

EDITORIAL

Reoperative Cardiac Surgery – Part II

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INTRODUCTION

Everything should be made as simple as possible, but NOT simpler. —Albert Einstein

The preparation for a reoperative cardiac surgical case was covered in Part I of this two part review [Tribble 2018]. Part II will cover primarily intraoperative strategies and techniques. As noted in Part I, there has been surprisingly little written about the strategies and techniques of reoperative cardiac surgery. Thus, the goal of this two-part review is to collect and collate some of the lessons, abjurations, and tenets related to reoperative cardiac surgery that may be valuable to cardiac surgeons, especially those in training or early in their careers.

Some time-honored admonitions that can apply to all complex operations, often enunciated by “old salts,” bear repeating:

- Everything matters. Nothing is neutral.
- Some say that a “life or death” decision is made, on average, every 10 seconds during cardiac surgery.
- If something can go wrong, presume that it will.
- If it seems absolutely impossible for something to go wrong, it will anyway, at least some of the time.
- When something does go wrong, it generally does so all at once.
- If what you are doing is working, keep on doing it. If it ain’t working, do something else.

MAKING THE NEW INCISION FOR A REOPERATIVE STERNOTOMY

When making the new incision for a repeat sternotomy, one should almost always use a longer incision than was used for the primary operation. The inferior end of the incision, in particular, should be a bit longer than the usual primary incision. Cosmesis is a lower priority than is safety at this point in the patient’s trajectory.

Once the initial incision has been made, it can be helpful to dissect the properitoneal fat off the back of the rectus fascia for a few centimeters on both sides and toward the umbilicus, allowing the fat to drop away from the rectus sheath. This technique is quite useful in primary operations as well. The

dissection will allow the surgeon to place fingers under the abdominal fascia, and can help avoid unintentional entry into the peritoneum. In addition, placement of chest tubes in the appropriate tissue planes will be easier later in the operation if one has spent a minute or two doing the dissection at this particular juncture. Finally, this dissection facilitates the secure closure of the upper abdominal fascia at the completion of the operation.

After the properitoneal fat is dissected from the back of the rectus sheath, two sternal rakes can be placed on the lower edges of the rib cage in the area of the xiphoid. The xiphoid is divided up to the beginning of the sternum, or removed. The Bovie is then used to dissect the retrosternal tissues away from the back of the lower part of the sternum while using a sponge stick and a sucker to help push the cardiac tissues, as well as the pleura and pleural fat, away from the back of the sternum. This allows one to optimize visualization.

THE DISSECTION THAT CAN BE DONE PRIOR TO STARTING THE REDO STERNOTOMY

In virtually all cases, one can clear at least 5 to 10 cm of the tissues underneath the lower portion of the sternum, starting from the area of the xiphoid. Depending on the shape of the sternum and the patient’s body habitus, one may be able to get all the way up to the level of the manubrium under direct vision, especially with good retraction on the lower portion of the sternum. Headlight illumination and loupe magnification are critical for this dissection. A cautery extender is usually necessary. Entering the pleural space on one side or the other (or both) is often helpful in continuing the dissection underneath the sternum. It is not essential to enter either pleural space at this point in a redo operation, but it can be helpful at times.

As an aside, entering the left pleural space when doing a mitral valve operation, especially in the setting of a reoperation, can allow the heart to ‘fall over’ to the left. This can make quite a difference in visualization of the mitral valve. Opening the left pleura should, therefore, be a routine part of a reoperative situation when exposure of the mitral valve will be necessary. This maneuver can be helpful in aortic valve surgery in the setting of prior cardiac surgery as well.

GAINING EVEN MORE EXPOSURE PRIOR TO THE STERNOTOMY

While the lower portion of the sternum can be pulled up with handheld rakes, the Rultract IMA retractor can also be used on

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either side of the rib cage to help lift the anterior chest wall. An extension for this retractor is available, which allows the wire of the retractor to pull straight up in the midline, and prevent pulling to one side. Alternatively, if the Rultract retractor extender is not available, two Rultract retractors can be used to pull up on each side of the lower rib cage. The Rultract can also be hooked on a lower sternal wire to pull on while one is doing the posterior dissection of mediastinal tissues away from the sternum.

The operating table level should be moved to a comfortable operating level, but the entire table should be in somewhat of a Trendelenburg position (head down) at this point in the operation. Dropping the back of the upper part of the table can sometimes provide even more exposure at this point. In some patients, these techniques will allow one to dissect all the way up to the manubrium. However, in other patients, the sternum can be somewhat convex posteriorly, in which case one may be able to get only one-third of the way up to the manubrium. The right ventricle can be dissected at least partially off of the sternum in most patients [Black 2014].

