# A Double-Lumen Cannula for Cardioplegia Delivery and/or Air Aspiration from the Aorta during Cardiopulmonary Bypass

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## Abstract

This paper reports the use of a double-lumen cannula designed to deliver cardioplegic solution, decompress the left heart during ischemic arrest, and aspirate air from the aorta before cardioplegic delivery and after the aortic cross-clamp is removed.

The unique feature of this cannula is its double-lumen design which allows air to be aspirated from the aorta prior to, and concurrent with, the beginning of the delivery of cardioplegic solution, to prevent the introduction of air into the coronary arteries.

We will outline the unrecognized sources of this air and why it is advantageous to evacuate it before a subsequent infusion of cardioplegia.

## Introduction

The use of cardioplegia is common during cardiac surgery and there are many different methods of delivering the cardioplegic solution to the coronary arteries. Common to all infusion techniques is a needle or cannula in the aorta through which the cardioplegic solution is administered.

The presence of air in the Left Ventricle (L.V.) associated with left ventricular venting or operations upon left-sided heart valves is well known.[1] There are a number of different techniques[1,2,3] used to prevent or evacuate some of this air including the use of a needle in the aortic root to which negative pressure is applied. A needle in the aorta may also provide decompression of the left heart during coronary surgery eliminating the use of a left ventricular vent. Some surgeons employ a needle/cannula in the aortic root,[3,4] on suction, to help remove air trapped in the heart during Aortic or Mitral valve surgery,[5] which air might be expelled during L.V. contraction[2,6,7] after the Aortic cross-clamp is removed.

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It is reasonable to use one needle/cannula to perform the functions of cardioplegic solution infusion, L.V. decompression, and air aspiration. Some products have been so designed. The purpose of this paper is to outline some additional ways air can enter the L.V. and Aorta, to discuss the danger of infusing cardioplegia while there is air in the aortic root, and to introduce the only cannula available which can simultaneously aspirate air and infuse cardioplegia through separate pathways.

*Unrecognized Air in the Aortic Root*

There are a number of ways air can enter the aortic root which are not generally understood. During coronary artery surgery, where an L.V. or pulmonary artery vent is used, air can be aspirated into the aorta through an open coronary artery. This will happen if the coronary artery is not totally occluded and if the Aortic valve is incompetent (during a circumflex anastamosis, for example). During Mitral Valve surgery, retraction of the atriotomy can render the Aortic Valve insufficient, allowing air to enter the aorta.

*The Danger of Air in the Aorta*

When there is air in the aorta and a dose of cardioplegic solution is given air is forced into the coronary arteries. This air (mostly nitrogen) is not very soluble and may act as an obstruction to flow in the coronary microcirculation.[2,8,9] The occurrence of arrythmias (particularly fibrillation) and right or left heart failure may be due in part to coronary micro air emboli[9] and are an extreme form of the damage caused by air. Most of the damage is probably subclinical, but real.[2,8,9] Even if cardioplegia is not given there still exists the possibility of coronary micro-air, from an intra-cavitary source,[2] upon removal of the aortic cross-clamp.

*Rationale for a Double-Lumen Cannula*

Air in the clamped aortic root may be removed by applying a negative pressure to a needle in the proximal aorta. The infusion of cardioplegic solution is slowly started and air mixed with solution aspirated

through the cannula. When all the air is removed and only solution is being aspirated the air vent is turned off and the infusion of solution continued until the appropriate amount is given. Only a double-lumen cannula allows the infusion of cardioplegic solution without the introduction of air through a cannula that has previously served as a vent for air. Only a double-lumen cannula allows the infusion of cardioplegic solution into the aortic root and the concurrent aspiration of air and fluid.

*The Double-Lumen Cardioplegia Cannula*

The cannula (Figure 1) we have been using at the University of Colorado and The Veterans Administration Hospital in Denver is made by a Utah company which specializes in double-lumen cannulae and is marketed by a Colorado company.[a] It consists of a stainless steel inner cannula through which a trocar is introduced. The trocar is withdrawn once the aorta is perforated and the cannula is then advanced into the aortic root. The stainless steel inner cannula is surrounded by a 12 ga. tapered polyurethane outer cannula that is 1.6 cm. long. Cardioplegic solution is infused through the female luer-lock fitting which serves to anchor the trocar during introduction. The cardioplegic solution flows through the inside of the stainless steel cannula and air/fluid are aspirated through the strategically placed holes in the outer cannula. The air/fluid are returned to the pump-oxygenator circuit through the cardiotomy suction line attached to the vent line of the cannula which suction can be turned on or off with a "Halkey-Roberts" clamp. This cannula has functioned well and has been used without problem for six months.

## Summary

We have introduced a double-lumen cannula that can be used to deliver cardioplegic solution and aspirate air. It is not uncommon, but generally unrecognized, that there is air in the aortic root after the initial infusion of cardioplegia. This air can easily enter the coronary arteries when a subsequent dose of cardioplegia is given and can have harmful or disastrous consequences.[2] This cannula can also be used to decompress the left side of the heart during ischemic arrest and replace the ventricular vent for those surgeons preferring this technique. The cannula can also be used as *part* of the effort to decrease the chance of intra-cavitary air entering the coronary or cerebral circulation after the removal of the cross-clamp.

The primary benefit of this cannula is that it allows for the simultaneous evacuation of air and the delivery of cardioplegia and it will not introduce air with the cardioplegic solution as will be done with other dual function cannulae that are not true double-lumen devices.

