

Retrograde Dissection During Cardiopulmonary Bypass

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Certainly one of the most dire emergencies related to cardiopulmonary bypass is a retrograde dissection resulting from common femoral artery cannulation for blood return to the patient.

The purpose of this communication is to discuss several aspects of extra-corporeal circulation techniques which relate to or increase the possibility of a retrograde dissection. Included are basic fluid dynamics, anatomy, cannulation, line pressure and diagnostic features.

FLUID DYNAMICS

The dynamic characteristics of blood passing through a cannula with a lumen smaller than the vessel into which it is placed are twofold. Firstly, there is high velocity "jet streaming" and secondly, there is turbulence.

Jet streaming results when a fluid is forced through a tubing system which becomes narrower along its course. For the same volume of fluid to pass a constricted area in a tube, the velocity of the fluid must increase. In the circuitry of arterial return to the patient, the narrowing is greatest at the tip of the arterial cannula. The jet stream created at that point has a great potential for elevating an intimal plaque and starting a retrograde dissection.

Turbulence is also created when the flow through the cannula tip exceeds Reynolds number for the inside diameter of the cannula. Turbulence results in eddy currents which swirl and may separate the intima from the adventitia and open a false passage.

ANATOMY

A brief consideration of the anatomy of the ilio-femoral vessels is in order at this point. The anatomy of these vessels is such that, passing *retrograde* from the site of arterial cannulation near the origin of the profunda femoral artery, the common femoral artery courses cephalad at about a 40° angle from the midline.

In addition, it dives downward or posteriorly into the pelvis to become the iliac artery which joins the aorta.

CANNULATION

One should now consider the actual arterial cannulation. It is our practice to insert the cannula before the bypass tubing is connected. Once in place, the cannula is allowed to bleed so that the force of ejection can be roughly qualified. On occasion, blood has only trickled out of the cannula. Although the surgeon was reasonably certain that the cannula tip had entered the true lumen of the vessel, in these cases it was obvious that flow through the cannula was partially obstructed.

Regardless of the source of the obstruction, this occurrence is an absolute indication for some other site of arterial cannulation.

To connect the arterial limb of the pump tubing to the cannula prior to insertion is an extremely hazardous procedure since one can never be certain about obstructions before bypass is begun. With *all* of the possible precautions, dissections do occasionally occur.

By cannulating prior to connecting the bypass tubing we feel we have averted six likely retrograde dissections.

Article available at <https://ject.edpsciences.org> or <https://doi.org/10.1051/ject/197462086>

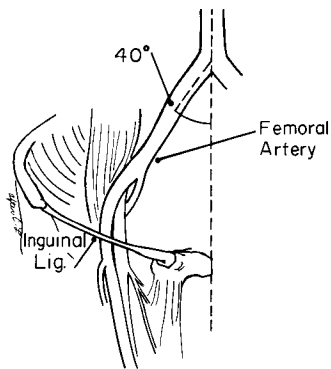


Fig. 1. Note the angle at the junction of the Iliac artery and the Aorta.

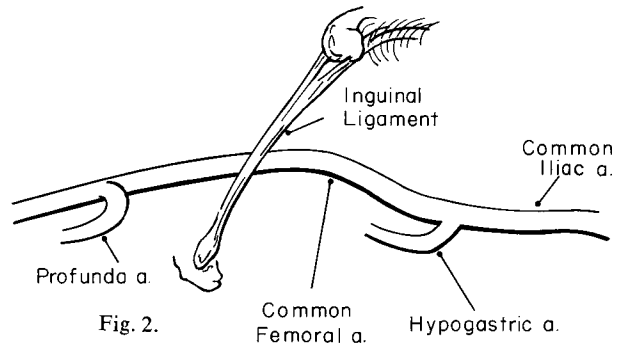


Fig. 2. A view of the Ilio-femoral vessels as seen from the inner aspect of the thigh.

From the discussion on anatomy of the femoral vessels, it is apparent that anchoring the cannula and connecting tubing to the leg along a line parallel to the midline will direct the jet stream toward the wall of the vessel rather than into the lumen of the artery. This procedure most certainly increased the likelihood of an intimal tear and dissection. Our practice is to position the tubing and cannula in a line which directs the stream of blood along the natural course of the femoral-iliac system.

One other observation should be made in this regard. Anyone who has had the femoral cannula separate from the artery knows the ramifications all too well. Most surgeons secure this cannula by vigorously tying some ligature around the vessel and cannula proximal to the arteriotomy. The ligature is usually placed while an assistant holds the cannula in position. Our technique employs a stainless steel connector with a stopcock attached to join the cannula and tubing. It was recently observed that during the entire cannulation and air removal procedure, the connector and stopcock orifice were directed toward the ceiling, but once these procedures were complete, the stopcock invariably ended up flat on the patient's leg. If the securing ligature is tight enough, it seems possible to create torsion in the artery if the cannula is unable to rotate freely under the ligature. I am unable to document this as a real problem; however, the potential is there and has been eliminated from our technique.

