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INDIAN SOCIETY
FOR HEART AND LUNG
TRANSPLANTATION

Intensive Care Management of Post-Transplant Patients

A Guide for Critical Care Specialists

(Heart and Lung Transplant)

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Volume 2

JAYPEE

Contents

VOLUME 2: HEART AND LUNG TRANSPLANT

SECTION 1: Heart Transplant

1. **Introduction to Cardiac Transplantation 1**
   Talha Meeran, Neeraj Kamat, Anvay Mulay

2. **Recipient Selection Criteria in Cardiac Transplant and Preoperative Evaluation of Potential Recipients 10**
   Vijay Shetty, Prajakta Shinde

3. **Organ Procurement and Preservation: The Process of Obtaining Donor Hearts, Including Preservation Techniques to Maintain Organ Viability 21**
   Biswarup Purkayastha

4. **Surgical Techniques in Heart Transplantation 28**
   Pankaj Garg, Mohammad Alomari, Kartik Patel, Si Pham

5. **Immediate Postoperative Care: Initial Hours and Days Following Heart Transplantation, Addressing Monitoring, Stabilization, and Early Complications 39**
   Rohit R Bunage, Gayatri Jain, Chintan Sheth, R Ravi Kumar

6. **Perioperative Ventilatory Management in Heart Transplant Recipients 55**
   Pinank Pandya, Ketan Kargirwar, Darshana Rathod, Anoop Mohandas

7. **Heart Transplant Rejection Recognition and Treatment 65**
   Timothy Sandstrom, Wandy Chan, Kiran Shekar

8. **Infectious Complications Postcardiac Transplant 72**
   Vasant Nagvekar, Parth Shah

9. **Mechanical Circulatory Support Device in Perioperative Heart Transplantation 82**
   Timothy Sandstrom, Kiran Shekar

10. **Analyzing Extracardiac Organ Dysfunction Postcardiac Transplant Patients: How do We Analyze and Manage Complications 91**
    Asir Tamboli, Prashant Sakhavalkar, Prachee Sathe, Pankaj Chendke

11. **Pain Management in Postoperative Heart and Lung Transplant Recipients 98**
    Aklesh Tandekar, Sanghamitra Ghosh, Amit Dikshit, Suvadeep Sen

12. **Role of Extracorporeal Membrane Oxygenation in Heart and Lung Transplant 106**
    Niranjan Panigrahi, Tharra Lakshminarayana

SECTION 2: Lung Transplant

1. **Lung Transplantation in India: Current Perspective and Evolution 113**
Menander M, Mohammed Sameer, Mahesh BN, Sandeep Attawar

2. **Donor Procurement and Preservation in Lung Transplant Setting 122**
Biswarup Purkayastha, Menander M, Mahesh BN, Sandeep Attawar

3. **Patient Selection Criteria in Lung Transplant: Ensuring Optimal Outcomes and Resource Utilization 132**
Owais Tisekar, Arindam Kar, RM PL Ramanathan, Ketan Kargirwar

4. **Surgical Techniques in Lung Transplantation: Challenges and How They Impact Postoperative Transplant Outcomes 141**
Menander M, Biswarup Purkayastha, Mahesh BN, Sandeep Attawar

5. **Hemodynamic Management in Postoperative Lung Transplant Patients 150**
Anoop Mohandas

6. **Ventilatory Support Strategies: Perioperative Lung Transplant Recipients 159**
Ketan Kargirwar, Prabhat Dutta, Mehul Shah

7. **Immediate Postoperative Concerns Following Lung Transplantation 165**
Prasanth Balasubramanian, Pramod K Guru, Maher A Baz

8. **Postoperative Surgical Complications Following Lung Transplantation 172**
Prasanth Balasubramanian, Tathagat Narula, Maher A Baz

9. **Postoperative Nonsurgical Complications After Lung Transplant: Recipient Identification and Critical Care Management 178**
Prabhat Dutta, Menander M, Owais Tisekar, G Akhila Rao

10. **Immunosuppression Strategies in Lung Transplant Recipients 188**
Vijil Rahulan K, Anoop Mohandas, MD Moiz Lalani

11. **Infection in Lung Transplant Setting: Pretransplant Evaluation, Prevention, Early Identification in Post-transplant Period, and Management 198**
Madhumitha R, V Ramasubramanian, Surendran R

12. **Graft Dysfunction in Lung Transplant: Patients Monitoring and Diagnosis 214**
Unmil Shah

13. **Intensive Care Unit Care of Extracorporeal Membrane Oxygenation Patients in Heart and Lung Transplant 222**
Niranjan Panigrahi, Tejasree R

14. **Pulmonary Rehabilitation after Lung Transplant: Strategies for Rehabilitation and Optimising Lung Function after Transplantation 230**
Unmil Shah

15. **Advancements and Future Trends in Lung Transplant Critical Care: Ongoing Research, Technological Advancements, and Potential Future Directions in the Critical Care Management of Lung Transplant Recipients 238**
Rahul Pandit, Bindu Mulakavalupil, Ketan Kargirwar

Index 245

CHAPTER 4

Surgical Techniques in Heart Transplantation

Pankaj Garg, Mohammad Alomari, Kartik Patel, Si Pham

INTRODUCTION

Heart transplantation remains the gold standard treatment for patients with end-stage heart disease (ESHD). The era of human heart transplantation began on December 3, 1967, when Christiaan Barnard performed the first human-to-human heart transplantation at Groote Schuur Hospital in Cape Town, South Africa.[1] This historic procedure was also the first donation-after-circulatory-death (DCD) heart transplant, as the donor's life-sustaining supports were withdrawn in the operating room. This first heart transplant utilized the biatrial technique described by Lower and Shumway.[2] Since this pioneering surgery, many techniques of heart transplantation have been developed and refined.

