Understanding the Cardiopulmonary Bypass Machine and Its Tubing

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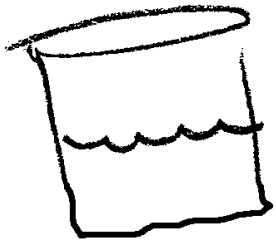
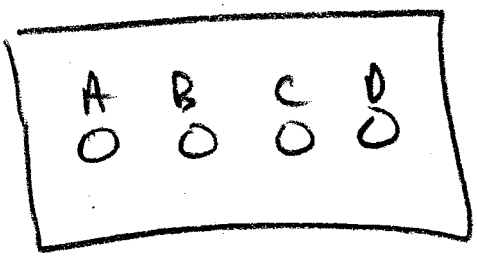


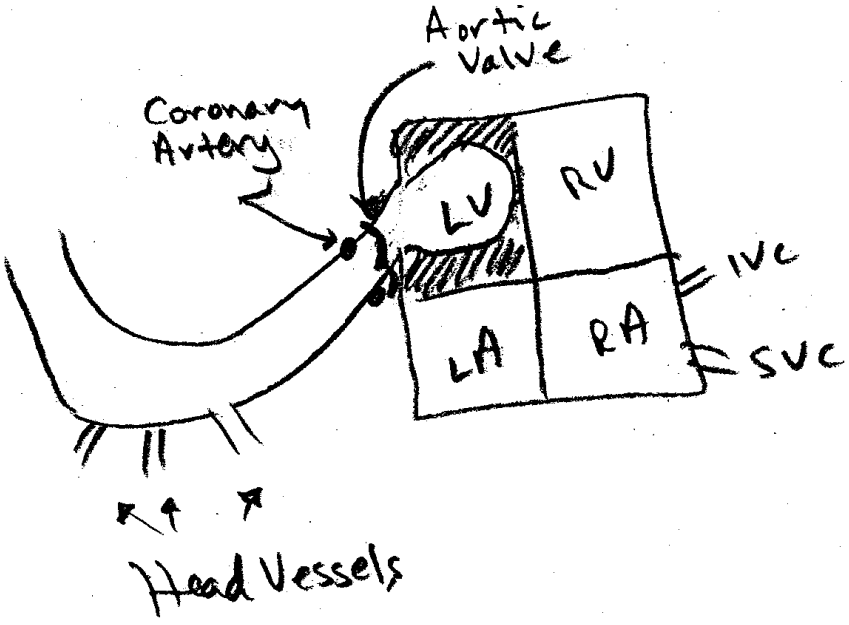


Reservoir
Bucket

This is a cartoon of the heart and the bypass machine as seen from the head of the bed by the anesthesiologist.

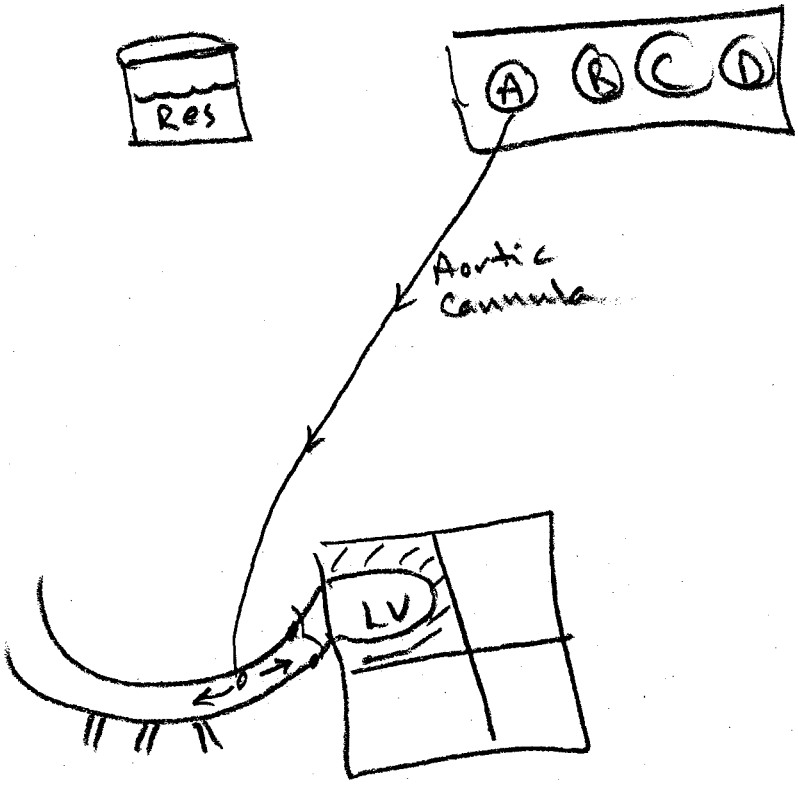
Note the 4 chambers of the heart, with the thick-walled LV leading into the LVOT, then to the aortic valve, beyond which the coronary arteries take off.

