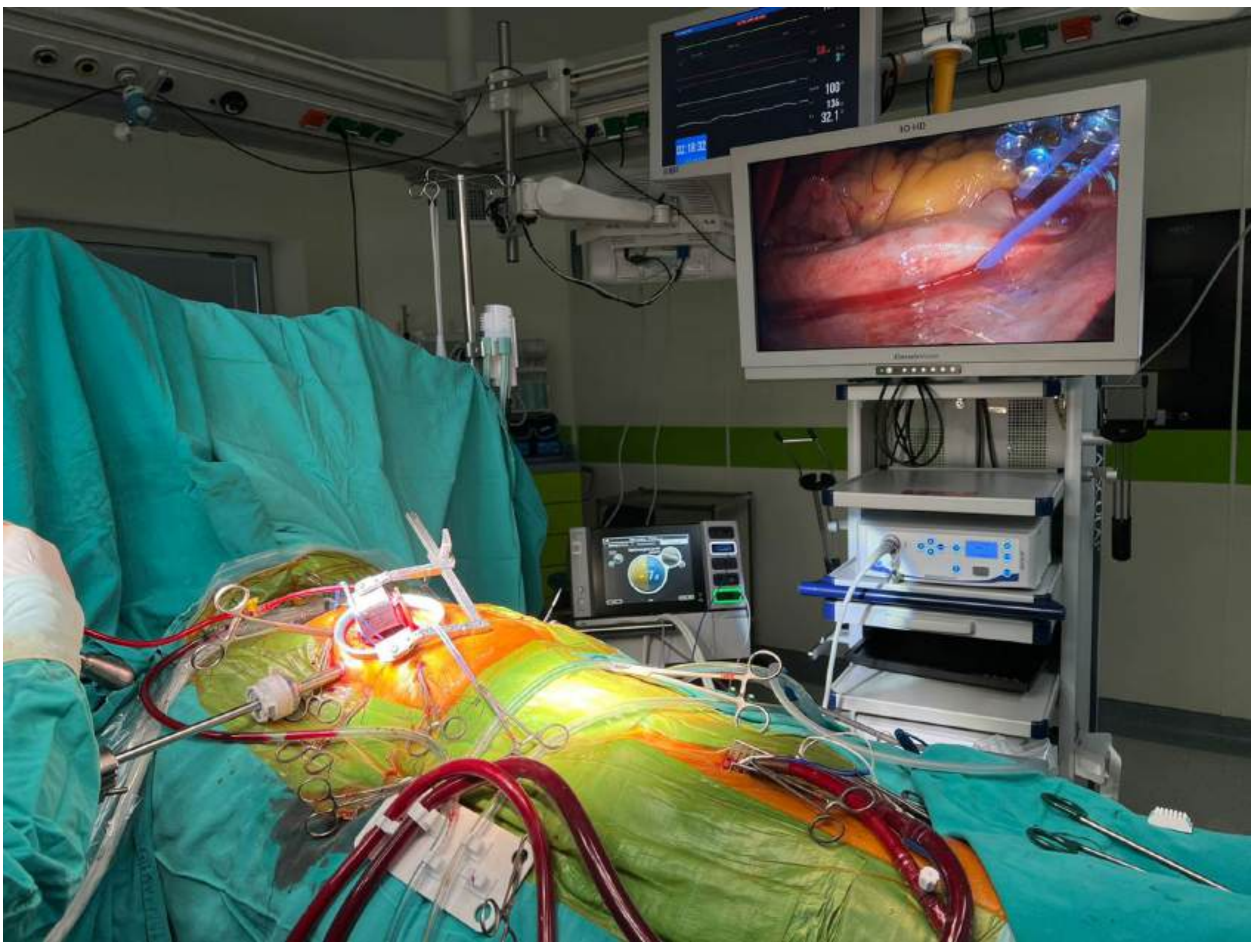

Photo 16.3. Cannulation and cardiopulmonary bypass.

