

Editorial

# Everything You Need to Know about Venting during Cardiac Surgery (And It's More than You Thought!)

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## Introduction

Venting in cardiac surgery is used for a variety of reasons, including to:

- improve visualization;
- prevent distention of the ventricles;
- enhance myocardial protection;
- prevent air emboli to the brain, heart, and other organs;
- supplement venous return to the pump.

However, while discussions and descriptions of venting strategies are not prominently featured in many of the current cardiac surgical textbooks, mastering the strategies of venting the heart is a basic competency of cardiac surgeons.

*“You can never go wrong with venting.”*

—Jay Gangemi, MD

The most common reason that venting is used during cardiac surgical operations is to prevent stretch injury of the myocardial muscle. In fact, at the cellular level, the actin and myosin fibers of cardiac myocytes can be quickly and permanently injured during even brief periods of being overstretched, a fact that is rarely discussed. The other types of damage to the heart that venting can ameliorate or prevent include ischemic injury from warming or from air emboli getting into the coronary circulation. Venting is also used to prevent air from getting into the systemic circulation, especially the brain.

## Venting in the Early Days of Cardiac Surgery

In the early days of cardiac surgery (prior to having effective and reliable cardioplegia), the primary strategy for myocardial protection was to make and keep the heart cold. While the systemic temperature while on cardiopulmonary bypass could be lowered (often to 25 °C or lower) and while topical hypothermia could be used to make the heart even colder, there was always concern about rewarming of the heart from the bronchial blood flow return to the heart through the pulmonary veins, which could rewarm the heart fairly quickly. Thus, vents were used in most cardiac surgical cases in that era. These vents were generally

placed through the left ventricular (LV) apex (after which the vent site was easily closed with a pledgetted horizontal mattress suture). A vent of this sort would not only remove blood from the heart, but it would also remove air from the left ventricle very effectively (especially with the patient in the Trendelenburg position and the apex of the heart ‘tipped up’).

As effective cardioplegia was developed and as better vents became available, apical venting was used less often. However, venting in this way remains an option that can be utilized in certain cases. Though this older technique is very reliable as far as ease of vent placement is concerned, drainage of blood from the left ventricle (LV) may sometimes be suboptimal if the muscle of the ventricle collapses around a vent tip placed through the apex of the left ventricle. Therefore, other approaches to venting were developed. We will describe many, if not most, of those approaches. Let's get started.....

## Creating a Work Space

It is important to create and manage your ‘work space’ in most surgical operations, and it is essential to manage that space during cardiac surgical operations, where one must manage multiple cannulas, drainage tubes, and sutures, as well as vein, arterial, and prosthetic grafts. Work space management includes keeping all lines secure, covering retractors and tubing with towels as much as is feasible, minimizing the number of instruments in the field at any given time, and managing your assistants' hands. Some have called the strategic deployment of towels ‘reverse archeology’.

## Insufflation of Carbon Dioxide during Cardiac Surgery

Since carbon dioxide (CO<sub>2</sub>) is much more soluble in blood than is air (which is about 80% nitrogen that is very insoluble in blood), suffusing the operative field with CO<sub>2</sub> to displace air during cardiac surgical operations seems imminently reasonable. Since CO<sub>2</sub> is also heavier than air (which is the principle of using CO<sub>2</sub> in fire extinguishers),

a catheter to deliver CO<sub>2</sub> into the operative field in cases in which the left side of the heart will be open (which includes almost all cases, other than coronary artery bypass operations) can be affixed to the side of the operative field to allow CO<sub>2</sub> to suffuse the field. Using this strategy seems all the more reasonable in operations being done on ‘sick hearts’ in which you want to take advantage of any and all adjuncts that might make the operation safer and more effective, of course.

### Sites and Techniques for Vent Insertion

Sites for inserting catheters for LV venting include the right superior pulmonary vein, the LV apex, the left atrial appendage, transeptal, and the main pulmonary artery. That is, there are many different ways that the heart can be vented, depending on the circumstances of any particular operation. Every ‘complete’ cardiac surgeon should have all of these strategies in their armamentarium.