PERFORMING THE STERNOTOMY

The chest x-ray (CXR) should be examined to discern the number of sternal wires present, and the technique of their placement. There are differing opinions about the removal of the sternal wires prior to a redo sternotomy. The wires can be untwisted, and can be left in place to aid in the use of the oscillating saw. While an oscillating saw will not usually cut through a sternal wire, the blade may be dulled quite a bit when encountering one. However, the old wires may help keep the saw from cutting too deeply. Some recommend that the anterior table of the sternum be cut, with the wires in place posteriorly. After this, the sternum can be pulled anteriorly with bone hooks or other retractors to lift it away from the right ventricle and aorta, while the oscillating saw begins to cut the posterior table of the sternum.

Any portion of the sternum which can be completely separated from the mediastinal tissue can be opened using the regular sternal saw. The remaining portion of the sternum overlying the undissected area will need to be opened with an oscillating saw. One needs to have a feel for the use of the oscillating saw: the surgeon must be able to feel the oscillating saw go through the anterior sternal table and, subsequently, the posterior sternal table. The surgeon should consciously avoid pressing the oscillating saw any deeper after the posterior sternal table is divided.

The information obtained from the preoperative computed tomography (CT) scan is critically important at this juncture. For instance, if the aorta is stuck to the back of the sternum, one should consider placing the patient on cardiopulmonary bypass (CPB) (or, at least, partial bypass) by way of remote cannulation techniques prior to opening the upper part of the sternum. If CPB is needed at this point, some cooling should be utilized, so that flows and pressures can be adjusted safely.

A laminectomy spreader can be helpful, once one has used the oscillating saw, to divide the remaining portions of the sternum (Figure 1). In addition, a small, 2-mm diameter, metal-tipped neuro sucker can be useful to aid in



Figure 1. Laminectomy spreader.

visualization. A pediatric sternal retractor can also be used to gain additional exposure. Heavy Mayo scissors can sometimes be used to cut the posterior table of the sternum when the anterior table has been sawed with the oscillating saw and there is bone remaining posteriorly. All of these instruments should be a part of the redo set of instruments pulled for these operations. Gentle dissection under direct vision, centimeter by centimeter, is essential at this stage.

USE OF CARDIOPULMONARY BYPASS TO FACILITATE THE REDO-STERNOTOMY

Some surgeons prefer to go on bypass routinely, prior to opening the sternum in most reoperative cases. However, most try to get as much dissection done as possible prior to going on CPB to aid in obtaining hemostasis. A warning is in order when going on CPB in this setting: be sure that the arterial return (i.e., the flow into the cannulated artery) is unobstructed before draining all the way out into the venous reservoir, in order to be sure that adequate flows can be obtained with the chosen cannulation site. A good strategy to avoid unexpected difficulty with arterial return to the patient is to ensure that the perfusion setup will allow return of blood in the reservoir via the venous cannula in the right atrium (RA), achieved by having a bridge in the circuit that will permit this reversal of flow, if necessary, by rearranging the clamps on the tubing of the system.

There will be at least some redo operations in which the preoperative CT scan and other information will prompt one to go on CPB before opening the sternum, or to go on CPB once the dissection cannot be continued safely (such as when the right ventricle is adherent to the sternum or when an aortic pseudoaneurysm is present). Remote cannulation can be accomplished with axillary, femoral, innominate, or even carotid arterial cannulation. It can also be achieved with femoral, or, rarely, internal jugular venous cannulation.

One can cool to some degree so that lower flows can be used during the final steps of sternal entry, which will allow the heart to be decompressed, and even allow one to be ready to use short periods of circulatory arrest. If necessary, longer periods of circulatory arrest can also be used on occasion, though, of course, a lower core temperature will need to have been reached. One may need to stop the pump for brief periods if worrisome bleeding is encountered, and doing so for short periods (under 5 minutes) at 28 degrees Centigrade

is considered reasonably safe. However, one must consider staying warm if aortic insufficiency is present, so that the heart does not fibrillate from the cold perfusate prior to a time when a left ventricular vent can be placed.