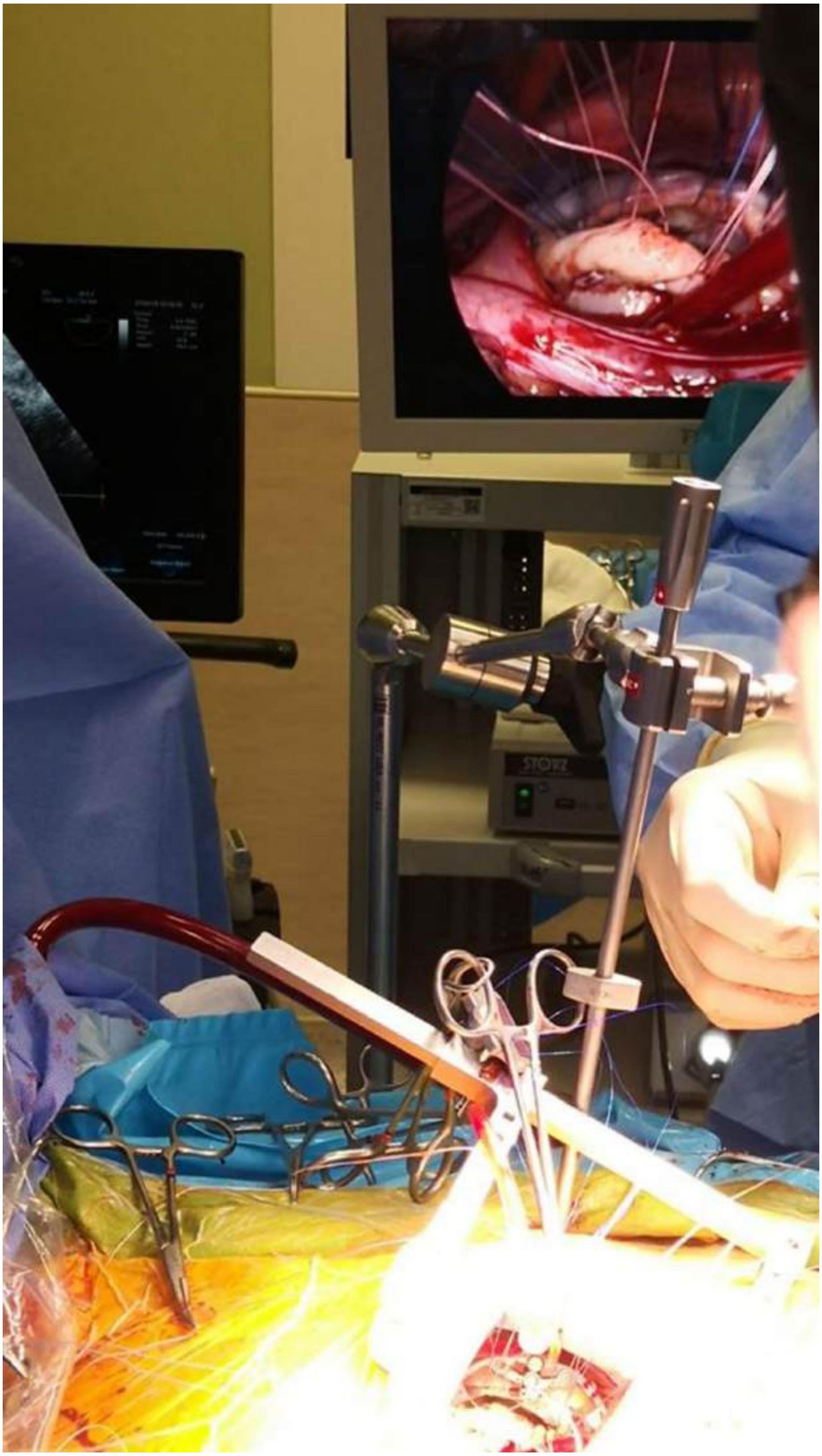

Photo 16.4. Atrial retractor.

according to the surgeon's preference. Video assistance not only provides additional visualization, but also illuminates the surgical field. Throughout the procedure, the surgical field can be filled with carbon dioxide through the camera port to prevent air embolism.

Aortic root cannula: After making the thoracotomy incision, an aortic root cannula is inserted in a way that does not obstruct the surgical field. The root cannula used in minimally invasive cardiac surgery should be different from the one used in standard surgery and should be long and multifunctional.

Transthoracic aortic clamp: The transthoracic Chitwood clamp is placed through a 5-mm incision at the right anterior-mid-axillary line, at the level of the second to third intercostal space, and clamps the emerging aorta. Care should be taken not to damage the pulmonary artery and left atrial appendage during aortic clamping. After clamping, cardioplegia is administered through the long root cannula.

