# Cardiothoracic Organ Procurement for Transplantation: How I Teach It

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Teaching cardiothoracic surgical trainees to perform thoracic organ procurement differs quite markedly from the majority of the technically challenging operative procedures that are reviewed in the "How I Teach It" series. The complexity of the procurement procedure is composed entirely of a series of straightforward and standardized surgical maneuvers. Thus, learning thoracic organ procurement is not at all like a valve-sparing root replacement or a complex endocarditis repair. There is not a single surgical maneuver in the entirety of the thoracic organ procurement procedure that cannot be flawlessly performed under the direction of an experienced cardiothoracic surgeon by even the most modest of cardiothoracic surgical trainees.

Space limitations preclude an exhaustive description of every step of the procurement procedure, which we have outlined in detail in a previous publication [1]. Instead, we will confine our remarks to five specific aspects of trainee instruction that can be expected to yield the greatest results: (1) sustaining an atmosphere of communication and flexibility; (2) establishing absolute responsibility for the donor organs; (3) clarifying the rationale for the order of events; (4) teaching donor cuff logic and diplomacy; and (5) changing the culture of thoracic organ procurement. Furthermore, we will confine our remarks to the issues surrounding the combined procedure by which both heart and lungs are procured from the same donor, as the nuances of single thoracic organ procurement are adequately addressed in the combined procedure.

## Preparation

### *Sustaining an Atmosphere of Communication and Flexibility*

On arrival at the procurement location, the cardiothoracic surgical trainee should review all of the pertinent donor and recipient information. That is often the only chance for the trainee to learn to differentiate the attributes that distinguish a good from a marginal thoracic organ donor. The immediate transmission of the updated donor information to the recipient team opens this vital line of communication.

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The need for communication does not end with the trainee's initial assessment of the donor organ. Because of the sensitivity of thoracic organs to ischemia, thoracic organ procurement is all about timing. Coordinating the movements of the procurement and implant teams so that ischemia time is minimized is always a priority. In this regard, the trainee must understand that rarely does everything go as planned in a thoracic transplant, especially regarding the procurement of the donor organ. The ability to accurately gather and communicate changes in donor information, combined with flexibility in altering procurement plans, is often critical to success. Conditions in the donor operating room that affect donor organ viability have the potential to change precipitously during the course of the procurement procedure. Perhaps in no other operative venue is the trainee more strenuously versed in the fundamentals of communication and flexibility than in dealing with the wide variety of adverse conditions that routinely inhabit the organ procurement setting.

Trainees must therefore understand that the donor operating room environment demands an ongoing, real-time assessment of threats to the donor organ. They must maintain a level of vigilance that allows the rapid diagnosis and treatment of the myriad problems that may arise—and then be able to communicate significant changes to the recipient operating room. The trainee must learn that the necessary level of vigilance can only be assured if vital lines of communication are opened by direct action. For example, direct communication with the anesthesia team to establish a range of tolerable hemodynamic and medication levels increases the likelihood of notification if donor values fall outside of these ranges. If a safe atmosphere of open communication has not been fostered by the instructor—both at the donor site and with the recipient implant team—then many trainees will struggle when faced by some of the daunting challenges to donor organ safety that routinely present themselves.

### *Teaching Absolute Responsibility for the Donor Organs*

The first step toward an excellent thoracic transplant recipient outcome is an optimized donor organ. As any experienced thoracic organ transplant surgeon will readily attest, there is nothing more demoralizing than starting a perilous recipient implant procedure with an already-compromised donor organ. Trainees must understand that the responsibility for the donor organ is entirely theirs. The implanting surgeon should not have

to worry about this; they have enough on their minds and deserve to start down this difficult pathway with an excellent thoracic organ as a "given." This responsibility is further emphasized in the setting of marginal donors and high-risk recipients in which case an acceptable patient outcome is not possible without well-executed organ retrieval.