In this chapter, we will describe various techniques used in heart transplantation for patients with normal cardiac anatomy. Additionally, we will briefly discuss a few modifications adapted for patients with congenital heart disease (CHD).

TECHNIQUES OF ORTHOTOPIC HEART TRANSPLANTATION

Phases of Heart Transplantation

The process of heart transplantation involves mainly four important phases. These are donor heart procurement, cardiectomy of the recipient's heart, donor heart preparation on the back table, and the heart implantation. During the whole process, communication between the recovering and transplanting teams is very crucial for the immaculate execution of the whole process as well as to reduce the donor heart ischemic time and total cardiopulmonary bypass (CPB) time and to prevent unnecessary delays. Further, whenever feasible, the recipient's cardiectomy should be performed once the donor heart is in the operating room, or shortly before that to prevent any unforeseen issues that may occur during the transportation of donor hearts.

In the last six decades, several techniques of heart transplantation have been described. A heart transplant is performed through a median sternotomy. The pericardium is usually opened in a reversed T-shape fashion. After heparinization, CPB is established by cannulating the ascending aorta just proximal to the origin of the brachiocephalic artery. For venous cannulation, the superior vena cava (SVC) is cannulated just below the origin of the innominate vein and the inferior vena cava (IVC) is cannulated at the level of the diaphragm. During the implantation of the heart, carbon dioxide insufflation into the mediastinum is used to reduce the risk of intracardiac air entrapment and cerebral air embolism. Before implantation, the donor heart is placed in a sterile basin of cold saline or cardioplegic solution on the back table and prepared as per the planned technique of transplantation. In the subsequent section, we will discuss various techniques of heart transplantation, including orthotopic and heterotopic heart transplants, their indications, and their pros and cons.

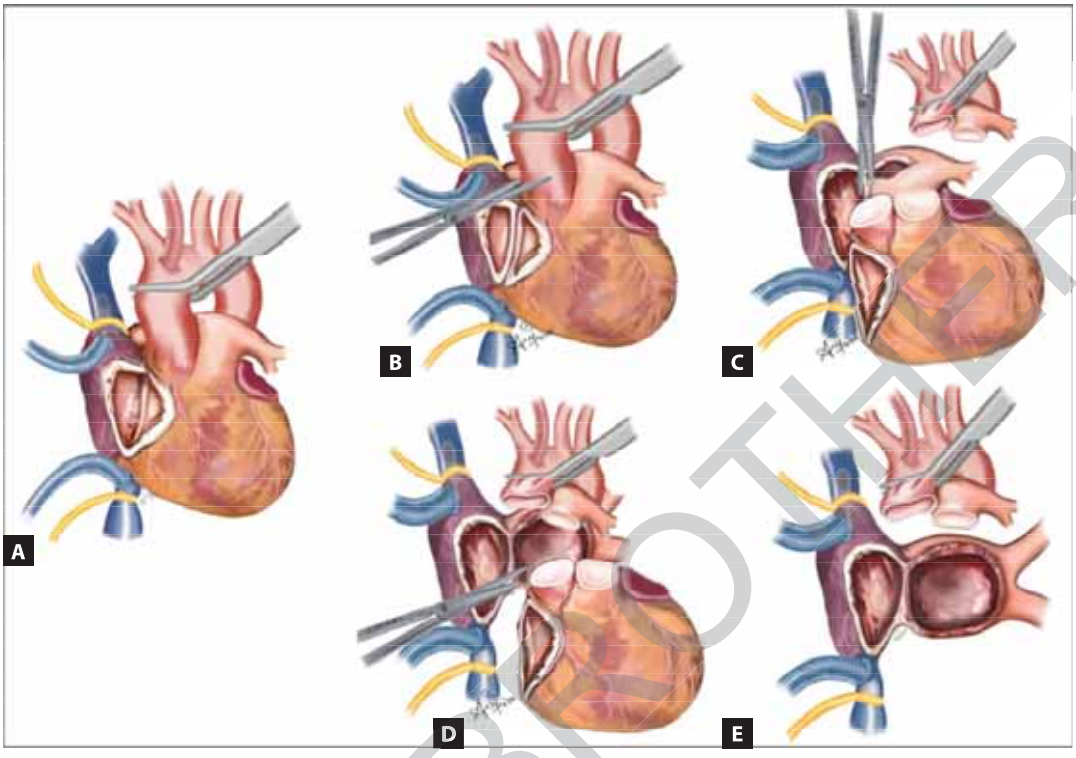
Biatrial Technique of Orthotopic Heart Transplantation

The biatrial technique of orthotopic heart transplant, also called the "Shumway" technique, was used in the first human heart transplant and remained the standard technique of heart transplantation until the 1990s.[2]

Recipient's Cardiectomy

After initiating the CPB, both SVC and IVC are snared using umbilical tapes, and the aorta is cross-clamped. For cardiectomy, the first incision is made in the right atrium near the right atrioventricular groove and extended inferiorly toward the coronary sinus and superiorly toward the roof of the left atrium between the SVC and the root of the aorta **(Fig. 1A)**. Then, the great vessels are transected just above the semilunar valves to create