Endoaortic clamp: In some cases, it may be appropriate to use an endoaortic clamp. The endoclamp is a multi-lumen catheter with an inflatable balloon at its distal end that provides endoaortic clamping. With the aortic endoclamp, antegrade cardioplegia can also be administered. A second lumen allows monitoring of aortic root pressure. Localization can be better adjusted using TEE during the placement of the endoclamp. However, it is possible for the endoclamp to move within the aortic lumen during the operation, which may be overlooked during the procedure. To detect this early, preoperative bilateral radial artery monitoring should be performed in patients who will undergo endoclamp placement to monitor pressure tracings.

Atrial retractor: After applying the aortic cross clamp and achieving cardiac arrest by administering cardioplegia, left atriotomy is performed. Then, to ensure mitral valve exposure, an atrial retractor is placed through a 5-mm incision parasternally at the

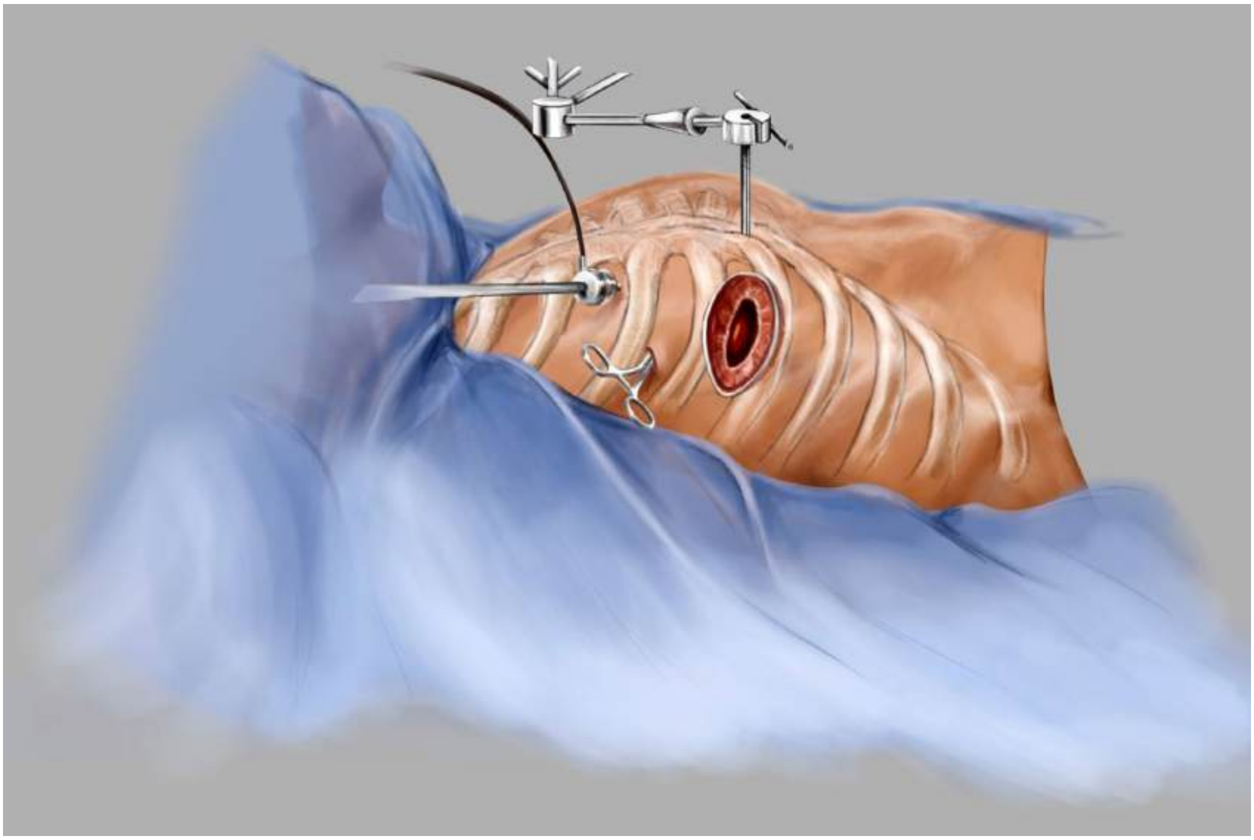

Figure 16.2. Atrial retractor, cross clamp, and camera port.

level of the fourth or fifth intercostal space. Once placed, the atrial retractor is fixed in the appropriate position. The part of the retractor corresponding to the left atrium is adjusted to the most suitable position for facilitating mitral valve intervention. This allows access to the mitral valve (Photo 16.4, Figure 16.2).

iv. Basic tools: Long-shaft instruments, Knot pushers (describing the usage), Cor-Knot® device

In addition to conventional operations, some special tools and equipment are required for minimally invasive cardiac surgery. These special tools and equipment have made minimally invasive surgical procedures more feasible and reliable.