On the CPB machine, there is a reservoir bucket at the left side, and then 4 roller-pumps, labeled A,B,C and D.



After heparinization, the first cannula that is almost always put in is the aortic. It takes oxygenated blood from roller pump A, and feeds into the high ascending aorta.

It is put in first because if there is a problem, either severe hemodynamic instability, bad arrhythmia, or ischemia, and you need to urgently initiate bypass to save the patient, it is best to have that one already in place. You do not want to hurry when putting this one in, as the aorta might tear/dissect. In addition, it serves as a conduit for rapid fluid resuscitation. Keep the systolic BP in the 90 to 100 mm Hg range during placement to lessen the chance of a tear, while this is being placed.



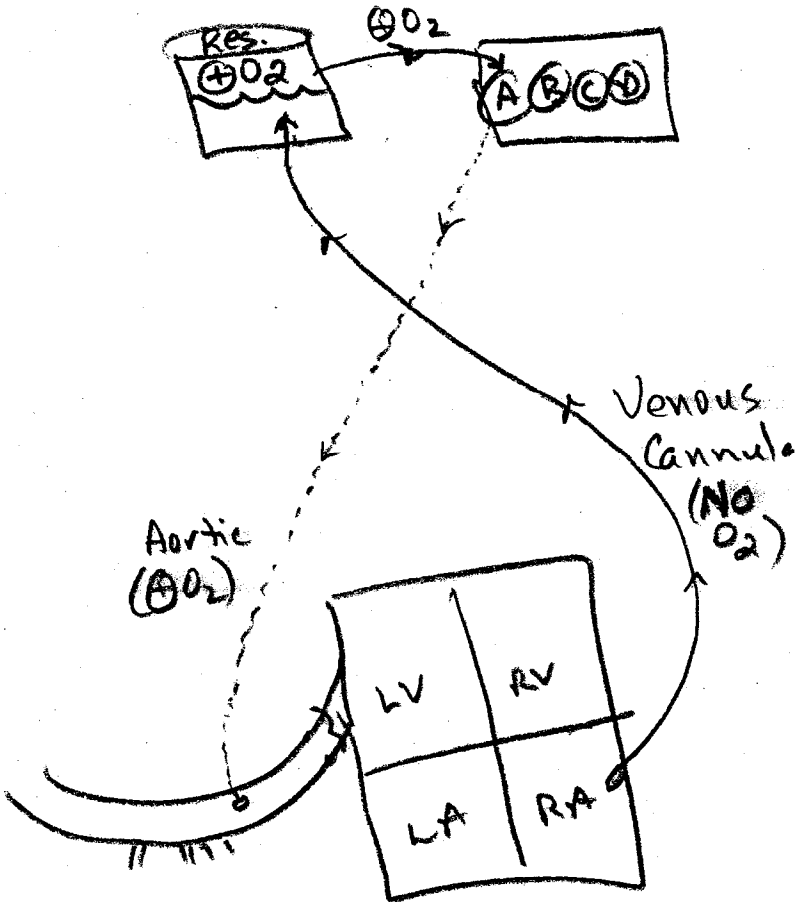
The second cannula that is placed is the venous. Usually the appendage of the right atrium is used, since tying it off at the end of the case doesn't matter.

Atrial arrhythmias are very common during its placement, so you need to have checked the defibrillator in case cardioversion is needed. Remember to synchronize the cardioverter/defibrillator for atrial dysrhythmias.