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Figs. 1A to E: Recipient's cardiectomy. (A) The recipient's cardiectomy is initiated by opening the right atrium along the atrioventricular groove. (B and C) The interatrial septum is open and extends inferiorly to the coronary sinus orifice and superiorly to the roof of the left atrium between the SVC and the root of the aorta. (D) The great vessels are transected above the semilunar commissures. (E) Final picture of the recipient's cardiotomy. (SVC: superior vena cava)

aorta and pulmonary artery cuffs **(Fig. 1B)**. Then, an incision is made in the interatrial septum in the area of the foramen ovale with a #11 blade, and the incision is extended inferiorly toward the coronary sinus orifice and superiorly to the roof of the left atrium to meet the retroauricular (RA) incision. This incision separates the RA cuff **(Figs. 1C and D)**. Finally, cardiectomy is completed by continuing the left atrial incision along the mitral annulus. After the cardiectomy, left and right atrial cuffs are trimmed **(Fig. 1E)**. The left atrial cuff is tailored to remove the left atrial appendage and any excessive tissue. It is important to establish good hemostasis as the cut edges of the left atria tend to bleed, and some of these areas may be difficult to access after implanting the donor heart. To prepare the aortic and pulmonary artery cuffs, the aortopulmonary septum is dissected to have a sufficient sewing margin for a hemostatic anastomosis. During the aortic mobilization, care should be taken to prevent injury to the right pulmonary artery as it crosses behind the aorta. After mobilization, the aortic and pulmonary artery stumps are retracted away from the surgical field using stay sutures to facilitate the exposure of the left atrial cuff for anastomosis. A vent is placed in the left atrial remnant through the right superior pulmonary vein.

Preparation of the Donor Heart

During the back-table preparation of the donor heart, the aorta is separated from the main pulmonary artery using a sharp dissection with scissors. The right and left branch pulmonary arteries are incised to make a common stump of the main pulmonary artery. In the left atrium, all four pulmonary vein orifices are connected, and redundant left atrial tissue is excised, leaving an adequate left atrial cuff for the anastomosis. The interatrial septum should always be inspected for the presence of patent foramen ovale, and if present, it is repaired primarily using 4-0 polypropylene (Prolene) suture. The SVC stump in the donor heart is ligated. An incision is made in the posterior wall of the IVC stump, continuing toward the SVC or toward the right atrial appendage. The incision is directed away from

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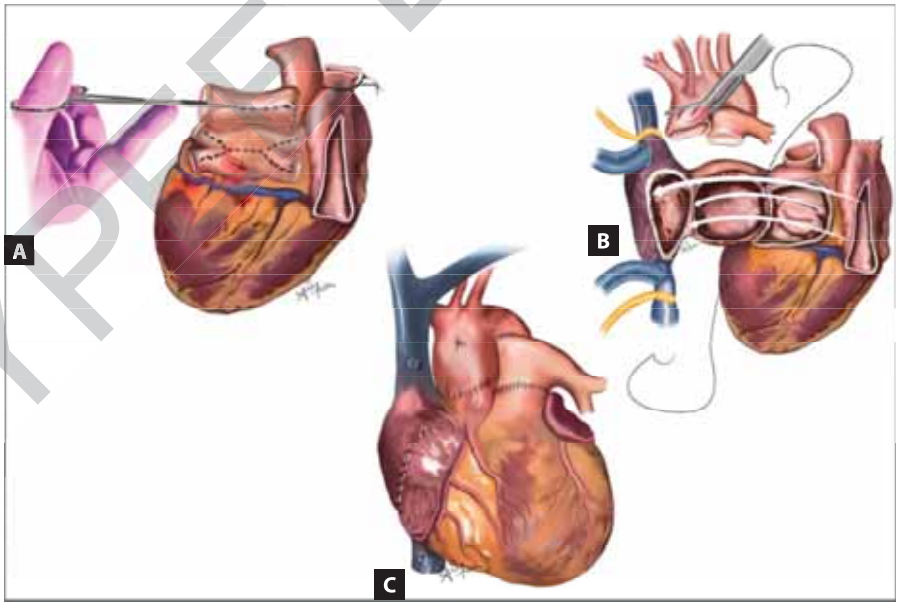
the sinoatrial node to prevent sinus node dysfunction **(Fig. 2A)**. After the preparation, the donor heart is covered in an ice-cold wet laparotomy pad and brought to the surgical field for implantation.

Implantation of the Donor Heart

The donor heart is held outside the recipient's chest cavity on the left side and oriented appropriately with the back of the heart facing up. For the left atrial anastomosis, the first stitch is very important to orient the heart, and it is begun at the inferior margin of the left atrial appendage in the donor heart and the confluence of the left superior and inferior pulmonary veins in the recipient left atrial cuff using a running double-armed 3-0 Prolene suture. After running the suture loosely —two to three times, the heart is parachuted into the chest cavity while tightening the suture. Suturing is then continued in a running fashion posteriorly and medially to the inferior aspect of the interatrial septum. Then the second arm of the Prolene is run along the roof of the left atrium till it meets the other end of the suture. Assessment of size discrepancy between the donor and the recipient left atrial cuff and the plication of excess tissues is necessary to achieve hemostatic anastomosis. For the right atrium, initial anchoring sutures are placed at the superior or inferior aspect of the interatrial septum. The anastomosis is begun in the middle of the posteromedial wall of the right atrium and continued in a running fashion similar to the left atrium so that both suture ends meet in the middle of the anterolateral wall **(Fig. 2B)**. Subsequently, for the pulmonary artery anastomosis, both the donor and the recipient pulmonary arteries are tailored to appropriate lengths to eliminate any redundancy and kinking and anastomosed end to end using 4-0 or 5-0 Prolene suture beginning from the posterior wall and continuing anteriorly. Finally, both the donor and the recipient aorta are tailored to an appropriate length, and end-to-end anastomosis is performed using running 3-0 or 4-0 Prolene suture **(Fig. 2C)**. Some redundancy is desirable in the aorta to prevent the suture-line stress and facilitate visualization of the posterior suture-line for bleeding. Based upon the surgeon's preference, two-layer aortic anastomosis can also be performed with or without bolstering the anastomosis with a strip of the recipient's pericardium for better hemostasis.