If, for some reason, the right ventricle or the aorta is injured after getting through the posterior table of the sternum, and one needs time to get on bypass or time to cool, the sternal edges can be pulled back together with towel clips. This will usually control most of the bleeding (Blood ejecting up through the narrow space between the newly divided sternal edges can form a thin “fin,” sometimes aptly called “the red tailed shark.” It is most certainly a sight one would rather hear about than see!) [Ellman 2008].

When considering the total CPB time, remember that low flow CPB essentially “shortens” the total CPB time, as does going on and off CPB intermittently (though one must always keep in mind the issue of clot forming in an arterial cannula which has no flow in it for an extended period of time).

One other consideration in setting up for CPB is that one may need bicaval venous cannulation in endocarditis cases, since there may be more extensive infection present than was evident preoperatively (i.e., with unexpected fistulae or involvement of more valves than was expected preoperatively).

THE INITIAL DISSECTION OF THE ANTERIOR MEDIASTINUM AFTER COMPLETING THE STERNOTOMY

Once the anterior and posterior sternal tables are divided, the soft tissues are then dissected away from the sternal edges using electrocautery and scissors, with strong retraction using bone hooks or rakes. Usually, freeing about two to three cm of the mediastinal tissue on either side of the midline is all that is needed to establish enough room to place a sternal retractor. Some advocate using the Rultract IMA retractor to dissect to the left (it can, of course, be used sequentially on both sides). This use of the Rultract IMA retractor is particularly useful to dissect to the left when a ventricular assist device (VAD) is being explanted for a transplant. Often, entry into the pleural spaces is also helpful, as noted earlier.

At this juncture, the surgeon should have a mental image of the anatomy and where the dissection needs to go for a particular operation. This mental picture allows the surgeon to continue the dissection with purpose, proceeding in a similar fashion in just about every case, at least initially.

It is worth noting that one should try to protect the sternum during retraction, since it may be more vulnerable in a reoperative situation than in a primary operation. Sternal retractors with broad blades to distribute the pressure can help. Some surgeons cut chest tubes and place them over the two sides of the divided sternum in an effort to protect it.

FREEDING THE SUPERIOR VENA CAVA AND INNOMINATE VEIN

Finding and following the superior vena cava early during the continued dissection in the mediastinum can

be beneficial. One should stay anterior and medial to the superior vena cava during this initial dissection. This focus is almost always a helpful strategy, as staying medial will keep the dissection away from the right phrenic nerve, and this approach will eventually lead one up to the innominate vein. One should find and free up the innominate vein, at least somewhat anteriorly, early on, before the sternal retractor is opened more than about five cm. The goal of this focus is to avoid tearing the innominate vein in a redo operation. The innominate vein can be tethered to tissue that is adherent to the sternum, or can even be adherent to the sternum itself, particularly on the upper left side.

One should divide any thymic and mediastinal tributaries of the innominate vein as these branches are encountered. Avoiding the innominate vein during redo operations can be a mistake. The innominate vein should nearly always be dealt with directly, as hoping that one will not have a problem with the vein can lead to trouble if one does not free it up appropriately. The innominate vein should also be dissected posteriorly eventually to move it off of the aorta, in order to allow optimal cannulation and clamping of the aorta. Any entry into the innominate vein should be repaired with fine Prolene sutures or a patch. If there is an injury to the innominate vein, the sternal retractor should be closed a bit to take tension off of it as the vein is repaired. The vein can then be freed up more thoroughly, which will allow the sternal retractor to be opened further.

The innominate vein should be dissected up to, and past, the left sternal edge, so that it becomes mobile. The right side of the innominate vein should be dissected all the way to its junction with the superior vena cava. A trick that one can consider in freeing up the innominate vein from the left side of the manubrium is to dissect between the left strap muscles and the sternum at this point in the dissection. This is because no vascular structures are between the strap muscles and the manubrium. This dissection can be helpful not only in freeing up the innominate vein but also in the placement of sternal wires at the end of the case.

The goal of this innominate vein dissection is obviously to avoid tearing it, which can be caused by the opening of the sternal retractor, and which can be a significant problem, especially if pacing wires are present inside it. Moreover, the mobilization of the innominate vein will allow a more complete view of the ascending aorta and transverse arch.

FREEDING UP THE ASCENDING AORTA FOR CANNULATION AND CLAMPING

After completing the diaphragmatic, inferior vena caval, right atrial, aortic, and innominate vein dissections, one should work further on the ascending aorta itself. Again, after the aforementioned areas have been dissected, the sternal retractor can be opened further, and one can easily go on CPB if needed at this point. When dissecting the aorta in a redo operation, a good place to start is on its right side, near the RA. The RA can usually be dissected away from the aorta reasonably easily. Dissecting the right side

of the aorta along the medial side of the superior vena cava and the posterior aspect of the aorta can help to free up the entire right side of the ascending aorta. One should dissect the aorta at least up to the innominate artery.

