PERFUSION OF THE CORONARY ARTERY DISEASE PATIENT

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With the development of coronary arteriography and the subsequent refinement of coronary artery grafting procedures the perfusionist is faced with a rapidly expanding patient load. The patient load has doubled and tripled in many institutions, and many hospitals without an open heart program are currently contemplating starting to "pump" the vein graft patient. Although the heart/lung machine is not always used for some of the easier approaches to the problem, it is usually necessary to have the equipment ready for use in case the need does arise.

Regardless of the technical approach to the problem, the surgery is directed with one idea in mind: to establish an increased supply of blood to a poorly perfused myocardium. The fact that the heart may be borderline should suggest that the slightest change in the patient's physiology may push it into acute failure. With this in mind the perfusionist should be especially careful with his technique.

It is becoming increasingly evident that the regular techniques of perfusion applied to congenital and valvular cases are not always adequate for the patient with coronary artery disease. Some of the special problems in perfusing these patients are usually recognized but nevertheless poorly understood. Indeed the available literature although recognizing the problems does little to delineate the physiological activity involved.

Problems

Four of the most widely recognized problem areas in dealing with coronary artery patients include control of hematocrit, pressure, serum electrolytes (especially potassium) and pre-surgical blood volume deficit. We have not completely resolved at our institution the question of hemodilution. Whereas we normally hemodilute to an hematocrit of around 25%, we are warned that reduction of the hematocrit below 35% is a significant cause for morbidity for patients with coronary artery disease. By necessity then, hemodilution techniques must be eliminated or modified so that a high hematocrit can be maintained throughout the perfusion. Normal serum electrolytes should be maintained.

At Ohio State, sodium and potassium determinations are made every 15 minutes while on bypass. Additional potassium chloride is added to the circulating volume through the pump to maintain a potassium ion concentration of from 3.5-4.5 mEq/L. This is extremely important if the patients are heavily digitalized at the time of surgery. We know that potassium concentrations can change remarkably fast and probably for a number of reasons including hyperventilation both off and on the heart/lung machine, acid-base imbalance and increased excretion of potassium by the kidneys.

The problems of maintaining a good arterial pressure and pre-surgical blood volume deficits are partially interrelated. Recognition of volume deficits in some coronary artery disease patients on an empirical basis is certainly not new. Studies already cited show that this phenomenon indeed does occur in many of these patients even when not on any regimen of diuretics.

It should be evident that the maintenance of good arterial pressure is not just dependent on flow alone but a functionally adequate volume in the patient-pump-oxygenator system. In the pressure = flow x resistance relationship resistance is dependent among other considerations, the compliance-volume-vasometer interaction.

Maintaining an adequate arterial pressure from the onset of bypass until its conclusion is certainly mandatory. Assigning specific values to what is adequate arterial pressure while on bypass is often done but is probably more of an empirical observation than documented fact. Discussions of critical closing pressure in the kidneys make for interesting conversations but to our knowledge have never been agreed upon by the scientific community. The effects of vasomotor sympathetic stimulation and inhibition, changes in hematocrit, and other changes in viscosity certainly affect renal blood flow. This is not to preclude the existence of such a physiological entity as critical closing pressure nor to understate the importance of maintaining kidney function throughout the perfusion but only to say that we are not cognizant of all the factors involved while on heart/lung bypass and
that central arterial pressure, while very important, is just one of many influencing factors in renal function and urine production.

THE DISEASED HEART

Why are the problems above so important, especially in the patient with coronary artery disease? A complete answer to this question is impossible at this time. However, in a general over-simplified way, we are sure of one thing. The diseased heart may be bordering between mere general over-simplified way, the patient with coronary artery disease? A good argument is yet to be resolved.

The diseased heart may have lost much of its ability to make compensatory changes and is severely limited in its blood flow autoregulation due to arteriosclerotic vascular changes. A significant stenosis greatly increases that vessel’s resistance. Blood flow and the perfusion pressure potential distal to the lesion are greatly decreased.

This fixed lumen imparts somewhat of a “fixed blood supply” effect at normal perfusion pressures. Should the pressure fall below what is “normal” for that heart, there may be a very pronounced decrease in the flow of blood in that vessel. As a general rule, we maintain at all times an arterial mean pressure while on heart/lung bypass equal to or greater than the pre-operative mean pressure.