Compounding the trainee's responsibility is that as many as 80% of heart recipients require redo sternotomy, with an increasing number of those patients needing ventricular assist device removal at the time of transplantation [2, 3]. Similarly, a growing percentage of lung transplants are also redo procedures. As soon as recipient surgeons initiate the dangerous reentry into the chest cavity, they must be assured that they are going to have a viable organ for implantation delivered on time. Trainees must understand that once the donor organ has been visualized and the "green light" given to initiate the recipient operation, returning without a viable donor organ is simply not an option. It is the instructor's responsibility to impart to the trainee an attitude of absolute responsibility for the safekeeping of the donor organ.

In practical terms, having this responsibility means that early in the procedure the trainee must prepare the donor for the possibility of an emergency rapid procurement. The accuracy of surgical incisions is too important for the necessary preparation to be left until the last moment, when it must be rapidly performed under less than ideal circumstances with ice slush, blood, and abdominal surgeons obscuring the trainee's view of vital vascular cuffs. The preparatory surgical exposure should be performed, the organ perfusate infusion tubing should be secured in position, and even the cannulation sutures should be in place. Indeed, all of the surgical dissection necessary for a rapid simultaneous procurement of both heart and lungs should be completed—including separating the aorta and superior vena cava from the right pulmonary artery, as well as dissecting out the interatrial groove and trachea. Furthermore, this dissection should routinely include the entire superior vena cava and both innominate veins. Not only is this extra vein occasionally vital in the cardiac recipient implant procedure, but also the dissection of this area by the trainee is of great educational importance. Rarely is the cardiothoracic surgical trainee allowed to dissect this anatomy in its normal, unadulterated state. Vital anatomic relationships are clearly visualized. Combined with the routine full dissection of the entire aortic arch, this portion of the donor procedure greatly expands the trainee's familiarity with important thoracic anatomic relationships.

The procurement team's responsibility further requires that at least one member of the team remain scrubbed at all times. Although catching an extra hour of sleep in the donor hospital doctor's lounge may sound inviting to the exhausted trainee, it most assuredly is not the plan. Trainees are there to return with not only viable but also perfect thoracic organs. Urgent heparin administration and rapid thoracic organ procurement can become necessary. That can occur for any number of reasons, such as unmanageable abdominal bleeding. The heart is too sensitive to ischemic injury to allow a cavalier attitude. It is simply unacceptable to phone the heart recipient team and tell them that a viable organ is no longer available after they have already injured their recipient's ventricular assist device conduits during redo sternotomy.

Indeed, the instructor must be quick to correct the mistaken, and yet pervasive, attitude that procurement procedures carry no risk because the "patient" (donor) is "already dead." The opposite is true. Thoracic organ procurement is one of the few cardiothoracic surgical procedures in which a surgical error can result in more than one death—not just 100% mortality, but as much as 800% mortality. The trainee must be encouraged to do the math in this zero-sum game where potential recipients far exceed the available donor organs. The shortage of donor organs in every transplant subset assures that every time a donor procurement procedure is put at risk by operative errors, potential abdominal and thoracic organ recipients face death as a direct threat.

### *Rationale for the Order of Events*

Although the trainees should be encouraged regarding their ability to complete the procurement procedure, they must also realize that the procurement protocol has been carefully designed over thousands of donor operations to render organs that are optimized for transplantation by the elimination of the technical pathways that lead to surgical error. Specifically, the order of events is designed to accomplish three primary objectives: (1) optimize visualization to eliminate surgical incision errors; (2) prioritize the delivery of protective infusions; and (3) prevent congestive organ distention.

Therefore, there is a reason that occlusion of the superior vena cava, incision of the interatrial groove vent site, and hemitransection of the inferior vena cava initiate the preservation portion of the procedure and precede placement of the aortic cross-clamp. This order allows the precise placement of the left atrial incision in the interatrial groove under direct vision without blood or slush obscuring the surgeon's vision. The surgeon can easily digitally obstruct blood flow from this incision to allow a similarly unobscured incision in the inferior vena cava. Care in making these incisions is vital to optimize the right pulmonary vein cuff and to avoid injury to the right atrial wall, coronary sinus, and inferior vena cava. These incisions should not be performed in a hurried fashion under a pool of blood or slush. Moreover, this order of events allows full decompression of the left ventricle before placement of the aortic cross-clamp, thereby avoiding left ventricular distension.