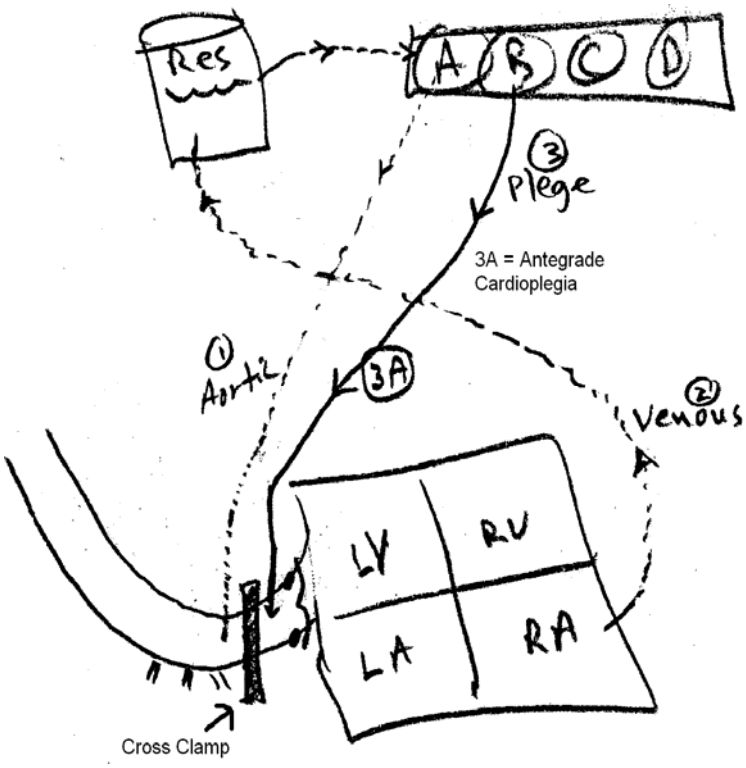
You will notice that the CPB machine is always low to the ground. It has to be lower than the patient, as much of the drainage into the venous cannula is gravity-dependent siphoning. Vacuum assist is generally used to help with drainage as well.

It drains into the reservoir bucket, where the oxygenator resides. Then it goes around roller pump A and back into the patient by way of the the aortic cannula. With adequate heparinization and these two cannulae, you can go on bypass and rescue patients from cardiac arrest, severe hypothermia, bupivicaine injection, etc. Keep in mind that CPB can also be achieved using the femoral artery and vein, without opening the chest.

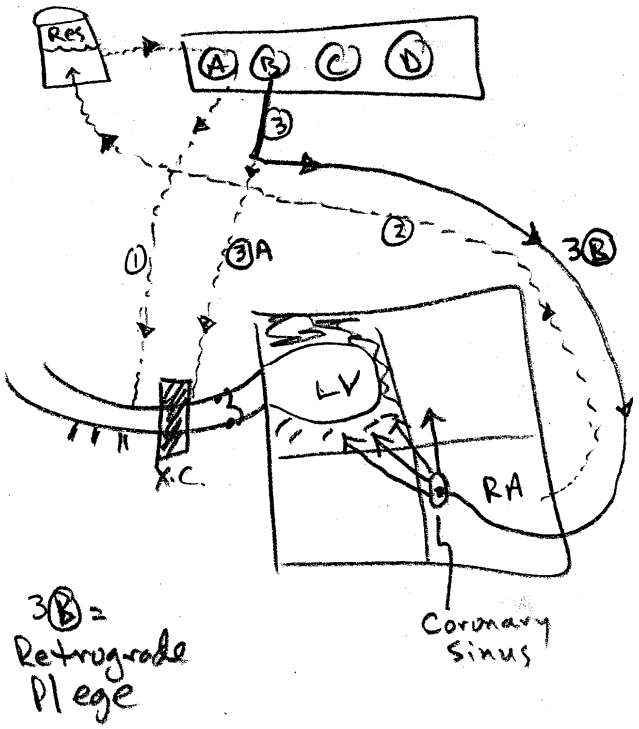
If cardiac surgery is planned, you need cardioplegia and a crossclamp. The Plege line is line #3.



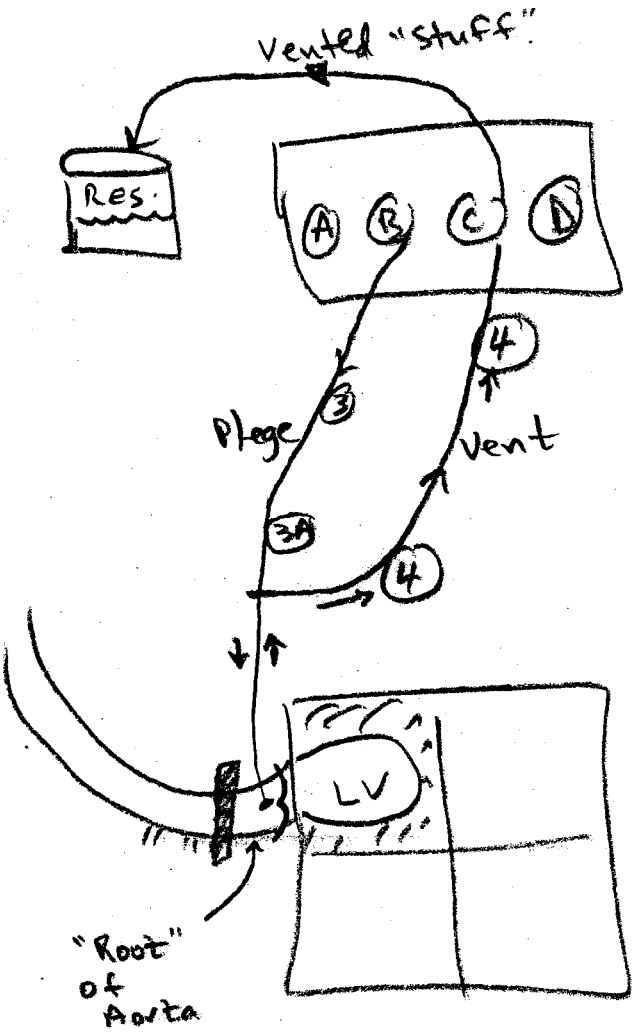
The cardioplegia has to get into the meat of the ventricles. It does no good in the chambers. There are 2 ways to get it in. One is called ***antegrade***, meaning it follows the normal course of blood down the coronary arteries. The other is called ***retrograde***, meaning it goes backward through the veins via the coronary sinus to feed into the myocardium.