Long-shaft surgical instruments: Due to the length and width of standard surgical instruments, difficulties may arise in accessing the mitral valve and performing necessary movements through the mini-thoracotomy incision. Therefore, thinner and longer shaft instruments have been developed. These special surgical instruments allow easy access to the mitral valve from the mini-thoracotomy incision without obstructing the field of view, and all types of manipulations can be performed (Photo 16.5).

Knot pusher: The mini-thoracotomy incision is too small to manually tie the knots of valve sutures. Therefore, a knot pusher is required to seat the knot, after the knot is tied outside the incision. After preparing the valve suture knot outside the incision, the threads are placed on the notches of the knot pusher, and the tool is pushed to seat the knot. The knot pusher ensures safe seating of the valve sutures and greatly facilitates minimally invasive valve surgery.

Cor-Knot® device (LSI Solutions, NY, USA): Developed to facilitate minimally invasive valve surgery, this device secures valve sutures with a titanium connector while simultaneously cutting excess suture tails, thereby working bidirectionally. This eliminates the need for manual knot tying and knot pusher usage, reducing operation times (Figure 16.3).

Photo 16.5. Long-shafted instruments.

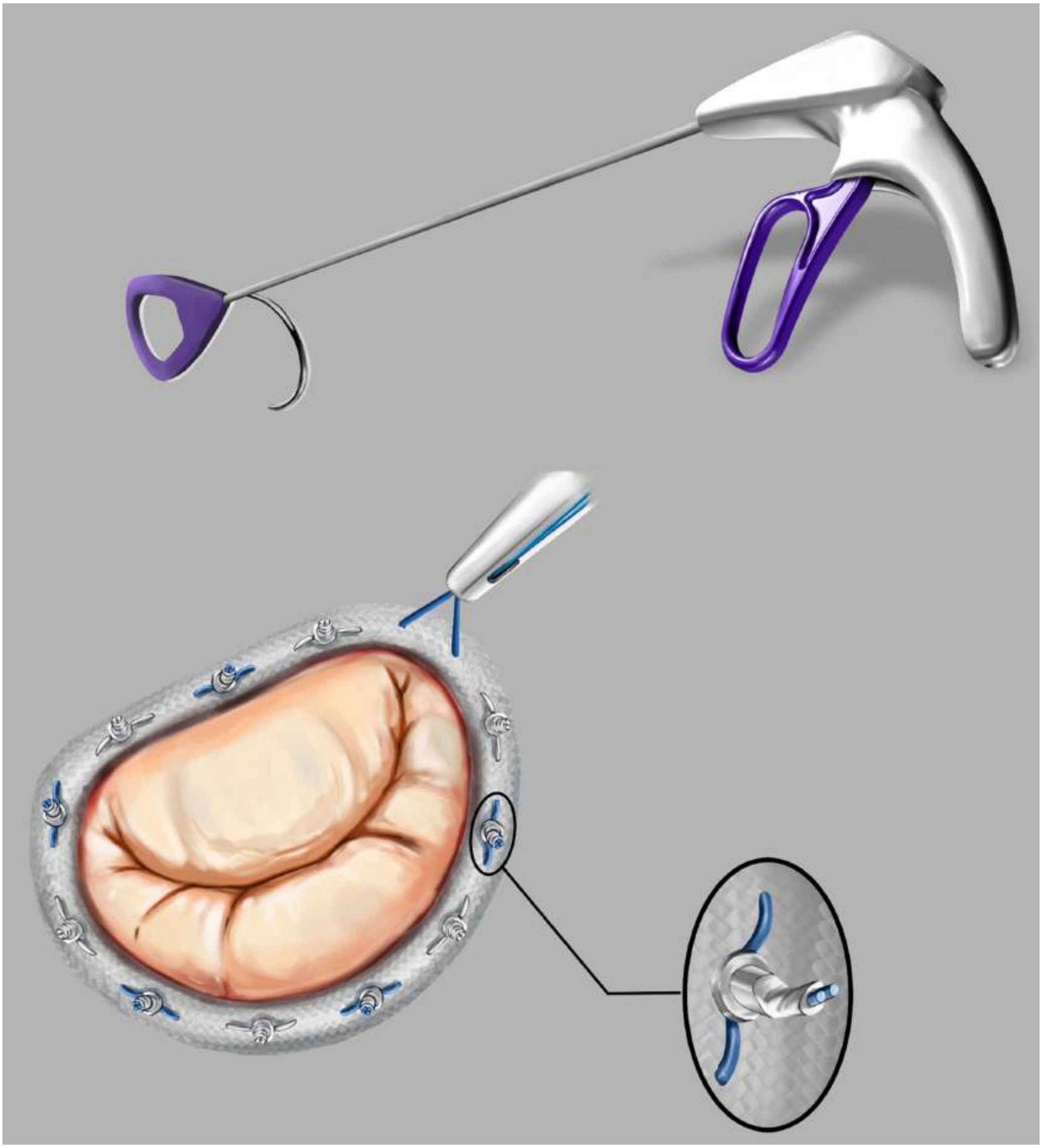

Figure 16.3. Cor-Knot® device (LSI Solutions, NY, USA).

SURGICAL STRATEGY

Unlike standard surgery, performing surgery endoscopically with video assistance and long-shaft instruments lengthens the learning curve. Although challenging at first, opting for the minimally invasive technique in suitable patients is important for patient comfort.

Determining the surgical strategy before the operation increases the success rate of the surgical