Avoidance of left ventricular distention is further ensured by left atrial venting through the interatrial groove incision. This vent site is far more effective than the inconsistent venting supplied by transection of the highly variable left atrial appendage. Furthermore, the need for suture closure of the left atrial appendage by the implanting cardiac surgeon is completely eliminated. Any left ventricular distention that does occur during cardioplegia infusion can be efficiently eliminated by

simply advancing the sucker tip temporarily across the mitral valve (just like a traditional left ventricular vent). This interatrial groove incision also guarantees an adequate right pulmonary vein cuff and will later be extended during the division of the left atrium into cardiac and pulmonary cuffs.

The trainee should be cautioned regarding the frantic moves that unfortunately so often accompany the cross-clamp portion of the procurement procedure. Unnecessarily hurried surgical maneuvers at best save only seconds and have the potential to endanger organs. The trainee must learn that "smooth and slow" is efficient and safe. Once again, trainees can only be expected to learn and to do what they observe.

The trainee must also understand that the variable tolerance of ischemia by thoracic organs governs the cross-clamp portion of the procedure. Recognition of the heart's far greater susceptibility to the early moments of ischemia allows the delay of pulmonary perfusate infusion and placement of slush into the pleural spaces. It is only after both heart and lung procurement surgeons are satisfied that the aortic cross-clamp has been appropriately placed, the heart safely vented, and a good cardioplegia perfusion pressure obtained in the ascending aorta that preservation of the donor lungs begins. The pulmonary perfusate can then be initiated after this short delay with no worries whatsoever in regard to lung preservation. Only when both surgeons are assured that both the cardiac and pulmonary infusions are proceeding normally is it then appropriate for the operative field to be obscured by the placement of slush in the thoracic cavity. The seconds that are required to assure optimal perfusate infusion and cardiopulmonary venting fall well within the ischemic time constraints of both organs.

### *Teaching Donor Cuff Logic and Diplomacy*

The trainee must acquire the interpersonal skills required to defuse the potentially challenging situations that arise when several teams are involved in thoracic organ procurement. Because the great majority of these issues arise over vascular cuffs, most can be prevented if the trainee who is doing the heart procurement has learned to be just as excited about getting perfect cuffs for the lung recipient as for the heart recipient—and vice versa. This attitude becomes the obvious and logical thing to do if the trainee understands the straightforward facts surrounding vascular cuff division. Specifically, the cardiac surgeon cares not about the bronchial cuffs, and the pulmonary surgeon is similarly indifferent toward the vena caval and aortic cuffs. The only cuffs shared by both heart and lung implantation procedures are the pulmonary arterial and left atrial cuffs. Experienced transplant surgeons know well that pulmonary artery cuffs for both heart and lung implant procedures should be kept short to prevent kinking. Length is therefore never an issue as long as the main pulmonary artery is divided somewhere near its bifurcation.

In contrast, all are in agreement that the optimization of the left atrial cuffs is vital to both heart and lung recipient implant procedures. A donor heart with only a thin cuff on the left lateral wall of the left atrium can necessitate a suture line that must course dangerously near the coronary sinus and left circumflex coronary artery. In a similar fashion, sewing a pulmonary vein cuff that has been cut back near the bifurcation of the pulmonary veins can result in pulmonary vein orifice narrowing. Both of these scenarios have resulted in unnecessary loss of donor organ and recipient life.