### Purse Strings Placed for Vent Site Management

*Purse Strings are for Removing Cannulas and are not Necessary for Inserting Them*

It is worth remembering that purse strings around a vent site can be placed either before or after the vent is placed. This concept is important when a vent must be placed expeditiously, a situation that can arise when venting had not been a part of the original operative plan. However, once a vent has been placed, it can be worth taking a few moments to place a purse string around that vent to enhance its effectiveness, to prevent air from being entrained around the vent insertion site, and to stabilize the vent in the desired position, which is accomplished by gathering the ends of the pursestring suture and securing them with a Rummel tourniquet and by placing a heavy suture around the vent and the rubber ‘bumpers’ used in this technique.

Remember too that the portion of a purse string suture that ‘does the work’ is that portion which is **outside** the structure being cannulated. Thus, small bites of the tissue should be taken, with more ‘travel’ of the suture being allowed on the surface of the structure cannulated, which will facilitate exerting optimal pressure on the outside of that structure. Another ‘principle of purse strings’ is that the smallest size needle and suture that seem practical should be used. The effectiveness of smaller sutures can be enhanced with the use of small pledgets, if needed.

### Venting the Left Ventricle during Routine Cardiac Surgery

For most standard coronary operations, direct venting of the left ventricle itself is not required and is not used routinely. If because of left ventricular hypertrophy or cardiomegaly, venting is deemed necessary, the standard way that LV vents are placed is by way of the right superior pulmonary vein. Many, if not most, cardiac surgeons do place an LV vent for aortic valve operations, and some use them regularly for mitral valve operations as well.

### Adding a Vent when Necessary

Occasionally, the need for an unplanned vent becomes apparent during an operation to enhance visualization or, especially, when unexpected distention of the LV occurs. To protect the heart transiently from stretch injury in such circumstances, one can hold the heart (which some call ‘the strong right-hand clamp’) or even temporarily place an aortic cross clamp until a vent can be positioned. After all, in the early days of coronary artery bypass surgery, cases were often done with intermittent cross clamping, placing and removing the aortic clamp between each graft. An old adage pertinent to these situations is that “stretch injury can occur much more rapidly than ischemic injury”, so your priority is to protect the heart from being stretched, while ameliorating ischemia is of secondary concern.

### Types of Vents Used in Cardiac Surgery

The most commonly used vents are DLP cannulas. (They were named ‘DLP’ cannulas because the inventor, Jim Devries, used the first initials of each of his children to name this cannula. They were named David, Lynda, and Phillip.). These cannulas are Y shaped, with one limb being dedicated for infusions (cardioplegia, mainly) and the other being dedicated to venting (air mostly but also blood, when necessary). These DLP vents are placed in the anterior wall of the ascending aorta and positioned so that there will be room for the aortic cross clamp, as well as for an aortotomy (for aortic valve repair or replacement), or for the proximal anastomoses of vein grafts (in a coronary artery bypass operation). These DLP cannulas should be inserted while the aorta is under full, or relatively full, pressure, as this strategy will lessen the chance that the needle in the DLP apparatus will injure the back or side walls of the aorta. The possibility of these injuries occurring can be lessened by pulling up on the sutures that will hold these cannulas in place and will be used to seal the insertion site at the end of the operation. The needle of the DLP cannula must be ‘aimed’ into the lumen and directed away from the side walls of the

aorta during insertion. It is worth noting that an insidious, partial thickness injury to the side or back of the aorta during DLP cannula insertion is thought to be the source of some aortic dissections that can occur during otherwise routine cardiac surgery, which is a rare but potentially catastrophic outcome.

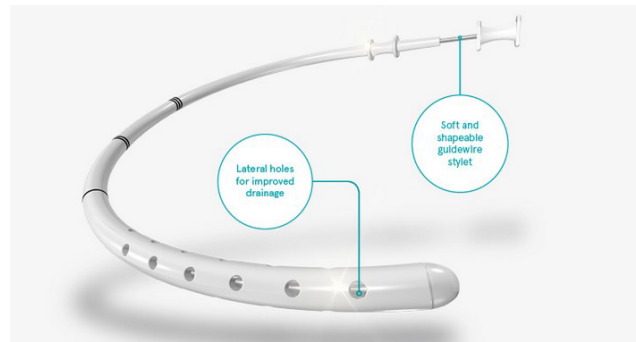
Less commonly used vents are those designed to be placed in the left ventricle. The older ventricular vents had a bendable wire built into them (Fig. 1).