DIAGNOSTIC FEATURES

Line Pressure: Line pressure is a parameter measured somewhere in the arterial line between the arterial pump and the cannula tip. Line pressure is a function of the length and diameter of tubing, the size of the cannula, the blood flow rate, and the patient's blood pressure (peripheral resistance).

A fairly constant value can be obtained from the tubing, cannula size and flow simply by pumping a given flow through a specific cannula into a bucket.

The major source of line pressure under these circumstances is the cannula tip as it narrows to its smallest inside diameter. The patient's blood pressure represents additional resistance to flow during cardiopulmonary bypass. Commonly, one will see a higher line pressure during partial bypass since the heart is still ejecting blood forcefully. When the heart stops ejecting on total bypass, line pressure will usually decrease.

Our philosophy regarding flow is that high volume pump output is essential. The majority of our patients are adult males in the 75 Kilogram range. The average value for line pressure obtained with a 22 french bardic cannula at 4.5 liters/mm flow with a mean radial artery pressure of 70 mm Hg is 240-260 mm Hg. This we

consider an ideal value for the system. As the patient's blood pressure increases so will the line pressure. The inverse is also true. Of some interest is the fact that one may frequently record higher line pressures when an aortic cannula is used, especially when the cannula is angled. This high line resistance is due primarily to the angulation of the cannula.

While under some circumstances one may be deceived by line pressure readings, line pressure monitoring is an invaluable tool in the diagnosis of a pending or actual retrograde dissection. At the onset of bypass, if a dissection is occurring, one will observe an immediate and profound increase in line pressure. The rate of increase is similar to what one would observe if the arterial line were clamped. This may or may not be preceded by low pressure in the line open between the patient and the gauge prior to bypass. Such an occurrence is an absolute indication to discontinue bypass until a determination can be made as to the cause.

Another situation is a dissection which occurs later in the course of bypass. In our experience, this is less common but equally or even more catastrophic a problem. The added complication of this type of dissection relates to the fact that maximum pump flow has usually been achieved and the dissection proceeds rapidly up the aorta to the aortic valve.

The line pressure in this type of dissection will usually show a marked increase to maximum and will frequently, depending on the extent of the dissection, be associated with an immediate decrease in radial artery pressure. In addition to a decrease in radial pressure, the pulse waveform may diminish or disappear. This phenomenon occurs when the dissection extends to the great vessels occluding the true lumen.

Neurological Signs: The only immediate neurological sign of a dissection are the pupils. If all the great vessels are occluded, the pupils will dilate. In the absence of medications which will induce pupillary dilation, when a dissection is suspected, the pupils may be valuable in establishing the diagnosis. It is possible for the dissection to affect only one of the vessels to the head, causing only one pupil to dilate.

Renal Function: A reduction in urine output is a common and usually ominous sign of a dissection. When the dissection extends completely around the aorta below the renal arteries, then proceeds cephalad, urine output will decrease to zero. Without a point of reentry, urine output will also drop to zero. Interestingly, this ischemia does not necessarily lead to permanent renal damage. In two cases in our experience, urine output was absent for several hours but returned to normal before the patient left the operating room.

Venous Drainage: One would certainly expect a reduction in venous return when the perfusate passes into a false passage. Without a reentry point, the venous system is bypassed and the blood is stored in the false passage. In addition, large quantities of blood may be lost when, for example, the dissection occurs during the pump run and a site for decompression of the dissection is available to the exterior, as through the aortic end of a saphenous vein graft. The pressure within the false lumen exceeds 350 mm Hg in most instances, thus the decompression may eject blood in large quantities out of the wound area. In either of the two instances, reservoir volume may be significantly compromised.

Reentry: Antegrade and retrograde dissections will frequently reenter the true lumen of the aorta. Reentry is a lifesaving occurrence for it may keep critical vessels open and create, in the case of retrograde dissection, antegrade flow which may help to re-expand compressed true lumens.

CASE REPORTS

The following are case reports of two dissections which occurred on bypass.

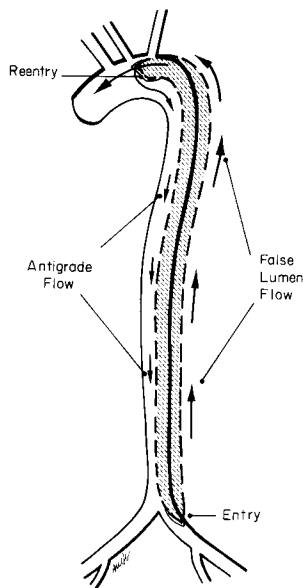


Fig. 3. Illustration demonstrating suspected pathway of the dissection in case #1. Note the reentry point between the subclavian artery and the left common carotid artery.