Pros and Cons of the Biatrial Technique

The advantage of the biatrial technique is its simplicity and the ease of implantation. Therefore, the heart transplant can be performed relatively quickly, reducing the donor



Figs. 2A to C: Donor heart preparation and implantation of donor heart: (A) The left atrium is tailored to the appropriate size by connecting all the pulmonary vein orifices and trimming the access tissue. The right atrium is opened via a linear incision in the posterior aspect of the IVC toward the SVC stump. (B) Lines of anastomoses for the left and right atria. (C) Final suture line after completion of all anastomoses. (IVC: inferior vena cava; SVC: superior vena cava)

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heart ischemia time. Important drawbacks of the biatrial technique are (1) large size of the common right atrium (combined donor and recipient) and (2) distortion of the right atrial geometry. Both these result in an increased risk of mitral and tricuspid valve insufficiency, rhythm disturbances, tendency of thrombus formation, and septal aneurysm.[3,4] Hence, the biatrial technique has mostly been replaced by the bicaval technique. Still, the biatrial technique remains invaluable in certain clinical situations.

Bicaval Technique of Orthotopic Heart Transplantation

In the early 1990s, Sievers et al.[5] from Germany and the Wythenshawe group[6] from England introduced the bicaval technique of heart transplantation. The bicaval technique is characterized by two separate caval anastomoses instead of right atrial anastomosis. Many studies have reported the superiority of the bicaval technique, and it has become a preferred technique for orthotopic heart transplantation.[7-13]

Recipient's Cardiectomy

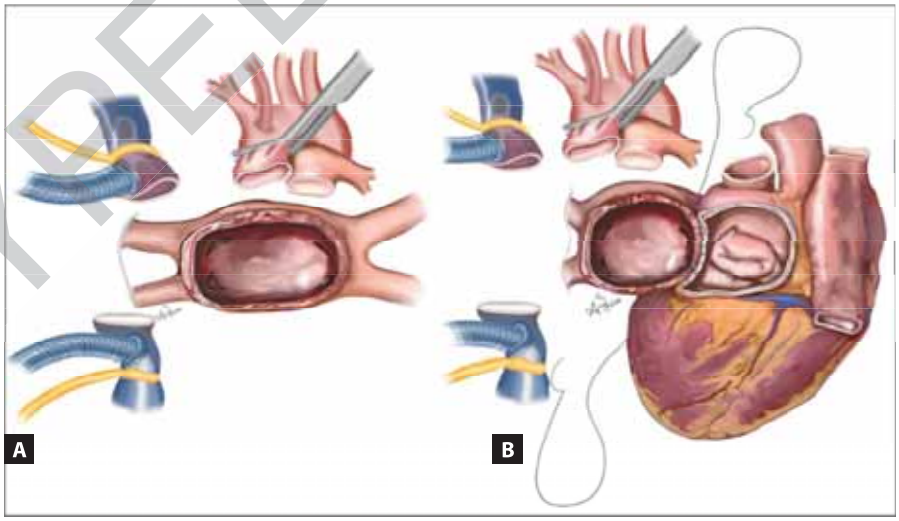
Cannulation for CPB and cardiectomy is performed in a similar manner as for the biatrial technique described above **(Fig. 1A)**. After the cardiectomy, the SVC and IVC are completely disconnected from the right atrial remnant to create separate SVC and IVC stumps **(Fig. 3A)**. It is important to create large SVC and IVC stumps posteriorly while taking care to avoid injury to the right pulmonary artery and pulmonary veins. To reduce the risk of IVC stenosis and right atrial distortion, a large cuff of the recipient's right atrial wall is left anteriorly along with the IVC stump.

Preparation of the Donor Heart

For the biatrial technique, procurement and back-table preparation of the donor heart are similar to the biatrial technique except following differences. (1) A long donor SVC remnant is created by dividing the SVC at its junction with the innominate vein, (2) the donor right atrium is left intact, and (3) the divided ends of the SVC and IVC are left open **(Fig. 3A)**.

Implantation of the Donor Heart

The left atrial anastomosis is completed as described in the biatrial technique. Following the left atrial anastomosis, an end-to-end anastomosis of the donor and recipient IVC stump is performed. Next, the pulmonary artery and aortic anastomosis are performed as described for the biatrial technique. Lastly, donor SVC is tailored as per the recipient's SVC length. Donor SVC is opened posteriorly to widen the anastomosis and prevent stenosis. Donor SVC is anastomosed end-to-end with the recipient SVC **(Fig. 3B)**. To reduce the donor heart ischemia time, aortic anastomosis can be performed immediately after the left atrial anastomosis. The aortic cross-clamp can then be



Figs. 3A and B: Bicaval technique of heart transplantation. (A) Complete excision of the right atrium with complete separation of the SVC and IVC in the recipient heart. (B) Anastomosis of the left atrium in standard fashion. Subsequently, the pulmonary arterial, aortic, IVC, and SVC are anastomosed. (IVC: inferior vena cava; SVC: superior vena cava)

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removed, allowing the donor heart to be reperfused while the remaining anastomoses are completed with the heart beating. To keep the operating field relatively bloodless during the rest of the anastomoses, one flexible sump suction can be placed in the right atrium via the SVC stump and another in the recipient's pulmonary artery stump. If the donor IVC opening is small, an inverted V incision can be made from the IVC stump toward the free wall of the donor right atrium to accommodate the recipient's large IVC.