**Fig. 1. Older vents with malleable wires.**

The good thing about these ‘shapeable’ vents is that you can maintain control over them while inserting them. However, there are several things to remember when cannulating the left ventricle from the usual site (the right superior pulmonary vein), with one of these vents. One is that these stiff catheters can be inserted too far and can be pushed all the way through the LV muscle, if one is not careful. An even more significant problem can occur when the vent tip goes into the muscle but not through the epicardium, which can allow blood to be pushed out of the LV where it can accumulate underneath the epicardium and cause a sinister, and sometimes difficult to sort out, reduction in LV compliance. An equally dangerous situation is when the LV vent is pushed in far enough to pass out through a left sided pulmonary vein and into the lung itself. Recognizing this situation can be very difficult, and it can result in a broncho-pulmonary vein fistula, which will result in air being pushed back through the pulmonary veins and into the LA once ventilation of the lungs has resumed. Both types of malpositioning of LV vents can and do happen, and the results can be catastrophic, especially if the situation is not quickly recognized.

For these reasons, the once common stiffer LV vents have ‘gone out of fashion’ and have been replaced, mostly at least, with softer vents. However, these more flexible vents proved to be difficult to position. To solve this problem, a type of LV vent was developed that has a more flexible and removable, stylet. These vents are actually fairly easy to place, once you get used to them (Fig. 2).



**Fig. 2. Softer vents without malleable wires.**

### Inserting an LV Vent

A trick for placing any kind of LV vent is to place one hand underneath the heart so that you can feel the tip of the vent in the left atrium with your fingertips after it has been inserted through the right superior pulmonary vein. Once you feel the tip of the vent, after beginning to insert it into the left atrium, you can ‘lift’ the tip up so that it will pass on through the mitral valve. This lifting of the tip helps to prevent the vent from passing out of one of the left sided pulmonary veins, which are posterior to the mitral valve orifice. Of course, you’ll need to pay attention to how much further you push the vent in after you sense that the tip has passed through the mitral valve, so that the vent tip will not pass out into the left pulmonary veins or injure the endocardium.

### Intermittent, Trans-Septal Venting

LV venting can also be accomplished with a needle passed through the RV and into the LV, a technique favored by Dr. John Kirklin (Fig. 3). This venting method can be used when an LV vent has not been (or cannot be) placed. It can also be useful in minimally invasive operations where an LV vent may be hard to position, or during a reoperation. The trocar in the Fig. 3 is an Argyle trocar catheter, size 10 French (available from Sherwood Medical, St. Louis, MO). Dr. Kirklin [1] used a Becton Dickinson 13-gauge disposable metal needle attached to the pump sucker tubing with a Luer connector. There is a limitation to how much volume can be vented with these needles, which is likely around 500 cc/min. Dr. Kirklin [1] asserted that, because of the small size of the cannula, a persistent ventricular septal defect would not result from this technique, which does seem plausible.

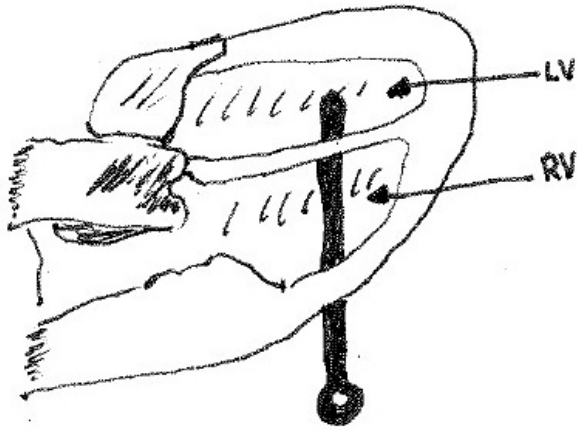


Fig. 3. Trans-septal venting of the left ventricle.

### Venting via the Pulmonary Artery

Another technique for cardiac venting is to place a vent in the main pulmonary artery (PA). Although not commonly used, the advantages of this approach include the ease of access and the ease of direct repair. PA venting is particularly useful when an acute vent is needed as, for example, after aortic unclamping when the heart (especially the right ventricle) fills and is not emptying well. While pulmonary artery venting can be helpful in this situation, it certainly does not prevent all blood from filling the left ventricle, especially if there is **any** aortic valve insufficiency (AI) (and, remember that ALL mechanical valves have some 'built in' AI, to 'wash' the hinges of the valves). Pulmonary artery venting can also help lessen bronchial return to the left atrium since, of course, there are no valves in the pulmonary circulation, which will allow a PA vent to decompress the pulmonary circulation, at least to some degree. However, this strategy is not as effective in preventing the rewarming of the LV caused by the bronchial blood return as an LA or LV vent would be. One should also be aware that a vent in the PA may pull air into the heart if either the left ventricle or the left atrium is open and thus, such a vent should be used only as much as it is needed (Fig. 4).