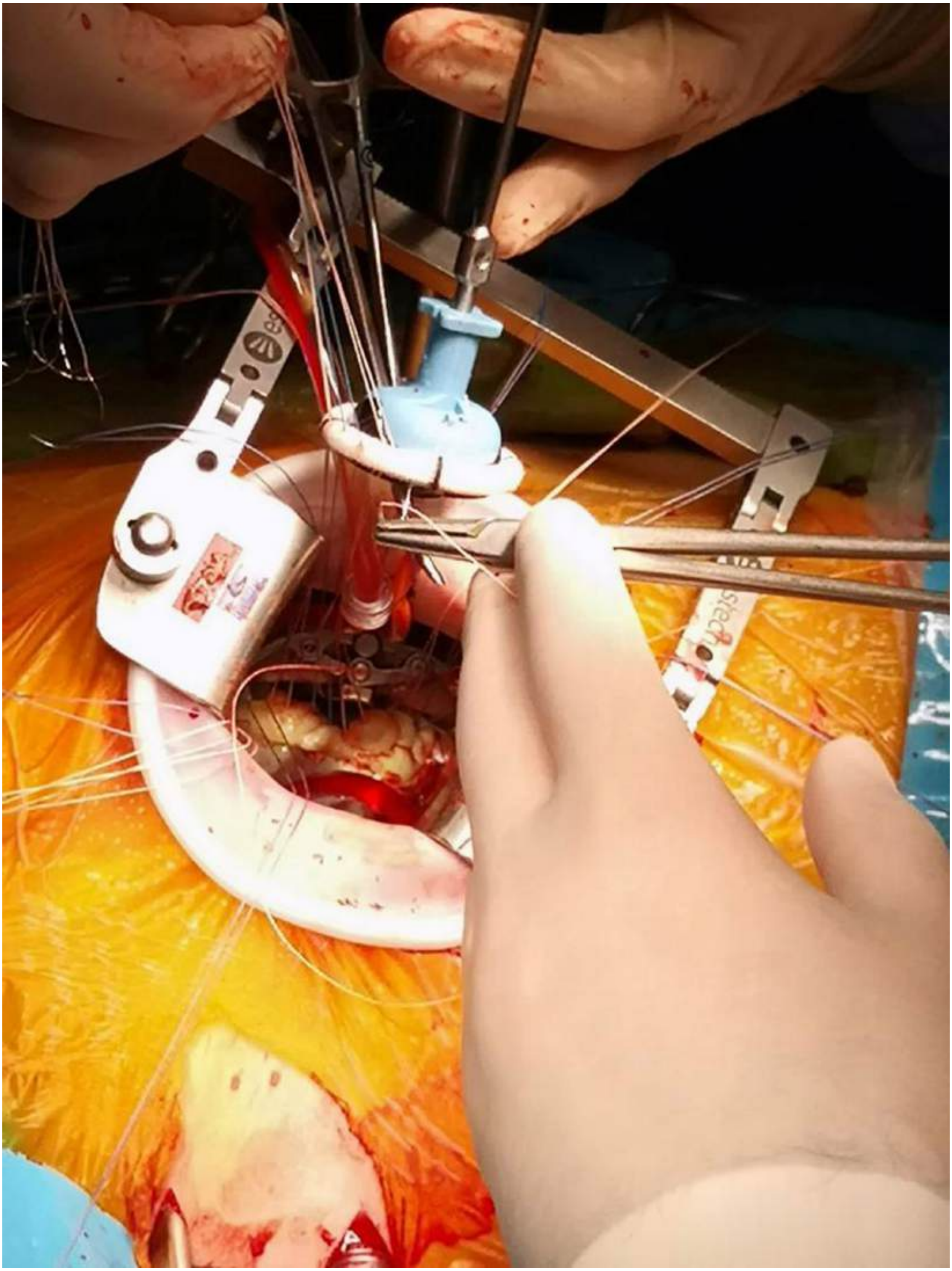

Photo 16.6. Passing of valve sutures.

Photo 16.7. Video-assisted minimally invasive mitral valve replacement.

procedure. Similar to classical surgery, repair or replacement can be performed using existing techniques (Photos 16.6 and 7).

TIPS & PITFALLS

Arterial and venous cannulation:

Choosing appropriate sizes and proper anatomical placement of cannulas is important to prevent possible complications.

Right mini-thoracotomy incision:

While accessing the thorax through the fourth or fifth intercostal space incision and the diaphragm obstructs the surgical field, it is preferable to choose the incision one intercostal space higher to achieve proper exposure.

Placement of ports and aortic cross-clamp:

If the aortic cross-clamp obstructs the camera's view and movement, it can be placed through the second intercostal space on the right anterior axillary line, while the camera port can be placed through the third or fourth intercostal space on the mid-axillary line. The locations of the interventions may vary according to the patient's anatomy and the surgeon's preference.

Care should be taken to avoid damaging the pulmonary artery and left atrial appendage while clamping the aorta. For this, the aorta is elevated upwards to move the pulmonary artery and left atrial appendage away. This ensures safe cross-clamping.

Retraction sutures:

To visualize the left atrium more clearly, retraction sutures can be placed in the right atrium and pericardium. It is of utmost importance to remove these sutures from the skin with a needle to prevent narrowing of the surgical field. Additionally, retraction sutures applied to the outer or inner surface of the left atrium after left atrial incision help achieve a better exposure area.

Placement of atrial retractor:

Using the camera while placing the atrial retractor is important to prevent damage to the right internal thoracic artery.