An argument that appears valid is that in decreasing the hematocrit with hemodilution techniques, we are decreasing the oxygen carrying capacity of the blood and therefore reducing the amount of oxygen delivered to an already hypoxic myocardium. In such a situation, a sudden decrease in RBC concentration might be enough to cause the heart to fail. Even with optimal utilization of the available oxygen content it may be insufficient in light of the possibility that it may have been barely sufficient to maintain viability initially due to its compromised blood flow.

However, another argument that may also be valid relies on the concept of Poiseuille’s Law (\( \Delta P = \frac{8L}{R^4} FV \)) where \( \Delta P \) = pressure drop across the restriction, \( L \) = length of restriction, \( R \) = radius of restriction, \( F \) = flow, and \( V \) = viscosity.) In such a case, the decreased viscosity of a hemodiluted perfusate might make up for or even enhance the oxygen delivery to the ischemic heart. The dichotomy of the two arguments is yet to be resolved.

We have used both techniques; hemodilution and a mixed hematocrit of 25-30% and maintenance of mixed hematocrit above 35% with no apparent difference in postoperative morbidity.

As an assurance against hypotensive problems at the initiation of bypass, measures are taken toward correcting functional volume deficits in the coronary artery disease patients. This may be accomplished by transfusing fresh whole blood prior to bypass or by adding enough additional priming blood in the oxygenator-reservoir components of the extracorporeal system so that the patient is transfused from the pump at the onset of perfusion. It has been found that 2-4 units of fresh whole blood are often necessary.

Serum electrolytes affect myocardial contractility. Inotropic activity of certain drugs are dependent on the availability of certain free ions. Many of the coronary patients are maintained on cardiac glycoside therapy. The effects of such drugs as digitalis on myocardial contractility are dependent on the levels of potassium and calcium. When these levels change as they often do at surgery, myocardial effects will change.
Of the available means of measuring electrolytes, results of flame photometry potassium determinations are most readily available to us. Since potassium level fluctuations may rapidly occur and in that potassium is important in contractility, it is appropriate that it be monitored and changes reacted to in a positive manner such that the potassium level is kept within normal limits.

ANESTHETIC EFFECTS

Choice of anesthesia is not the responsibility of the perfusionist. Nevertheless, the choice of anesthesia may have implications on the perfusion. Penthrane and Fluothane are two agents often employed in cardiac surgery. These drugs depress metabolism and oxygen requirements so that we can usually pump these patients at basal or even below their resting cardiac indices and not incur a metabolic debt due to hypoxia.

"... make bypass as 'physiological' as possible."

This does not appear to be the case in the narcotized patient. Recent changes here have been to morphine, followed by morphine and alcohol, Innovar, and Fentanyl and alcohol. These drugs seem to increase the perfusion requirements by up to 50%. This increase is necessary to prevent anaerobic glycolysis with its decreasing base excess and pH.

We constantly monitor the venous pO2 with a Bentley IBC analyzer and attempt to achieve a flow rate that will provide a normal venous pO2. This is, of course, complimented with serial blood-gas and pH studies at 15 minute intervals while on bypass.

CONCLUSION

The management of the perfusion in all other respects is similar to the routine pump cases at this institution. Arterial blood pressure is monitored via a catheter inserted into the radial or femoral artery and connected to a Statham transducer and a Hewlett Packard series 780 8-channel thermal recorder and oscilloscope. Central venous pressure is monitored in either the IVC or SVC or both through the same recording system. ECG, arterial and venous pO2, esophageal and rectal temperatures are also recorded.

Blood is drawn at 15 minute intervals and pH, pCO2 and pO2 determinations performed on an Instrumentation Laboratory model 113 analyzer. At the same time, plasma potassium and sodium concentrations are determined by an Instrumentation Laboratory model 143 flame photometer along with a hematocrit determination using the microcapillary tube technique. Plasma samples are saved and subsequent plasma hemoglobin determinations made. Normal values are strived for during the perfusion in an attempt to make bypass as "physiological" as possible.

REFERENCES

10. Ibid. Gadum's Pharmacology.