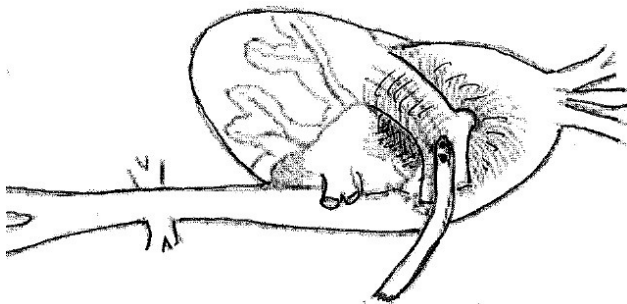


Fig. 4. Venting from the left chest via the pulmonary artery.

### Venting with Inflow Occlusion

Occasionally, one can allow the heart to vent itself, if it is beating and ejecting, by using inflow occlusion, which is achieved by occluding one or both of the vena cavae. As an aside, inflow occlusion is a much more controlled way to drop the pressure for aortic cannulation than having an anesthesiologist give a dose of a vasodilator. It is also worth noting that the technique of inflow occlusion can be used transiently, and quite effectively, in a variety of other circumstances such as repairing a penetrating wound to the heart.

### Venting with an Aortic Clamp in Place

An aortic root vent can be used to decompress the LV with an aortic clamp in place. This important caveat is worth emphasizing: an aortic cross clamp can always be replaced if the LV distends when the clamp is taken off, which can allow time to consider venting strategies that might be needed at such a time. Remember that the LV is defenseless when it's fibrillating and especially when aortic insufficiency (AI) is present, even when the AI is mild. If an aortic clamp does need to be placed or replaced, you will have plenty of time to sort out whether to use more cardioplegia, to try to defibrillate the heart, to place or replace an LV vent, or to consider other strategies for keeping the LV decompressed, including manual compression.

### Venting during Heart Transplantation

Venting is also used routinely by some surgeons during heart transplants (positioning the tip of the vent in the left atrium) to prevent rewarming during the implantation of the donor heart and to aid in visualization during the PA anastomosis, especially when the PA anastomosis is done after the aortic anastomosis, which some surgeons prefer to do in order to reduce ischemic time for the donor heart by removing the aortic clamp earlier during the implant. A left atrial vent is easily placed through the right superior pulmonary vein and positioned in the left atrium, after the recipient heart has been removed and prior to starting the left atrial anastomosis. This strategy can also aid in de-airing the heart during the implantation of the new heart.

### Venting during Lung Transplantation

Venting the aorta to remove air after lung transplantation is an important consideration, as air will often end up in the left atrium, depending on the technique used for implanting the donor lungs. If there is access to the aorta



(as there will be with clamshell or median sternotomy incisions), an aortic vent should be placed to minimize air emboli that can enter the systemic or coronary circulation, as blood flow through the lungs is restored after implantation of the donor lung.

### **Venting during Reoperative Cardiac Surgery**

While LV venting is commonly used in operations on the aortic valve when there is known aortic insufficiency, and when circulatory arrest is planned or contemplated, venting can be quite useful outside of these indications as well, especially in the setting of reoperations. Reasons to consider venting in a reoperative case include: decreased bleeding during dissection, better visualization afforded by less distention of the heart, less rewarming of the heart, and decreasing the LV injury that can occur as a result of distention. Remember that an apical LV vent can be placed urgently through a small left thoracotomy, if necessary. This approach is most likely to be needed if one is doing a reoperation on a patient with aortic insufficiency and the heart is distending.

### **Venting the Heart from the Left Chest during Aortic Surgery**

Venting the LV will frequently be necessary if hypothermic circulatory arrest will be employed. Options for LV venting when working through a left thoracotomy, such as during a thoracic aortic aneurysm repair that requires a period of circulatory arrest, include getting a vent into the LV through the left atrial appendage or placing a vent in the LV apex. Getting into the LV through the LA appendage is easier said than done, though it can be accomplished some of the time. The pulmonary artery can be vented from the left chest as well, though this strategy is not useful if there is any aortic insufficiency and if the heart is not beating (Fig. 4).