REFERENCES

1. Navia JL, Cosgrove DM 3rd. Minimally invasive mitral valve operations. Ann Thorac Surg 1996;62:1542-4. doi: 10.1016/0003-4975(96)00779-5.
2. Cohn LH, Adams DH, Couper GS, Bichell DP, Rosborough DM, Sears SP, et al. Minimally invasive cardiac valve surgery improves patient satisfaction while reducing costs of cardiac valve replacement and repair. Ann Surg 1997;226:421-6. doi: 10.1097/00000658-199710000-00003.
3. Gammie JS, Sheng S, Griffith BP, Peterson ED, Rankin JS, O'Brien SM, et al. Trends in mitral valve surgery in the United States: results from the Society of Thoracic Surgeons Adult Cardiac Surgery Database. Ann Thorac Surg 2009;87:1431-7. doi: 10.1016/j.athoracsur.2009.01.064.
4. Algarni KD, Suri RM, Schaff H. Minimally invasive mitral valve surgery: Does it make a difference? Trends Cardiovasc Med 2015;25:456-65. doi: 10.1016/j.tcm.2014.12.007.
5. Dogan S, Aybek T, Risteski PS, Detho F, Rapp A, Wimmer-Greinecker G, et al. Minimally invasive port access versus conventional mitral valve surgery: prospective randomized study. Ann Thorac Surg 2005;79:492-8. doi: 10.1016/j.athoracsur.2004.08.066.
6. Raanani E, Spiegelstein D, Sternik L, Preisman S, Moshkovitz Y, Smolinsky AK, et al. Quality of mitral valve repair: median sternotomy versus port-access approach. J Thorac Cardiovasc Surg 2010;140:86-90. doi: 10.1016/j.jtcvs.2009.09.035.
7. Moscarelli M, Fattouch K, Casula R, Speziale G, Lancellotti P, Athanasiou T. What Is the Role of Minimally Invasive Mitral Valve Surgery in High-Risk Patients? A Meta-Analysis of Observational Studies. Ann Thorac Surg 2016;101:981-9. doi: 10.1016/j.athoracsur.2015.08.050.
8. Van Praet KM, Stamm C, Sündermann SH, Meyer A, Unbehaun A, Montagner M, et al. Minimally Invasive Surgical Mitral Valve Repair: State of the Art Review. Interv Cardiol 2018;13:14-19. doi: 10.15420/icr.2017:30:1.
9. Barac YD, Glower DD. Port-Access Mitral Valve Surgery-An Evolution of Technique. Semin Thorac Cardiovasc Surg 2020;32:829-837. doi: 10.1053/j.semtcvs.2019.09.003.
10. Murzi M, Kallushi E, Tiwari KK, Cerillo AG, Bevilacqua S, Karimov JH, et al. Minimally invasive mitral valve surgery through right thoracotomy in patients with patent coronary artery bypass grafts. Interact Cardiovasc Thorac Surg 2009;9:29-32. doi: 10.1510/icvts.2009.203745.