The aorta should then be dissected anteriorly. Pulling the aorta to the left and dissecting under it will facilitate eventual placement of the cross clamp superior to the right pulmonary artery. Subsequently, one should start dissecting the left side of the aorta along the pulmonary artery. The pulmonary artery can be fairly adherent to the aorta. The goals in the dissection of the aorta should be to establish a cannulation site and a cross-clamp site, to define the origins of any old bypass grafts, and to create an approach to the aorta for aortic valve replacement or aortic root replacement if those procedures are part of the planned operation.

It is important to note that it is not hard to get into the wrong plane (i.e., sub-adventitial) on the aorta in a redo situation. It is critical to avoid getting into the plane below the adventitia, as getting into this inappropriate plane is surprisingly easy to do and must be guarded against. The three clues that this may have happened are that: the dissection suddenly gets ‘too easy,’ the color seen becomes almost white instead of a more red color, and the consistency of the surface is smooth instead of appearing ‘ragged.’

Many surgeons believe that it is advantageous to get an umbilical tape around the aorta to facilitate its complete cross clamping, which can be a challenge in the redo situation. Doing so requires circumferential dissection of the aorta, at least at the site of the anticipated clamping. Having the aorta dissected circumferentially and having a tape around it will not only facilitate complete cross clamping, but will also help avoid sticking one end of an aortic cross clamp into the right pulmonary artery, behind the aorta.

STARTING THE INTRAPERICARDIAL DISSECTION

One will nearly always want to start the intrapericardial dissection wherever the adhesions seem least dense. If one happens to encounter a redo operation with few adhesions, then the place at which one starts does not make much difference. However, if the adhesions are moderate to severe, then starting along the diaphragm (inside the pericardium, of course) and then moving along the right side of the pericardial space (especially the more posterior aspects of the right side, if possible, since the usual sites cannulated on the RA at the prior operation are likely to be more anterior on the right atrium), is usually the optimal way to begin the dissection around the heart. An old adage about such dissections is that one should strive to “dissect the patient away from the heart rather than dissecting the heart away from the patient.”

Dissecting along the diaphragm is usually easier than it is in other areas, as this area usually has less dense adhesions (possibly because both the heart and the diaphragm move, which is thought to diminish adhesion formation). Furthermore, it is worth remembering that one should dissect against the diaphragmatic side as opposed to the inferior

wall of the heart, because that surface is, of course, a relatively safer place for dissection. One can usually dissect down to the inferior vena cava and then begin to establish a dissection plane along the lower lateral border of the RA.

The pericardial interface with the upper border of the RA as it meets the right ventricle is often a problematic site. As noted, sometimes the most helpful way to do this RA dissection is from a more posterior point on the RA, moving gradually to a more anterior point, as the adhesions in this posterior area are almost always less dense. One should assiduously search for the edge of the pericardium. Once identified, it should be grasped with appropriate clamps, such as Kocher clamps or Allis clamps. Doing so provides reliable control of the pericardial edge, and keeps the hands of those assisting from becoming as tired from holding the pericardial edges with forceps. The pericardium can be suspended with sutures, eventually, but one should take care not to rip the pericardium when doing so. Sometimes the best strategy is to place pericardial sutures, but to control them with Kelly clamps rather than tying them to the wound edges early in the dissection, which may prevent tearing through the pericardium.

Repairs of the RA, if needed, can usually be accomplished with small (5-0 or 6-0) monofilament suture. These stitches can be placed as figure of eight stitches, or as small purse strings, while taking care not to put too much tension on the tense, and usually thin, atrial walls. Pledgets can also be very helpful in these repairs. The “Laws of Lilliput” are applicable for any repairs of the structures encountered during this part of the dissection. (Remember that the Lilliputians tied Gulliver to the ground with many small strands of string, a reminder that many small, fine sutures can sometimes be better than a few bites with large needles and heavy suture). Patches of autologous or bovine pericardium can also be used on any vascular or cardiac structure to obtain hemostasis.