Pros and Cons of the Bicaval Technique

Adaptation to the bicaval technique has led to improved hemodynamics and a lower incidence of atrial arrhythmias and tricuspid valve insufficiency in the long term. However, the bicaval technique is technically more demanding. Further, orientation of the IVC may be challenging, and the donor heart ischemia time is longer.[7]

Modified Bicaval Technique of Heart Transplantation

The modified bicaval technique was introduced by Kitamura from Japan in 2001. In this technique, both SVC and IVC are left connected posteriorly by a bridge of right atrial tissue between the SVC and IVC.[14]

Recipient's Cardiectomy

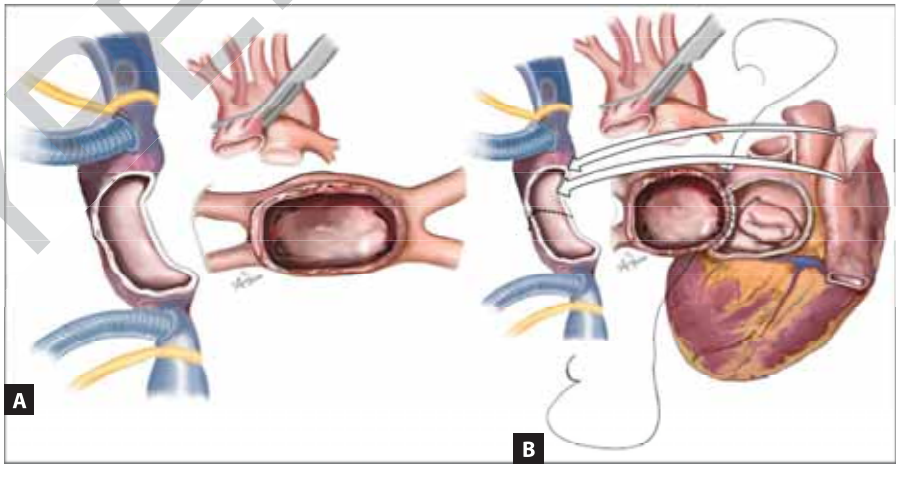
The technique of cardiectomy in modified bicaval is very similar to the biatrial technique, with a few differences. Most of the lateral and anterior walls of the right atrium are resected, leaving the posterior right atrial wall intact that connects the SVC and IVC **(Fig. 4A)**.

Preparation of the Donor Heart

The donor heart preparation is similar to the bicaval technique with a few differences. Approximately 3-cm-long V-shaped incision is made in the posterior aspect of the donor SVC using the azygos vein as a marker **(Fig. 4B)** to widen the anastomosis and reduce the risk of SVC stenosis. This incision also helps to orient the donor SVC (the apex of the V in the donor SVC corresponds to the posterior midline of the recipient SVC).

Implantation of the Donor Heart

Implantation of the heart by modified bicaval technique is like the original bicaval technique except for the few differences **(Fig. 4B)**. One, all Thebesian vein openings in the right atrial wall remnant should be ligated to prevent bleeding. Second, the end-to-end anastomosis of the SVC is performed by incorporating the right atrial remnant into the suture line. SVC anastomosis starts from the caudal part of the V-shaped cut in the donor SVC to the midpoint of the right atrial remnant. It is better to tie the first stitch, then run one arm anteromedially, and the other arm anterolaterally. Sometimes, it is easier to perform the IVC anastomosis as in the original bicaval technique (**Fig. 4B**, dotted line). As with the bicaval technique, IVC, pulmonary artery, and SVC anastomoses can be performed with either an aortic cross-clamp on or the aortic cross-clamp off.



Figs. 4A and B: Modified bicaval technique. (A) Partial excision of the right atrium, leaving the posterior wall intact, which connects the SVC and IVC. (B) Anastomosis of the left atrium in standard fashion with a V-shaped slit in the SVC and IVC for anastomosis to prevent stenosis. (IVC: inferior vena cava; SVC: superior vena cava)

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Pros and Cons of the Modified Bicaval Technique

The modified bicaval technique has several advantages over the standard bicaval and biatrial techniques.

- This technique prevents the retraction of the recipient caval stumps, making the caval anastomoses easier.
- Anatomical orientation of the recipient's IVC may be lost in the presence of caval snares, resulting in twisted or kinked IVC anastomosis. The modified bicaval technique helps in maintaining the orientation of the IVC stump.
- When the donor heart is significantly smaller than the recipient's heart, caval anastomosis may become stenotic due to insufficient donor-recipient intercaval length, causing excessive tension on the suture line. This technique provides the leverage to adjust the sites of caval anastomoses. Studies have shown that the modified bicaval technique results in reduced incidence of caval anastomotic stricture in the long term.[14-16]

The main disadvantage of this technique is that the IVC anastomosis, especially the posterior wall, may be challenging due to the inadequate exposure of the IVC since the IVC cannula is usually on the way.