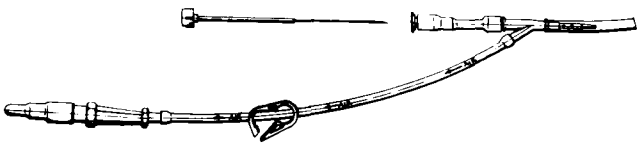

**Figure 1:** Drawing of double-lumen cannula. Cardioplegic solution is delivered through the female luer port. Air is aspirated through the holes in the polyurethane outer cannula and out the side-arm tubing to which cardiotomy suction has been attached.

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a HemoTec Inc., Englewood, CO 80112-3992

## Questions from the Audience

*Question—Lanier Allen:* When you said you hooked up a vacuum to that side port, how much vacuum do you put on that and what type?

*Answer:* It's a standard, roller pump cardiotomy suction, and we try to regulate that when we're allowed by cost constraints, surgeons, and whatnot with some kind of an air vent—either a needle in the line, or some kind of one way valve with a maximum negative pressure release.

*Response—Lanier Allen:* The reason I asked that, is one thing that we've seen over the years, and one reason when we use a left ventricular vent, which is very rare, is that we put it on gravity drainage. It's when we have some anastomosis already in the aorta, when we put much negative pressure there, the air comes around the sutures into the aorta. So I think in this situation, too, you have to be very aware of not only that you can pump air in, but you can draw air into the aorta by putting too much vacuum at that source.

*Response—Richard Berryessa:* And if I understand your question correctly, that is not a problem in the areas where we work, because we generally do not use this needle, except for the performance of distal anastomosis. These particular surgeons construct their proximal anastomosis after the needle is out and with a partial occlusion clamp.

*Response—Lanier Allen:* I see you take this out before you start any of the proximal anastomosis.

*Response—Richard Berryessa:* The cross-clamp is off and the site arm alone would be open to evacuate air. But with the cross-clamp off, and therefore you have an adequate amount of blood in the aorta, you should have very little chance of creating sufficient negative pressure or any kind of air around the anastamosis in the aorta. There is no reason why this site arm can't be hooked up to gravity drainage, either into a cardiotomy resevoir or a bag or a venous line or whatever.

*Question—Richard Kramer:* Would you clarify again, please when you are delivering cardioplegia is the evacuation arm in the open or closed position?

*Answer:* Initially, the Halkey-Roberts clamp is open. Then cardioplegia is begun slowly. As the air in the aorta theoretically rises, it then goes out the side arm. As long as there is air coming out the side arm with the delivery cardioplegia, the Halkey-Roberts clamp is left open. And when you get only solution—very interestingly, you can put your fingers on that side arm and feel air. In fact, you can even feel it after the cross-clamp is off when you use it as an air evacuation needle. The surgeon describes it as a tug on a fly rod when you have a fish biting. Once you have primed the solution out you close out the Halkey-Roberts clamp and give cardioplegia. It's a matter of 15 to 20 seconds that you are giving cardioplegic with the air evacuation line open.

*Question—Kramer:* Before the advent of cardioplegia, a lot of surgeons would use alligator clips on either side of the anastomosis of the coronary arteries that they were doing. Do you think it would be helpful to reinstitute alligator clips on the coronary in order to limit the entrance of air?

*Answer:* I'm afraid that's a little out of my realm. That's more of a surgical thing. It certainly could help to cut down on air, but I'm not sure. In fact, I would be very concerned about the problem of damage to the coronary arteries and subsequent increase in coronary disease. It has been shown that you can cause intimal proliferation by applying an aortic cross-clamp to an aorta and by applying any type of clamp to a vessel—that you get intimal injury and proliferation build-up of plaque and all tha stuff. So I'm a little reluctant to advocate that.

*Question—Philip Wagoner:* Excellent paper. Would you identify this cannula more closely? Is this a DLP slotted coronary cannula?

*Answer:* Not to my knowledge. It's marketed by HemoTec. DLP has one which is excellent, side arm cannulas. It's very good. It's not a double lumen cannula, though. I do believe they have a double lumen cannula with a side arm on it—the double lumen portion, to my understanding, the pressure monitoring portion of the cannula, so that it actually has an infusion port, an air aspiration port, not separate lumens. But be careful to get the air out that you have been evacuating in that tip of that cannula. Then every time you give cardioplegia, you'll push the air that's in the tip back in.

*Question—David Mills:* What sort of pressure drop do you have in administering this at 150 cc's per minute across this inner cannula? Also, is the consideration of using the dual lumen and the aspirating portion of it for pressure monitoring been evaluated?

*Answer:* Answer to the first part of your question: I don't know what the pressure drop at 150 cc's a minute is. We use blood cardioplegia, which, of course, will increase the viscosity at any given flow, and we flow at approximately 350 to 400 cc's per minute: Total mix delivery. And our total infusion system resistance is less than 300 millimeters. So at 150 with crystalloid it will be extremely low. With blood it will be much lower. The second part of your question is pressure monitoring capabilities. I think that is an interesting application and that it could be done, for instance, with a needle connected to a monitoring line and a transducer just stuck in the side port of the thing. And maybe you can come up with some better technique—for instance, a leur port on the connection between the cardiotomy suction line and the side port. We have always used the digital manometer to measure infusion pressures. Very scientific.