Cardioplegia, or plege, is pushed by roller pump B. If antegrade, it leaves the CPB machine and goes to a cannula stabbed into the proximal ascending aorta. The cross-clamp (X-C) is placed between the aortic cannula and the plege line. The X-C's job is to keep the plege from going out to the rest of the body. Also, it will keep the regular bypass blood from the aortic cannula from chasing the plege down the coronaries and flushing it out which would allow the heart to wake up from its period of intended potassium- and cold-induced hibernation. The closed space between the X-C and the aortic valve is called the aortic root.
They only escape for plege under pressure there is via the coronaries. If you are using plege, you need a X-C.
When you are done with the plege, the X-C can come off.
The Retrograde line goes to the coronary sinus, which is in the right atrium. The retrograde line looks like a Swan in the sense that it is a long tube with a balloon near the end and an infusion port beyond that. When the balloon is wedged up into the sinus, the plege is given under pressure and can only go back up the coronary veins into the meat of the myocardium. You still need a X-C, so that the plege doesn't get flushed out**.**

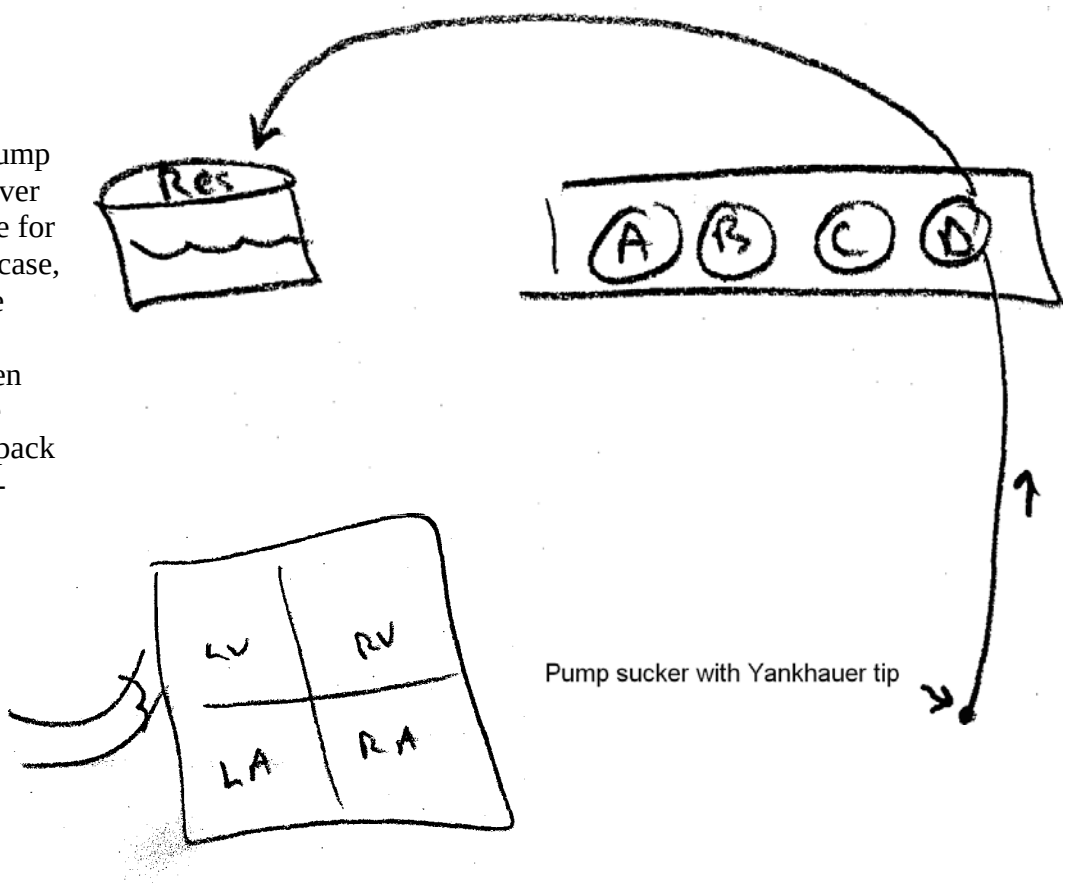


Cannula #4 is called the vent. It has nothing to do with ventilation of the lungs. It is a line which is used to decompress the LV during CPB. If your CPB is good, all the blood coming to the RA is being diverted to the CPB machine and will not go through the RV, PA, and PV's to the LA and LV. But there is still "stuff" that starts to fill the LV. This “stuff” is made up of the drainage from the Thebesian veins which come out of the LV walls directly into the LV chamber, some trickle of plege that finds its way through the aortic valve if it is not 100% perfectly competent, and drainage from the bronchial circulation which drains into the pulmonary veins into the LA and LV. The more COPD someone has, the more bronchial blood flow they will have. In this situation, the LV will start to distend and will get hurt if not vented properly.



There are a few ways to do this. Nobody wants to directly stab a line thru the LV wall. You might hit something bad and leave a bleeding hole afterwards. You could put a cannula thru a PV, into the LA and thru the Mitral Valve. This is sometimes done, especially in aortic valve surgery, to keep the field decompressed. In a CABG case, we simply turn a stopcock on the Plege line, after some plege has been given and allowed to set in the myocardium, roller pump C can be used to gently suck back “stuff’. Anything under any pressure in the LV will be allowed out thru the aortic valve, into the ascending aorta, which is being aspirated by the vent line. The perfusionist will not suck hard or air will be pulled into the aorta around the cannula site and, when the clamp comes off, these bubbles will go out the aorta. When he sees that the vent line is being sucked enough to go from a round shape to a slightly "flat" one, he will say the vent is flat and he will turn it off.

