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HOW I DO IT
Median Sternotomy for Lung Transplantation: Techniques and Advantages

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ABSTRACT

Lung transplantation is traditionally performed with a clamshell thoracotomy or bilateral anterior thoracotomy incisions. We have performed 121 lung transplants with a median sternotomy incision from 2013-2017. We present our technique for lung transplantation utilizing cardiopulmonary bypass with a median sternotomy, and discuss the potential advantages of this technique.

INTRODUCTION

The most commonly used incisions for lung transplantation are a clamshell thoracotomy or a bilateral anterior thoracotomy, especially as single lung transplants (usually done through a posterolateral thoracotomy) have become infrequent. A median sternotomy is a much less commonly employed incision for lung transplantation. However, there may be significant advantages to a median sternotomy for bilateral lung transplantation over the clamshell approach, including improved wound healing and better postoperative pulmonary function.

In 1990, Pasque et al described their experience with a then-novel method of bilateral lung transplantation utilizing a 'cross-bow' surgical approach consisting of bilateral thoracotomy incisions in the anterior fourth or fifth interspace joined by a transverse sternotomy [Pasque 1990]. Notable advantages of the 'cross-bow' (now better known as the 'clamshell') incision included technical ease as well as excellent access to the pleural space and posterior mediastinum.

Meyers et al, noting a relatively high incidence of sternal wound complications with the clamshell incision, assessed the utility of bilateral anterolateral thoracotomies without sternal division [Meyers 1999]. The authors compared 52 bilateral lung transplantation cases in which the sternum was not initially divided with a historical cohort of 50 patients who underwent full clamshell incisions. Seventeen (34%) of the historical patients who had had clamshell incisions had some type of wound complication related to the sternal closure, while none of the patients in the sternum-sparing group had such complications.

One report compared the clamshell approach to median sternotomy for consecutive double-lung transplants (DLTs) or heart-lung transplants (HLTs) completed over an 8-year period [Macchiarini 1999]. Of 70 transplant procedures (38 DLTs and 32 HLTs), 37 were done via clamshell and 33 were done via median sternotomy. Sternal overriding occurred in 12 (32%) of the clamshell operations but none of the sternotomies. The clamshell approach was also associated with a significantly higher incidence of postoperative chronic pain (27% vs 6%). Furthermore, vital capacity and FEV1 were significantly worse in patients who had undergone a clamshell incision when compared to those who had been operated on with a median sternotomy. There was no significant difference between the two operative techniques in terms of bronchial anastomotic complications or five-year survival.

Another group described their experience with median sternotomy in a series of seven consecutive patients undergoing double lung transplantation with cardiopulmonary bypass (CPB) [Kohno 2012]. Of note: no patient developed wound infection or sternal instability. All except one patient were extubated within two days of surgery and transferred out of the ICU within 10 days. Median total hospital stay in this series was 29 days.

Dark described his group's technique for using a median sternotomy for bilateral lung transplantation that included modifications for improved access to the left side via an intrapericardial approach [Dark 2015]. He cited ease of the initial incision, more secure sternal closure, improved postoperative pain control, and better chest wall function as advantages in patients who had undergone a sternotomy versus those who had undergone a clamshell incision. Dr. Dark's article has an excellent set of illustrations and should be accessed by those contemplating this approach for bilateral lung transplantation.

The current report, based on extensive experience with over 100 double lung transplants, will address the specific techniques for utilizing a median sternotomy for bilateral lung transplantation and will review the potential advantages of using the median sternotomy approach for lung transplantation.

THE PROCEDURE

The recipient is put to sleep after the suitability of the donor lungs has been assured. The patient is positioned supine with the patient's arms at the sides. Prepping and draping is carried

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out in a manner similar to that used for cardiac surgery. Specifically, the groins are kept accessible for cannulation, should that be needed for the operation or for postoperative extracorporeal life support. The patient is intubated with a single lumen endotracheal tube, as a double lumen tube is unnecessary when the case is done with cardiopulmonary bypass.

A median sternotomy is performed, and hemostasis is assured. A pericardial well is created. Heavy sutures that are clipped, rather than tied, to the drapes are used to facilitate entry into the pleural spaces. A line is placed to allow flooding of the field with carbon dioxide to lessen the amount of air entrained in the heart.

Preparation for aortic cannulation is carried out with pursestring sutures in the ascending aorta. The cannulation site does not need to be as distal as might be used in a standard cardiac operation, as cross clamping will not be utilized. A vent in the ascending aorta for de-airing is also placed, though no other vents are used. A right atrial pursestring is placed for a 2 or 3 stage venous cannula, the tip of which will be directed into the inferior vena cava (IVC), and a second pursestring is placed in the superior vena cava (SVC) so that a separate SVC cannula can be inserted. This second cannula will allow nearly complete venous drainage.

Heparin is given and adequate anticoagulation is assured with an activated clotting time (ACT) measurement. When an adequate ACT is achieved (>500 seconds), the cannulas and the aortic vent are inserted, and cardiopulmonary bypass is instituted. The aortic root vent is left on suction throughout the implant procedure.