Total Orthotopic Heart Transplantation

Yacoub et al.[17-19] proposed the technique of total heart transplantation by modifying the bicaval technique. In this technique, the right and left atria are excised completely, and the left and right pulmonary vein cuffs are anastomosed separately to the ipsilateral openings in the donor heart's left atrium. Then, separate IVC and SVC anastomoses are performed as in the bicaval technique. The rationale for this technique is to prevent nonphysiological geometry of the transplanted heart, which is responsible for the increased incidence of tricuspid and mitral valve insufficiency, atrial arrhythmias, thrombus formation, and septal aneurysm.[20]

Recipient's Cardiectomy

The recipient's cardiectomy technique is like the bicaval technique except that after creating the left atrial cuff, the left and right pulmonary veins are separated by dividing and removing most of the back wall of the left atrium. This creates separate right and left pulmonary vein cuffs containing ipsilateral superior and inferior pulmonary veins **(Fig. 5A)**.

Preparation of the Donor Heart

The donor heart procurement and back-table preparation are similar to the bicaval technique except that during the heart retrieval, all donor pulmonary veins are cut close to the pericardial reflection, and the entire donor left atrium is kept intact. A bridge of tissue between the ipsilateral superior and inferior pulmonary veins is divided to create a common orifice on either side, while the posterior wall of the left atrium is left intact. At the end of donor heart preparation, the left atrium should have two oval-shaped openings on each side **(Fig. 5B)**.

Implantation of the Donor Heart

Total heart transplant is technically more demanding than the standard bicaval technique. This technique involves a total of six anastomoses, including two left atrial anastomoses. The procedure starts by anastomosing the recipient's left pulmonary vein cuff to the corresponding orifice on the donor's left atrium. Next, the right pulmonary vein cuff is anastomosed to the corresponding orifice on the donor's left atrium. For ether anastomosis, the suture line starts posteriorly and then continues anteriorly. After finishing this step, the rest of the procedure is similar to that described for the bicaval technique **(Fig. 5B)**.

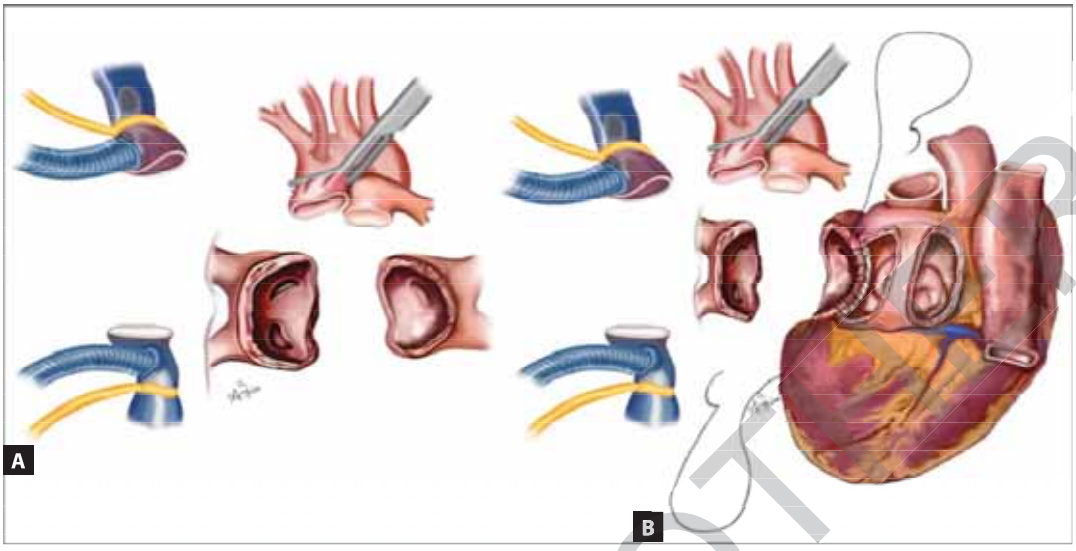
Pros and Cons of Total Heart Transplantation Technique

Total heart transplantation is the most anatomical technique of orthotopic heart transplant. It reduces the chances of mitral and tricuspid annular distortion, atrial arrhythmias, and thrombus formation. Important drawbacks of this technique are prolonged donor heart ischemia time and the potential for pulmonary venous anastomoses stenosis. Further, bleeding from the back wall of the left atrium is more difficult to control. Apart from being more challenging, there is no convincing evidence of the physiological or clinical advantage of this technique over the bicaval technique. Furthermore, since most heart donors often donate one or both lungs to different recipients; preservation of an intact left atrium becomes impossible. Therefore, this technique never gained wide acceptance.

TECHNIQUE OF HETEROTOPIC HEART TRANSPLANTATION

In 1974, Barnard and colleagues introduced the technique of heterotopic heart transplantation[21] for patients

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Figs. 5A and B: Total orthotopic heart transplantation. (A) Excision of left atrial tissue between the right and left pulmonary veins, creating two left atrial cuffs. (B) Anastomosis of both atrial cuffs separately.

with ESHD and severe pulmonary hypertension (PH). Heterotopic heart transplant is rarely performed currently, but the technique still remains useful in patients with irreversible PH or significant donor-recipient heart size mismatch.[22] The technique may also be used as a bridge to recovery, similar to a left ventricular assist device (LVAD) in patients with cardiogenic shock. An important advantage of heterotopic heart transplant is the maintenance of the circulation by the native heart in the event of the rejection of the transplanted heart. This was an important consideration in the early days of heart transplants when acute cellular rejection was common. If the heterotopic heart transplant was performed for patients with severe PH, the recipient's hearts could be removed at a later time after the resolution of PH.[23]

Preparation of the Donor Heart

During back table preparation, the IVC and both right pulmonary veins are oversewn with continuous 5-0 Prolene sutures, taking care to avoid occluding the coronary sinus orifice. Subsequently, the tissue bridge connecting the left superior and inferior pulmonary veins is divided and excised to create a 3.5–4 cm orifice. The midpoint of the posterior wall of this opening is marked with a suture for reference during implantation. The main pulmonary artery is divided at its bifurcation to allow for increased length. A 5 cm longitudinal incision is made to the right of the interatrial septum, beginning at the posterior aspect of the SVC and extending into the right atrium; at least half of this incision should involve the right atrial wall.[24]