It is, therefore, really only the left atrial cuff that is worth "fighting" over. In this regard, more good news arises from the obvious agreement from both cardiac and pulmonary teams that the posterior wall of the left atrium is given without contention to the pulmonary allograft venous cuffs. Similarly, the sides of the pulmonary vein cuffs should not be a problem, as their presence on the cardiac left atrial cuff offers no advantage to the implanting cardiac surgeon. Therefore, that narrows the focus of the two procurement surgeons to simply assuring that the tops of the pulmonary vein cuffs for the lungs are adequate while assuring a minimum left atrial cuff width of 1.5 cm on the donor heart. That allows procurement instructors to focus their teaching efforts on emphasizing the specific preservation of the anterior portions of the pulmonary vein cuffs.

The problem gets even easier to solve when the anterior margin of the right pulmonary vein cuff is guaranteed by a generous interatrial groove dissection of at least 1.5 cm. There should be no argument from the cardiac procurement surgeon who knows well that there is no problem suturing the right side of the left atrial cuff in the implant procedure. This suture line is adjacent to the septum, and no vital structures are at risk. Because familiarity with the implant procedures is obviously important in the procurement procedure, the instructor may need to supply this perspective until the trainee has gained adequate implant experience.

The anterior portion of the right pulmonary vein cuff is automatically assured as adequate when the left atrial venting incision is made in the previously dissected interatrial groove. This incision can be made 1.5 cm to 2.0 cm from the pulmonary vein bifurcation without adversely affecting the cardiac left atrial cuff. A sucker is placed through this incision into the left atrium to allow complete venting of all pulmonary perfusate. After all infusions are completed and the inferior vena cava divided, the left atrial incision is begun at this vent site. The incision is carried parallel to the inferior vena cava, leaving a centimeter of left atrium attached to the inferior vena cava. The trainee is cautioned against the natural tendency to cut posteriorly. After the incision in the left atrium is carried beneath the inferior vena cava, the apex of the heart is lifted up to allow the trainee to continue the incision across the inferior portion of the left atrium.

In contrast to the right side of the left atrial cuff, the left side, which lies directly next to the coronary sinus and circumflex coronary artery, deserves special attention. As noted, a short left atrial cuff on the left side of the donor heart can be dangerous. The trainee must be instructed regarding reliable and consistent landmarks. Specifically, the focus should be on leaving a minimum of 1.5 cm left

atrial cuff in the area of the coronary sinus and circumflex coronary artery. The incision is aimed at the base of the left atrial appendage where it inserts into the left atrial wall. Use of this landmark is critical because it precisely defines the cuff incision in the narrowest portion of the left atrium. From the base of the appendage, the incision across the top of the left atrial cuff is easily visualized from inside the left atrium. It is vital, once again, to remind the trainee to not direct this incision posteriorly, thereby compromising the left superior pulmonary vein.

In a similar fashion, the trainee can be instructed that there is no reason to contest the inferior vena cava cuff with the liver procurement surgeon. We have yet to encounter an abdominal procurement surgeon who was not satisfied with an inferior vena cava cuff that extends 1 cm above the diaphragm. That also leaves a generous cuff of inferior vena cava for the cardiac implantation. The practice of routinely cutting the inferior vena cava at the diaphragm serves no purpose but to maintain the friction between procurement teams.

## Comment

### *Changing the Culture of Thoracic Organ Procurement*

It is unfortunate that cardiothoracic surgeons have earned an unfavorable reputation from years of overzealous participation in procurement "turf battles." These battles are misguided and unnecessary. The reversal of this reputation will mandate a change in culture. As is true in any learning scenario, actions speak louder than words. Trainees learn by observing. It is pointless to tell them one thing and then do something to the contrary. They will do what we do. If we tell them to treat everyone in the donor operating room with respect and then fail to do that ourselves, our instruction will fall on deaf ears.

If, however, we treat the other surgeons as if we are just as concerned about and responsible for their recipients as they are, our trainees will do the same. If we are precise and directed in actually making sure that every anastomotic cuff is optimal—whether it is going to our recipient or to someone else's—they will do the same. If we treat every donor hospital nurse, anesthesiologist, procurement coordinator, and janitor with the respect they deserve, they will do likewise when it comes time for them to "solo." It is our responsibility to establish a culture of friendliness and cooperation by actually acting friendly and being cooperative.

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