An early goal in a redo dissection is to have some RA dissected free if one is still off pump, because doing so enables one to be confident that the RA could be cannulated if necessary. (Note that RA cannulation may sometimes be needed, even when femoral venous access has already been obtained, to achieve optimal venous drainage). If the atrial tissues are particularly thin or delicate, then the use of pledgets in the atrial cannulation purse-string sutures can be helpful.

At least some of the aorta should be dissected free relatively early in the dissection so that it can be cannulated as well, if necessary. As noted earlier, almost every reoperative patient should have a femoral arterial line in place. The necessary dilators and cannulas should be available, so that quick femoral cannulation can be accomplished should it be urgently needed during the initial dissection. Dilators are available in graduated sizes, and can be useful in cannulating both the femoral arteries and the veins. Also worthy of note is that, while the femoral artery can be cannulated percutaneously if necessary, a limited cut-down must be done later to remove that cannula, after the placement of a purse-string around the cannulation site.

Staying in the proper tissue planes is important throughout the dissection. One example of this is the fact that finding the pericardium, and following the pericardial edge and its interface with the cardiac surfaces can be useful. An admonition learned in General Surgery, “The adhesions are generally tougher than the serosa of the bowel wall,” is also true of the epicardium of the heart, “The adhesions are often tougher than the epicardium on the heart.” Thus, one of the principles of dissecting out the heart in a redo is that “all fat stays on the heart” when one is dissecting inside the pericardium.

The posterior portion of the left atrium and left ventricle (LV) can usually be freed with gentle, blind dissection with the surgeon’s right hand. Often, little work has been done in this area in prior operations, so the adhesions are usually not as dense. This posterior dissection is often best done on bypass, when the heart is more decompressed.

DEALING WITH LIVE SAPHENOUS VEIN GRAFTS

In reoperative surgery when patent older saphenous vein grafts are present, much of the LV should be dissected while on bypass after clamping, with retrograde cardioplegia running. The reason for this strategy is that old vein grafts often have atheromatous debris in them, which can embolize during manipulation of the grafts. The proper strategy for dealing with patent older grafts has been called the “no touch technique.” If some dissection of these grafts is necessary, some of this dissection can be accomplished with sharp dissection, sometimes with a scalpel. If the goal of the operation is to re-bypass some previously bypassed vessels, it is “legal” to open the most distal end of the vein graft when ready to perform the distal anastomosis. This is because it is usually a “privileged” area of the graft, and free of disease. Using this technique can help locate the desired coronary artery, which can be challenging in the reoperative situation, especially in the presence of significant adhesions. As noted, retrograde cardioplegia should be used, rather than antegrade cardioplegia, in this circumstance, with the idea that debris might be flushed out of the distal coronary circulation, particularly if the old veins have been divided.

As mentioned, one should consider dividing old vein grafts early in the dissection— but after cross clamping the aorta— to prevent embolization. This division should be done with a knife rather than scissors, to avoid pushing atheromatous debris down the vein, like squeezing toothpaste from a tube. Dividing old vein grafts is best done at a site that seems relatively free of disease, if such a place can be found. Once the divided site has been cleared of debris, if any is present, the divided ends of the graft can be controlled with clips, ties, or sutures.

One common question in reoperative surgery in which there are old saphenous vein grafts is whether ‘old’ grafts should be replaced. Some vein grafts seem to have been ‘privileged’ and not diseased, even after many years. In

fact, one can occasionally (and seemingly paradoxically) find a combination of diseased grafts and pristine ones in the same patient. If, with a combination of preoperative evaluation and intraoperative examination, a graft is found to be completely normal, most surgeons believe it can be left “in service.” Still, others recommend replacing all saphenous vein grafts that have been in place for over seven years, no matter what their condition seems to be.

Finally, the routing of new grafts can be challenging. Consideration can be given to routing new grafts under the inferior vena cava if leading to an inferior coronary branch, or under an internal mammary artery (IMA) pedicle, if that graft is leading to the lateral wall. Having the graft arch over the inferior vena cava or the left IMA (LIMA) pedicle might lead to kinking of the new vein graft, especially near the distal anastomosis.

MANAGING A PATENT LEFT INTERNAL MAMMARY ARTERY DURING REOPERATIVE CARDIAC SURGERY

First of all, it must be recognized that an injury to a patent IMA during reoperative surgery can be quite serious. In a recent report from the Cleveland Clinic, the mortality associated with intraoperative IMA graft injury was 8.6%, and the incidence of perioperative myocardial infarction was nearly 40% when a patent IMA is injured beyond repair [Roselli 2011]. These risks obviously demand one’s full attention when working around a patent IMA graft during reoperative cardiac surgery.