Fig. 3.

Each demonstrates some or all of the features discussed above.

CASE #1: This patient was a 57 year old white male. He was admitted for chest pain and fatigability. Coronary angiograms revealed diffuse coronary artery disease with a bypassable L.A.D. At surgery a CVP and left radial artery cutdown were carried out. Surgery was uneventful until bypass was begun. Line pressure at the outset of bypass was higher than usual at four liters of pump flow; however, blood gases and pH drawn immediately were normal and the systemic pressure contour had a normal configuration. The systemic pressure was 70 mm Hg mean. Mention was made to the surgeons that a possible dissection was in the progress. No sign was apparent at the operative site. Immediately following this exchange, and while I was watching the blood pressure display tracing, the pressure dropped to 25 mm Hg and the contour became flat. Within a single 6 second sweep of the oscilloscope beam, the pressure returned to 70 mm Hg and the waveform returned to a contour characteristic of our pump. Frequent examination of the pupils showed them to be of normal size throughout the entire case. Urine output was absent. Since no clear-cut sign of dissection was apparent, it was decided to continue the procedure as begun. When all anastomoses were completed, the aortic clamp was removed. Immediately the dissection became obvious when the diameter of the ascending aorta expanded markedly and the aorto-saphenous anastomosis began spurting large quantities of blood. The aorta was extremely tense.

An aortic cannula was inserted and antegrade flow established. The patient was cooled to 22°C. The false passage was oversewn and a synthetic tubular graft inserted to join the aortic ends. The circulation was then arrested to facilitate closure of the dissection plane at the site of aortic cannulation. The cannula was then reinserted through the synthetic graft and the patient rewarmed. During re-warming, urine began to flow, slowing at first, then a diuresis followed. Bypass was terminated and the patient had an uneventful recovery.

DISCUSSION

In this case, reentry probably saved the patient's life. Two features made the outlook fairly bright: (1) frequent blood gas and pH determinations throughout the pump run were normal. (2) the fact that the pupils did not dilate gave some hope of an intact brain. Interestingly, during the brief period of circulatory arrest, the pupils did dilate but returned to normal when perfusion was reestablished.

The suspected mechanism in this case was a dissection beginning somewhere in the iliac artery or abdominal aorta below the renal arteries (no urine), extending to, and briefly occluding the left subclavian artery, then reentering the true lumen of the aorta between the left subclavian artery and the left common carotid artery. Fig. 3.

When the aortic clamp was removed, the least resistance was toward the aortic root and site of the aorto-venous anastomosis for decompression.

CASE #2: This was a 53 year old white male, admitted to another hospital following a "fainting spell" at a dance. He was transferred to the VA Hospital, Long Beach, for further study. A loud systolic murmur could be heard over the aortic valve. Significant heart catheterization data revealed a 60 mm Hg gradient across the aortic valve.

At surgery a radial artery cutdown was done for pressure monitoring. Cannulation was routine and bleeding from the femoral artery site was vigorous.

Bypass was begun and within 5 minutes the surgeon noted the dissection as it passed the aortic arch.

Fortunately, the extracorporeal circuit incorporated an extra bullet type heat exchanger. The patient's temperature was lowered to 20° after aortic cannulation had been completed. The diseased valve was replaced, the false passage oversewn and the patient rewarmed. Bypass was terminated and the patient left the OR in fair condition. His postoperative course was smooth except for some mental confusion which cleared.

DISCUSSION

In this case, the dissection was immediately apparent to the surgeon. Line pressures were quite high, however, because of 2+ aortic insufficiency the heart continued to eject despite the fact that total bypass had been instituted. The pulse tracing was a normal phasic waveform with a systolic component of 100 mm Hg. This factor confused the issue until the dissection was manifest to the surgeon. Line pressure under these circumstances will record the extracorporeal resistance plus the patient's peripheral resistance or blood pressure. A patient pressure of 100 mm Hg. resistance will usually yield line pressure readings in excess of 300 mm Hg at pump flows less than 4 L/mm.

SUMMARY & CONCLUSION

In our experience, dissection occurs despite the many precautions we follow. The precautions outlined herein have averted at least 6 likely dissections where bleeding from the cannula in the femoral artery was not vigorous. Line pressure monitoring is an essential component of the extracorporeal circuit and exceedingly valuable in avoiding potential retrograde dissection. The largest possible cannula should always be inserted into the femoral artery. In adults where the femoral artery will not accept at least a #18 french cannula, an aortic cannula is used. Using a cannula smaller than a #18 french creates extreme stress on connectors in the arterial pump line, increases the "jet stream" flow from the cannula and increases the turbulence at the cannula tip.

Early recognition of the signs of dissection and immediate attention to establishing antegrade flow can reduce the mortality of retrograde dissection.