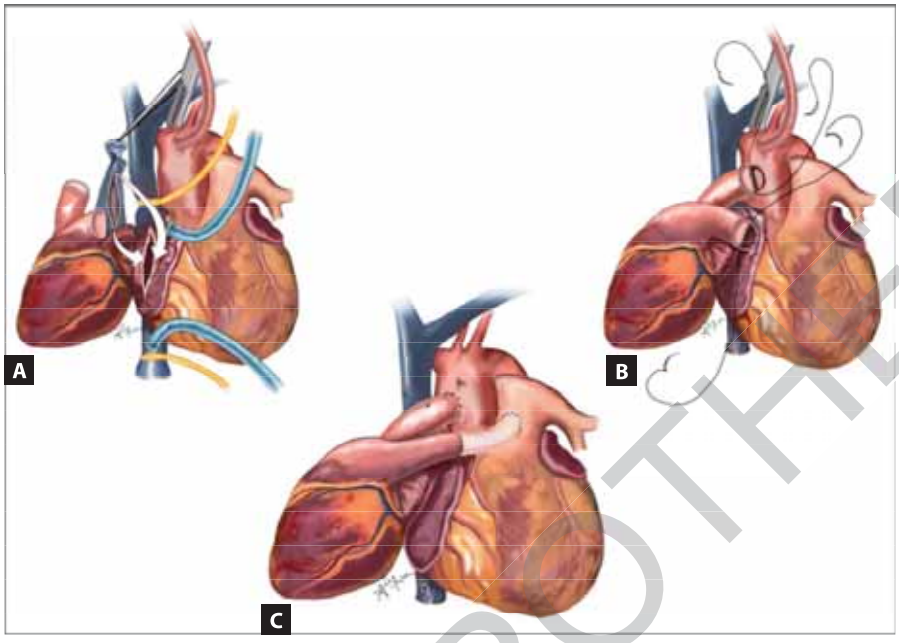
Preparation of the Recipient

The preparation of the recipient for heart transplantation is similar to other transplant techniques, with a few modifications. Following pericardiotomy, a large rectangular section was excised from the right side of the pericardium, creating a pericardial window of sufficient size to accommodate the donor heart within the right pleural cavity. Meticulous hemostasis of the pericardial edges is achieved since the exposure may become challenging after heart transplantation. Particular attention is paid to avoid injury to the right phrenic nerve. Subsequently, CPB is initiated, and the patient is cooled down to 28°C. Following aortic cross-clamping, root cardioplegia is administered to arrest the recipient's heart.

Implantation of the Donor Hearts

The donor heart is positioned carefully within the right thoracic cavity through the pericardial window, mirroring the orientation of the recipient's native heart. A 4–5 cm opening is created in the left atrium along the Waterston's groove. The midpoint of the posterior lip of the recipient's left atrial incision is then sutured to the marked stitch

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Figs. 6A to C: Heterotopic heart transplantation: (A) After finishing the left atrium anastomosis, a longitudinal incision is made on the recipient's right atrium anterior to the interatrial groove, and the incision is extended superiorly into the SVC. The anastomosis between the donor and recipient's right atria is performed in a diamond shape. (B) Left ventricular support configuration. The donor aorta is anastomosed to the recipient by end-to-side anastomosis, and the PA is connected to the right atrium appendage. (C) Biventricular support configuration. The PA is connected, via a Dacron graft, to the recipient's PA. (PA: pulmonary artery; SVC: superior vena cava)

on the donor heart, facilitating the completion of the anastomosis. Meticulous attention is paid to achieve hemostasis as this anastomosis becomes inaccessible at the end of the procedure. Subsequently, a longitudinal incision is made in the lateral aspect of the recipient's SVC, starting 2–3 cm above the SVC and extending almost 3 cm into the right atrium just anterior to the interatrial groove. The midpoint of the posterior lip of the recipient's right atrial incision is sutured to the most caudal point of the incision in the donor's right atrium, followed by a posterior and anterior continuation to form a diamond-shaped anastomosis **(Fig. 6A)**. This configuration allows the widest possible opening without kinking of the right atrial anastomosis. Position of the ligated donor azygos vein remnant anteriorly at the midpoint of the suture line confirms the correct orientation of this anastomosis. Although the right atrial anastomosis can be performed with the recipient's heart beating, it is technically easier to perform the anastomosis on the arrested heart.[25]

Next, the donor aorta is tailored to an appropriate length and anastomosed to the recipient's aorta in an end-to-side fashion. Donor aortic length should be kept to a minimum to prevent the donor heart from dropping into the right pleural cavity and causing compression atelectasis of the right lung. When the heterotopic heart transplant is performed solely for left ventricular support, the donor pulmonary artery is connected to the right atrial appendage **(Fig. 6B)**. In patients who need biventricular support, the donor pulmonary artery is extended using a suitable conduit (typically a 22 mm Dacron graft) and anastomosed end-to-side with the recipient's main pulmonary trunk **(Fig. 6C)**.[26]