Cannula #5 is called the pump sucker. There are 2 cell-saver lines in the OR. One is like for any other ortho or trauma case, and is located down by the patient's right foot. The problem with it is that when blood is salvaged from the field, it is spun down to a pack of RBC's which we can re-infuse to the patient, but the platelets and plasma are thrown in the trash!



Heparinized Blood <u>ONLY</u>!!

So there is a 2$^{\circ d}$ cell-saver, which is on the machine. It will take blood from the field and put it back into the reservoir bucket, keeping the plasma and platelets "in play". The only problem with that is that blood has to be heparinized before being taken into the CPB tubes or it will clot off all the tubes and the oxygenator. So there is a window of opportunity to use this cell-saver using something called the pump sucker. It can come on after the full dose of heparin has been given but has to be turned off as soon as the protamine starts at the end of CPB. That is why everyone in the room must agree and be aware that the protamine is OK to start, otherwise going back on CPB to fix something is a big problem.

At the end of bypass, the tubes come out in the reverse order they were put in. The pump sucker has to stop immediately upon starting protamine. The plege line/vent can come out either just before or just after separation from bypass. Once you are off CPB, the venous line is usually taken out so the blood in it can be returned to the patient. The aortic cannula is left in as long as possible. It is used to return as much blood as possible to the patient, and we sometimes use

reverse Trendelenberg and touches of NTG to make the patient accommodate this volume so they become temporarily hypervolemic. We would like to leave the aortic cannula in for as long as possible in case there is a problem and you have to crash back on CPB. It is a good safety net, and as stated earlier, it is not good to hurry it in. Therefore, we leave it in as long as we can but once about ½ or so of the protamine is in, there is too great a chance of getting clots on the end of it, so it has to be pulled.

Again, a pressure in the 90 to 100 range is a good idea during decannulation to prevent tears and to let the surgeon tie knots on a loose, slack aorta. Then the aorta can become tense again after the knots are all finished. Keep in mind though that the aorta is still being held together by these knots, so from this point on systolic pressures of 130 and higher might be dangerous, so keep a lid on it.

Once all the cannulae are out, the chest will be closed. Watch for sudden drops in BP when the chest comes back together, as this will push on the heart and decrease your pre-load. Also, there is a chance that a graft will get kinked on sternal closure, causing sudden ischemia with hypotension or dysrhythmias.