11. Glauber M, Karimov JH, Farneti PA, Cerillo AG, Santarelli F, Ferrarini M, et al. Minimally invasive mitral valve surgery via right minithoracotomy. Multimed Man Cardiothorac Surg 2009;2009(122):mmcts.2008.003350. doi: 10.1510/mmcts.2008.003350.
12. Abu-Omar Y, Fazmin IT, Ali JM, Pelletier MP. Minimally invasive mitral valve surgery. J Thorac Dis 2021;13:1960-1970. doi: 10.21037/jtd-20-2114.
13. Harky A, Chaplin G, Chan JSK, Eriksen P, MacCarthy-Ofosu B, Theologou T, et al. The Future of Open Heart Surgery in the Era of Robotic and Minimal Surgical Interventions. Heart Lung Circ 2020;29:49-61. doi: 10.1016/j.hlc.2019.05.170.
14. Barac YD, Glower DD. Minimally Invasive Mitral Repair: Direct Aortic Cannulation Via Right 2nd Intercostal Space. Innovations (Phila) 2018;13:315-317. doi: 10.1097/IMI.0000000000000512.
15. Carpentier A, Loulmet D, Carpentier A, Le Bret E, Haugades B, Dassier P, et al. Open heart operation under videosurgery and minithoracotomy. First case (mitral valvuloplasty) operated with success. C R Acad Sci III 1996;319:219-23.

16. Chitwood WR Jr, Wixon CL, Elbeery JR, Moran JF, Chapman WH, Lust RM. Video-assisted minimally invasive mitral valve surgery. J Thorac Cardiovasc Surg 1997;114:773-80. doi: 10.1016/S0022-5223(97)70081-3.
17. Mohr FW, Falk V, Diegeler A, Walther T, van Son JA, Autschbach R. Minimally invasive port-access mitral valve surgery. J Thorac Cardiovasc Surg 1998;115:567-74. doi: 10.1016/S0022-5223(98)70320-4.
18. Chiu KM, Chen RJ. Videoscope-assisted cardiac surgery. J Thorac Dis 2014;6:22-30. doi: 10.3978/j.issn.2072-1439.2014.01.04.
19. Akpınar B. Minimal invaziv mitral kapak cerrahisi. In: Çaynak B, Akpınar B, editörler. Minimal invaziv ve robotik kalp cerrahisi. Bölüm 3. İstanbul: Bayçınar Tıbbi Yayıncılık; 2016. s. 19-29.
20. Kitamura M, Uwabe K, Hirota J, Kawai A, Endo M, Koyanagi H. Minimally invasive cardiac surgery in the adult: surgical instruments, equipment, and techniques. Artif Organs 1998;22:765-8. doi: 10.1046/j.1525-1594.1998.06227.x.
21. Jenkin I, Prachee I, Sokal PA, Harky A. The role of Cor-Knot in the future of cardiac surgery: A systematic review. J Card Surg 2020;35:2987-2994. doi: 10.1111/jocs.14953.