BEATING-HEART TRANSPLANTATION

In 2022, Yin et al. from China reported the first total beating heart transplant from a brain-dead donor. For the procurement, the ascending aorta, right atrium, and left ventricular apex were cannulated, and perfusion was initiated with a heart-lung machine. Then the ascending aorta was cross-clamped, and the heart was procured. The heart was assessed for adequacy for transplantation during ex-situ perfusion. Then, the beating heart still connected to the ex situ heart-lung machine was brought to the operating table and transplanted by bicaval technique.[27] Krishnan et al., from Stanford University, USA, in 2023 also published a report in which a DCD

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donor heart reanimated on the TransMedics (Andover, MA, USA) Organ Care System (OCS) was transplanted with the heart beating during the transplantation. Before transplantation, while the heart was still being perfused ex vivo on the OCS, a cardioplegia catheter was inserted into the donor ascending aorta and connected to the recipient's CPB circuit. The donor ascending aorta distal to the cardioplegia catheter was cross-clamped, and perfusion with the recipient's blood from the CPB circuit was initiated with simultaneous discontinuation of the OCS perfusion. The donor heart was then disconnected from the OCS and brought to the operating field, and standard implantation by bicaval technique was performed while the heart was perfused and beating, starting with the left atrial followed by aortic anastomosis. After the aortic anastomosis was complete, both donor and recipient aortic cross-clamps were removed, and the remaining anastomoses were completed. The main advantage of this technique is the reduced donor heart ischemia time and reduced risk of ischemic-reperfusion injury.[28] However, this technique is technically and logistically challenging. This is an innovative idea; however, there is no data yet to prove its clinical benefits. This technique, however, may be useful for hearts with prolonged cold static preservation and have long ischemic time due to unexpected events.

POST-HEART IMPLANTATION MANAGEMENT

Rewarming is usually begun during the pulmonary artery anastomosis. At the completion of all the anastomoses, caval tapes are released. Prior to aortic cross-clamp release, lidocaine (100–200 mg intravenously) and the remaining dose of methylprednisone are administered. The cardioplegia catheter is connected to pump suction, left ventricular deairing is performed, and the aortic cross-clamp is released. If required, cardioversion is performed. Ventricular and atrial temporary pacing wires are placed, and pacing is initiated if required. Suture lines are inspected carefully for hemostasis. After reperfusion of the heart (usually 10 minutes for every 1 hour of cold ischemia time) and optimization of the inotropes, the patient is weaned off CPB. After achieving stable hemodynamics, heparin is reversed with protamine, aortic and venous cannulas are removed, and hemostasis is achieved. Finally, appropriate size mediastinal and pleural tubes are inserted, and the sternotomy incision is closed in the standard fashion.

SPECIAL CONSIDERATIONS IN PATIENTS WITH END-STAGE CONGENITAL HEART DISEASES UNDERGOING HEART TRANSPLANTATION

Heart transplantation for CHDs has unique technical challenges. Surgical complexity is further increased in patients with visceral heterotaxy and systemic complications of Fontan physiology.[29,30] Most patients with CHD have previously undergone multiple cardiac repairs or palliations, and failure of palliative surgery remains the main indication for heart transplantation in these patients.

Consideration of Donor Heart Procurement

Oversizing the donor heart >2:1 should be avoided, if possible, especially in patients with scarred mediastinum, with the exception in recipients with PH. Cardiac and vascular tissues that need to be recovered during procurement depend upon the recipient's anatomy, associated anomalies, and prior interventions. In general, it is advised to obtain extravascular tissues with the heart such as the innominate vein with the SVC and branch pulmonary arteries with the main pulmonary artery. The importance of communication between the recovery and transplanting teams cannot be overemphasized.

Consideration of Operative Techniques

Sternotomy and cardiectomy in patients with CHD may be very challenging due to multiple prior sternotomies. In addition, vascular access may also be challenging and may need a cutdown to access the vessels. Extra caution should be taken during sternotomy to avoid massive bleeding and air embolization. Central cannulation, whenever possible, is preferred; however, alternative access such as the groin and subclavian or axillary vessels should always be considered and prepared. In difficult cases, deep hypothermic circulatory arrest may be needed to complete the transplant. If the pericardial space is small, the left side of the pericardium is excised, and the pleural cavity is opened, taking care to avoid injury to the phrenic nerve. Further adaptation during transplant is guided by the complexity of cardiac malformations.[31,32]

These patients are also at an increased risk of bleeding due to the associated liver dysfunction, chronic anticoagulation, dense mediastinal adhesions, multiple sternotomies, collateral vessels, splanchnic venous congestion, prolonged operative and CPB times, cyanosis, and thrombocytopenia.

JAYPEE BROTHERS

PARTIAL HEART TRANSPLANT

In 2024, Turek et al. from the USA reported the first-in-human partial heart transplant. The authors performed a ventricular outflow tract containing aortic and pulmonary valve transplant from a neonatal DCD donor into a neonatal recipient with truncus arteriosus. The rationale behind partial heart transplant is the preservation of native ventricles that obviates the inevitable ventricular dysfunction of the transplanted heart in the long term while the transplanted outflow tracts grow just like the valves in the pediatric heart transplants, obviating the need for repeated conduit replacements.[33]

CONCLUSION

The technique of heart transplantation has significantly advanced from its early experimental stages, which primarily tested vascular anastomosis, to include various sophisticated methods such as biatrial, bicaval, total heart transplant, beating heart transplant, and partial heart transplant techniques. This remarkable progress is the result of the ingenuity and perseverance of numerous professionals across diverse fields, creating a viable therapeutic option for patients with ESHD. These advancements have substantially improved and extended the lives of thousands of patients. The future holds the promise of further enhancements in the quality of life for patients with ESHD. Innovations are anticipated to extend graft longevity through improved graft tolerance, expand the donor pool, and explore the potential of xenografts.

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