One should strive preoperatively to know where the LIMA is located by studying the old operative notes, the catheterization, the CXR (looking for clips), and CT scans (especially a CT angiography (CTA), if available). The CT scans can be reconstructed to aid in localizing grafts, as well as identifying the location of any calcium in the aorta. One should never forget that the LIMA, if patent, is usually supplying a large and important part of the heart. It is advisable to avoid dissecting too close to a patent LIMA graft whenever possible. IMA injury has been reported to occur in 15% to 20% of reoperations, though the risk is likely less than that in recent years.

If a LIMA is known to be stuck to the sternum, especially near the midline, one can consider opening an interspace (as one might do for a Chamberlain procedure) and dissecting the IMA off the sternum from lateral to medial. This approach can be used from either side, guided by preoperative imaging. It may also be considered to help free the aorta or an aortic graft from the back of the sternum (Figure 2).

One can use a scalpel or scissors to dissect tissue that might be between an IMA and the back of the sternum. Another trick for dealing with an IMA stuck to the back of the sternum is to use an osteotome to cut away a small portion of the posterior table of the sternum, after it has been opened, to avoid trying to dissect the IMA directly off of the sternum.

One tip for the initial dissection during a reoperation

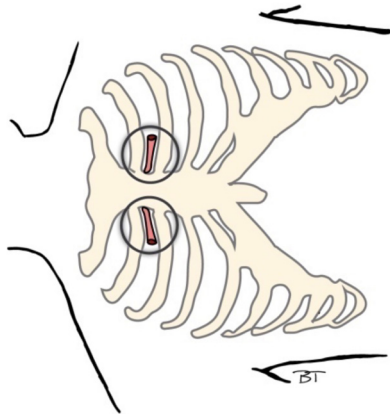


Figure 2. Opening an interspace in order to dissect the internal mammary artery (IMA) off the sternum from lateral to medial.

once inside the chest, to protect an IMA, is to reduce tidal volume on the lungs, as full inflation will push an IMA towards the operative field in many cases. A safe course of action in some cases in which an IMA is near the midline can be to implement CPB early, which will allow complete deflation of the lungs and decompression of the heart, and which may facilitate dissection near the IMA.

Given the overwhelming importance of a patent LIMA to the myocardium dependent on it, one must always be prepared to go on bypass if the IMA is injured during re-entry and dissection. It's important to remember that an empty beating heart uses about 10% of the oxygen used when the heart is full and working. Thus, being on bypass will buy a lot of time to sort out what to do with an injured IMA. As noted earlier, one should remember that one can cycle on and off CPB during difficult reoperations, in an attempt to reduce the total time on bypass. If the IMA is injured, it can often be repaired. However, adequate visualization to do such a repair requires obtaining control, at the very least, of the proximal end of the graft, while recognizing that distal control will also often be needed. One might consider giving a small dose of heparin while clamping the IMA, if not on already on cardiopulmonary bypass.

The best strategy for repair of an injured IMA is to use interrupted sutures of fine suture (7-0 Prolene will usually be optimal), with the stitches placed from the inside out on both ends of the open IMA. It is optimal under these conditions to avoid dividing the IMA any more than is necessary, which will help maintain proper alignment. Again, one should not quickly give up on an injured IMA, as these vessels can be repaired successfully at least some of the time.

If the re-entry has been accomplished without injury to the IMA, the next question in dealing with a patent IMA is what to do with it while doing the planned operation. The answer to this question is fairly straightforward if the IMA is easily visualized. Under these conditions, one knows one can put a bulldog on it whenever one wants. However, more often than not, it is not visible. It is worth remembering that a Doppler probe will not work well, if

at all, if there is no pulsatile flow (as when on full CPB). Thus, if a Doppler is used to localize the IMA, it is best done before bypass is instituted. However, remember that weaning off CPB transiently (while the heart is still beating) will restore pulsatile flow, and this move can allow the Doppler to be more useful.

As noted earlier, some of the final bits of dissection of the LV can be done effectively with gentle hand dissection, especially posteriorly. This dissection will also often help define, at least partially, the pedicle of tissue that contains a LIMA if one is present.