The right lung is usually removed first, which is facilitated by the lack of ventilation and the diminished perfusion of the lung. The same preparation of the hilum is utilized for both sides. The pleural space is entered, and intrapericardial mobilization of the pulmonary veins is performed in the same manner as would be done in preparation for a Maze procedure performed for atrial fibrillation. Care is taken to minimize dissection around the bronchi to avoid devascularization. The hilar structures are further mobilized once each lung is removed. The pericardium is opened circumferentially around the hilum, with attention to protecting the phrenic nerve on each side. The bronchi are stapled and divided during the pneumonectomies. The pulmonary veins are stapled and divided. The pulmonary arteries are stapled initially with a vascular stapler and are later clamped with an angled DeBakey vascular clamp just prior to sewing each of these anastomoses.

When both lungs have been removed, the donor lungs are prepared for implantation on the back table. The order of implantation is not important, though the right lung is usually implanted first. Iced laparotomy pads are placed behind each lung during the implantation to minimize warm ischemic time, and these pads are removed once both lungs have been implanted.

The anastomoses are carried out in the following order: bronchus, pulmonary artery, and atrial cuff. The bronchial anastomoses are done with absorbable, monofilament suture. These anastomoses, when feasible, are done so that the generally smaller donor bronchus is telescoped into the larger recipient bronchus.

The recipient pulmonary artery cuff is clamped with an angled DeBakey clamp, and the staple line is excised. This anastomosis is performed with the DeBakey clamp in place. The staples are then cut off the pulmonary veins, and the bridge of atrium between the two veins is incised to open the left atrium so that it will match the atrial cuff of the donor lung. With complete emptying of the right side of the heart while on CPB, there is a minimal amount of blood in the left atrium. The exposure of the atrial anastomotic site is excellent when no clamp is in place. The atrial cuffs are much easier to sew together when the atrium is not clamped, as there is an optimal amount of tissue visualized for this suture line. Additionally, the anastomosis is created between two circles, rather than having the recipient side being held in a straight line by a clamp. This technique allows optimal apposition of the endocardium of both atrial cuffs, which is essential to prevent clot formation and to minimize bleeding. The posterior wall of each left atrial anastomosis must be completely hemostatic as it will be inaccessible once the anastomosis is complete.

The pulmonary artery clamp is left in place while the atrial cuff anastomosis is being constructed. The clamps on the pulmonary artery are removed prior to tying down the atrial cuff sutures to allow de-airing and washout of the preservation solution. Then, after de-airing and flushing the right lung, the right pulmonary artery clamp is removed and is left off, since, even with two venous cannulae, there is always some blood flow through the right lung, effectively decreasing ischemic time for that lung, while the left lung is implanted. The right lung is gently ventilated while preparations are made for the second implant. This ventilation is stopped while the second lung is implanted to optimize visualization. The low flow perfusion is allowed to continue during this period, but it is important to reduce the flow of the CPB circuit so as to not over-circulate the single lung, which could induce pulmonary edema. When both lungs have been implanted, the patient is slowly weaned from CPB, to allow a period of controlled reperfusion of both lungs. This period of controlled reperfusion varies depending on the preferences of the implanting surgeon, ranging from 10 to 30 minutes.

The chest is drained with four 19 French Blake drains (Ethicon, Somerville, NJ), with two on each side. These drains are positioned in the upper abdominal area, as they would be for a cardiac case. This avoids placing tubes through intercostal spaces, since tubes passing through intercostal spaces can contribute to postoperative pain. On each side, the tip of one drain is positioned just above the diaphragm, and one is positioned inside the pericardium and led through the pericardial opening to lie in the apex of the respective pleural spaces. The Blake drains are long enough to be placed from the traditional upper abdominal sites used for cardiac surgery and to reach to the apex of the chest cavity or to the lower posterolateral area of the pleural space. Pacing wires are unnecessary and, therefore, are not used.

The patient is then weaned from CPB, utilizing transesophageal echocardiography to aid in de-airing, though the windows for viewing the left ventricle are usually somewhat suboptimal, most likely due to the mobilization of the left atrium. When adequate functioning of both lungs is assured, the sternal incision is closed in the standard manner.

DISCUSSION

This technique has been used successfully in 121 bilateral lung transplants over the past five years. One patient had a non-fatal stroke, and the 30-day mortality was 4%. The intubation times for these patients transplanted with a sternotomy were shorter when compared with those operated on with the clamshell incisions used in an earlier era. The sternotomy patients seemed to have less pain and better pulmonary toilet than the clamshell patients. Since there is less pain and since no epidural anesthesia is used, the patients can be mobilized sooner and urinary retention is uncommon. There have been no sternal wound complications, either early or late in this series.

When using a median sternotomy for bilateral lung transplantation with the aid of cardiopulmonary bypass, there is no need for double lumen endotracheal intubation, which can be a complex and even, occasionally, dangerous procedure. The use of cardiopulmonary bypass is considerably easier with a median sternotomy than with a clamshell incision. A median sternotomy is also a less painful incision and is associated with better healing and a quicker recovery. De-airing is also easier with a median sternotomy than with a clamshell incision. There is less bleeding, and stenosis of the vascular anastomoses may be less common. Controlled reperfusion of the first lung implanted is also possible with this strategy, therefore allowing for a shorter warm ischemic time for the first implanted lung in most cases.

Summary

The use of a median sternotomy for double lung transplantation has a number of advantages over the use of a clamshell incision, while having few, if any, disadvantages.

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