### **Venting during Repair of an Acute Aortic Dissection**

Acute aortic dissections involving the ascending aorta will almost always be accompanied by at least some degree of aortic insufficiency (AI). A clue as to how much AI might be present in these cases will be a lower than expected diastolic pressure. Thus, during an operation to repair such a dissection, you will want to get a vent into the LV while the heart is still beating, if at all possible. If the aortic insufficiency is quite significant, you will want to get the vent in before you start cooling the perfusate, which can lead to ventricular fibrillation and subsequent distention of the LV.

As an old adage goes, “never move electively from a position of clinical stability to one of instability”. Even if you do not plan to use an aortic clamp during the repair of the ascending aorta in such a case, you can, of course, temporarily place a clamp on the dissected aorta to protect against LV distention during this challenging part of the case. It is essential to avoid even transient ventricular distention in these circumstances.

### **‘Venting’ Air from Vein Grafts**

If the distal vein graft anastomoses in a coronary artery bypass operation are done first, and if the valves of the vein grafts have been cut (a useful strategy for various reasons that some surgeons do routinely), the veins may de-air when retrograde cardioplegia is given. Still, despite your best efforts, there will sometimes be an air bubble in a vein graft, especially if the valves in the veins have not been cut. This air should not be allowed to be pushed into the coronary artery, if at all possible. A safe way to manage this air is to keep a bulldog clamp on the vein after the proximal anastomosis to the aorta is completed and to insert a small 27-gauge, hollow core needle (not a suture needle) into the vein graft at the exact site of the air bubble and to move the proximal bulldog to a more distal spot on the vein to allow the air to be expelled through the needle, and to prevent it from being pushed into the coronary circulation. An air bubble of this sort should not be allowed to enter the coronary circulation, as air in a coronary artery can impair perfusion of the coronary bed for quite some time afterwards.

### **‘Burping the Heart’ (Terminal Venting of the Left Ventricle)**

As transesophageal echocardiography (TEE) began to be used routinely in cardiac surgical cases, it became evident that there was almost always some air trapped in the LV if any part of the left side of the heart had been opened. Venting this air is very satisfying, as there is no good that can come of air retained in the LV, at least some of which will be ejected and end up in one capillary bed or another. Furthermore, using TEE guidance can add to the effectiveness of this maneuver.

I have almost always vented the apex of the heart at the end of such cases, when the heart is filling (after the clamp is off). The apex of the heart is tipped up and a large bore needle is inserted into the tip of the left ventricle. The needle will allow any residual air to be expelled, which is, frankly, a most satisfying sight! Some call this maneuver “burping the heart”. There will virtually always be some air expelled. One almost never needs to repair the needle hole, though it is easy to put a stitch of some sort there, if it seems prudent to do so.

## Using Multiple Vents

There will be a time when it will be useful to utilize more than one vent or venting strategy, in any given case. For example, having a vent in the ascending aorta can supplement other vents or venting techniques used to vent the left ventricle, as part of a 'final round' of de-airing.

## Trendelenburg Position at the End of a Cardiac Case

It almost goes without saying that, if there is any chance that air is inside the heart or between the aortic cross clamp and the aortic root, one should tip the head of the bed down prior to taking the cross clamp off, with hope of directing any residual air bubbles into the aortic root vent so that those bubbles will not be pushed up into the cerebral circulation.

## Repairing Cannulation and Vent Sites

*"I am certain that I saved many lives with a pericardial patch, a trick I learned from you."*

—Mike Butler, MD

The higher the pressure (to be contained), the larger the hole, and the more friable the tissue, the more you may need a patch to supplement your purse-string sutures. The best patch material is usually pericardium, either autogenous or bovine pericardium. These patches are best secured with a relatively fine running suture, such as a 5-0 or 6-0 monofilament suture.

## Summary

Venting the heart is more nuanced than many realize, and the consummate cardiac surgeon must be proficient in all the various ways that the heart, brain, and systemic vascular beds can be protected with a wide array of venting strategies, sometimes with multiple vents being used in any given case.

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## Conflict of Interest

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