As an aside, it is also important to know not only the status (patency) of the LIMA, but to also know the status of the left subclavian artery (LSA). It is surprisingly common to find that the orifice of the LSA was not examined during the catheterization done prior to a reoperation. If the LSA orifice has not been demonstrated to be free of disease on the preoperative catheterization, one must consider whether a repeat catheterization or a CTA should be done to evaluate it. This consideration is even more compelling if the left arm blood pressure (BP) is lower (by 10 mmHg or more) than the right arm BP. Also, one should consider the possibility that the LIMA, if not used in the first operation, could have been injured during sternal closure, which is occasionally an issue. Most cardiologists will do an LSA injection to insure that the native LIMA has not been injured in the prior operation.

ALTERNATIVES TO STERNOTOMY FOR REOPERATIVE CARDIAC SURGERY

Depending on the objectives of the reoperation, one can consider approaching the heart from either a right or a left anterior thoracotomy to avoid a patent IMA graft. A right thoracotomy may be particularly attractive for operations on the tricuspid or mitral valves, or for placement of a temporary left ventricular assist device (LVAD) in the setting of a patent LIMA graft [Tribble 1995]. Though not as commonly done in recent years, the mitral valve can also be approached through a left lateral thoracotomy (Figure 3). Note that the pulmonary artery can be used for venous drainage in this setting [Cooley 1984]. This technique can drain the right side of the heart surprisingly effectively.

Some idea of the orientation of the mitral valve can be gained from CT scans, as it may face more to the right than to the left, which would make a left thoracotomy approach less attractive. A left thoracotomy can also be used to revascularize the lateral or inferior walls of the heart if vessels in these areas are the primary objective in a redo coronary artery bypass graft (CABG). If a left thoracotomy approach is used for a redo CABG, the descending aorta or the left subclavian artery can be used for the proximal sites for the grafts. Another alternative incision that can be considered is a clamshell incision, such as when performing complex, redo aortic arch surgery, as is advocated for by Kouchoukos et al [Kouchoukos 2008].

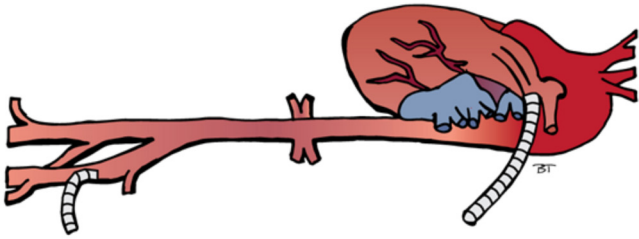


Figure 3. Left thoracotomy for mitral valve surgery.

CARDIAC PROTECTION WHEN AN INTERNAL MAMMARY ARTERY GRAFT IS PATENT

It is clear that, in many cases, the IMA can be left open during aortic cross clamping. (It used to be taught that the IMA had to be controlled to obtain adequate cardiac protection during cross clamping.) Obviously, the myocardium perfused by the IMA will receive adequate blood flow and oxygenation. The question is what to do about the rest of the heart. A combination of antegrade and retrograde cardioplegia will usually provide adequate protection of the rest of the heart, under these conditions. The effectiveness of a retrograde cardioplegia cannula can be enhanced by placing a stitch around the orifice of the coronary sinus inside the RA (if the atrium can be opened, which is always the case when bi-caval cannulation has been employed, and is sometimes even possible when some suction is being used on the venous lines). Alternatively, a stitch can be placed around the coronary sinus from the inferior surface of the heart, near the entrance of the coronary sinus into the RA (A good suture for this purpose is a 2-0 Prolene on an SH needle, and the Prolene can be tightened with a Rummell tourniquet.) [Calcaterra 2007].

Some surgeons favor running retrograde cardioplegia continuously when allowing the IMA to continue to flow into its perfused territory [Smith 2009]. However, if concern remains about adequate delivery of cardioplegia to the rest of the heart not perfused by the IMA, keep in mind that the systemic perfusion temperature can be dropped, which will add to the overall protection of the heart under these conditions. As the systemic temperature is dropped, the flows—and pressures—can be dropped as well. These strategies will both keep the heart cooler and lessen the amount of systemic perfusion of the heart, through a patent IMA or through collaterals. The lower systemic temperature and flow will also lower the amount of bronchial return to the left atrium and lower its temperature as well. Venting strategies, which may help control this bronchial return as well, will be covered elsewhere in this document. Topical cooling with ice or even a cooling jacket can supplement the myocardial protection.

Another setting in which a patent IMA can interfere with carrying out the planned operation is in the setting of an aortic valve replacement (AVR). Blood pouring out of the left main coronary artery (LMCA) can impair visualization

of the aortic annulus. Some have controlled this blood flow by placing some kind of blocker or even a small vent in the LMCA orifice. Similarly, someone can hold a pump sucker in the left coronary sinus while sutures are being placed in the annulus. (One must be very careful not to injure the coronary ostium or the proximal coronary artery when using suckers or blockers in the aortic root.) A CO₂ blower can be helpful in this setting, as well. One can even gently occlude the LMCA with finger pressure on the outside of the aortic root.

However, if these techniques do not allow adequate visualization, the LIMA, even when not directly visualized, can sometimes be clamped by “closing in on” the LIMA by placing a clamp on a fairly large pedicle of tissue on the left side of the field. This can be done by having the left pleura open and placing a large, gently curved aortic clamp (such as a DeBakey aortic clamp or a Stoney hypogastric vascular clamp) on either side of such a clump of tissue, if one has room to do so. This strategy will often provide control of the IMA. When such a clamp is used and the aorta is open (as in an AVR) if excessive bleeding from the LMCA is visible, the clamp should be tightened no more tightly than is necessary to control the IMA.

Other aspects of cardiac protection during both primary and reoperative cardiac surgery will be covered in a separate treatise.

VENTING DURING REOPERATIVE CARDIAC SURGERY

While LV venting is commonly done when operating on the aortic valve, when there is known aortic insufficiency, or when circulatory arrest is planned or contemplated, venting can also be quite useful in other situations as well, especially in the setting of reoperations. For instance, venting is sometimes used in heart transplants (with the vent in the left atrium) to prevent rewarming during the implant and to aid in visualization during the pulmonary artery (PA) anastomosis, especially when the PA anastomosis is done after the aortic anastomosis, which some surgeons prefer to do to reduce ischemic time.

Sites for LV venting include the right superior pulmonary vein (the most common site for an LV vent), the LV apex (used routinely in an earlier era), the left atrial appendage (used in operations on the descending aorta on occasion, though it's tricky to get the vent through the mitral valve, especially when working through the left chest), transeptal (with a relatively small, blunt needle vent) inserted through the right ventricle (done routinely at some centers), and the PA (which will not decompress the LV if there is aortic insufficiency, but will aid in visualization, temperature control, and in enhancing venous return if the right ventricle is distended). One should be aware that a vent in the PA may pull air into the left side of the heart and, thus, should be used only as much as needed. In fact, any part of the heart or the great vessels can be vented. Finally, purse strings can be placed either before or after a vent is placed, since purse strings are for removing the cannulas and are not necessary for placing them.

Again, reasons to consider venting in a reoperation include: decreased bleeding during dissection, better visualization (less bleeding and less distention), less rewarming of the heart, and decreasing the chance of LV injury that can occur as a result of distention.

FINDING SITES FOR NEW VEIN GRAFTS

First of all, it is “legal” to use an old proximal vein graft site for a new vein graft. A common observation is that the old proximal vein graft sites are usually relatively free of disease. Some say that the proximity to the usually normal endothelium of the aorta protects against atherosclerosis in the proximal portions of vein grafts at these sites. One should also always be thinking of alternate sites for proximals, including other areas of the aorta or even the innominate artery.

CLOSING THE STERNUM AFTER A REOPERATION

One should be meticulous, and consider using every available strategy to close the sternum under these conditions. Consider using more wires than usual (such as Alfred Tector’s technique of using 12 wires, one in each interspace and one in the sternum between each interspace) [Tector 1996]. Consider using at least some figure of eight wires. And, as always, one should use heavy absorbable sutures that dig into the periosteum between each wire (the old National Heart, Lung, & Blood Institute technique of Glenn Morrow and colleagues). Finally, it is crucial to use interrupted figure of eight sutures in the upper abdominal fascia, rather than running sutures, as the fascia around the xiphoid is often difficult to pull into the midline.

CONCLUSIONS

Reoperative cardiac surgery can be accomplished effectively and with a reasonable degree of safety. However, effectiveness and safety will not be achieved without meticulous attention to thorough preoperative planning and meticulous intraoperative technique. More detailed discussions of the particulars for reoperations for valve surgery or LVAD explantation are beyond the scope of this treatise.

Part I

The first part of this review of reoperative cardiac surgery addressed preoperative considerations and was published in Volume 21, Issue 1 (2018) of this journal.

ACKNOWLEDGMENTS

Ben Tribble created the figures in this review. Reid Tribble, MD provided many useful suggestions for this review.

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