

The Necessity for Arterial Extra-Corporeal Line Pressure Monitoring for Cardiopulmonary Bypass

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Abstract

The measurement and monitoring of the pressure generated by the arterial pump in the tubing proximal to the arterial cannula of the extra-corporeal circuit is important, as malposition of the arterial cannula can be avoided or corrected in many instances. This paper reviews the technique of arterial line pressure monitoring for cardiopulmonary bypass.

Introduction

Arterial line pressure monitoring is as old as perfusion itself,¹ however, it is not used universally by modern perfusionists. Some of them feel that it is an unnecessary complication of the perfusion circuit and that the line pressure can be assessed by feeling the arterial line with the fingers.

There are scattered but repetitive accounts in the literature of the hazards of arterial cannulation for cardiopulmonary bypass.^{2,3,4,5,6} The most recent account describing inadvertent carotid cannulation was

published in 1981.⁷ The technique, the potential dangers and the advantages gained before and during cardiopulmonary bypass (CPB) by using line pressure monitoring are given.

Technique and Potential Hazards

Arterial line pressure may be measured by connecting a pressure transducer or an aneroid manometer system to any point in the arterial circuit of the heart-lung machine between the arterial pump and the arterial cannula. Care should be taken that the pressure measurement system is air-free and that all connections in the system resist negative pressure air leaks.

This is important since a loose luer fitting in the pressure measuring system may be watertight under pressure, but may allow air to enter the arterial line of the heart-lung machine during the low-pressure phase of the pump cycle. A typical line pressure trace is shown in Figure 1.

The low-pressure phase is dependent on the elasticity of the pump tubing, the height of the pump head above the arterial reservoir of the oxygenator and the pressure gradient across the arterial cannula. Negative pressure exceeding -10 mmHg may be produced.

Routine monitoring of the line pressure at the connector which joins the arterial tubing of the heart-lung machine to the aortic cannula is recommended. Radial artery and superior vena caval pressures should also be

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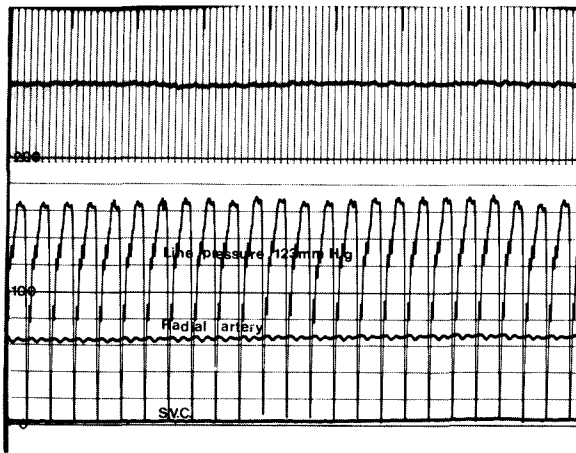


FIGURE 1. A typical line pressure trace is shown with a radial artery trace and a superior vena-caval trace. This trace was taken during total bypass and is identical to the oscilloscope display at that time.

monitored during bypass. These pressures should be displayed in phasic mode on an oscilloscope with digital meters so that they can easily be seen by the perfusionist, surgeon and anesthetist.

Information Obtainable After Cannulation_____

After aortic cannulation and before bypass is commenced, the arterial line of the heart-lung machine distal to the pump should be sharply squeezed between the fingers and palm of the perfusionist's hand. The following events should occur (Figure 2):

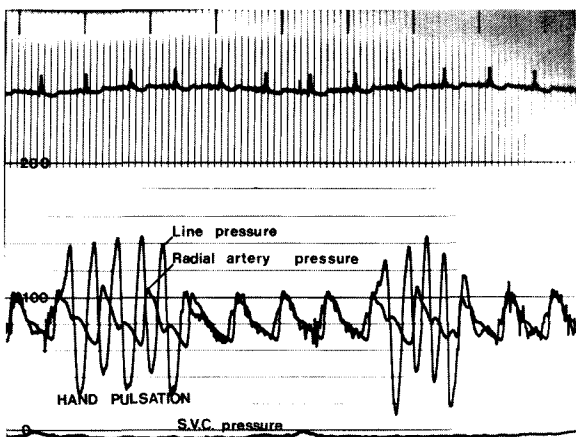


FIGURE 2. Before bypass the arterial line should be sharply pulsed by hand. These pulsations should be clearly seen on the line pressure trace but they should have little or no effect on the atrial pressure trace.

1. The line pressure dynamic trace on the oscilloscope should clearly show these extra pulsations.

2. These pulsations should not be obvious on the radial artery pressure trace.

3. The mean line pressure should remain unchanged through this period and should not fall with each pulsation of the line.

The perfusionist may derive the following information from this simple test:

1. The arterial and venous tubing of the machine are not reversed, and there is no clamp on the line between the pump head and the patient.⁸

2. The arterial cannula is probably not directed at or into the aortic arch vessels.

3. The cannula tip is not abutted against the aortic wall or positioned so as to cause an acute dissection of the aorta.

Information Obtainable During Bypass_____

Factors governing the arterial line pressure measured just proximal to the cannula include: the extra-corporeal blood flow rate; the length, configuration and internal diameter of the aortic cannula; the systemic vascular resistance (the radial artery pressure). Arterial line pressure should not exceed 200 mmHg at the blood flow rate required for cardiopulmonary bypass if proper care has been exercised in the choice of the right size of aortic cannula.⁹ Choice of the size of the aortic cannula should be based on the pressure drop across the cannula at the predicted blood flow rate required for the perfusion. Normally the pressure drop across the cannula of choice for aortic cannulation does not need to exceed 50 mmHg.⁹

As the blood damaging action of the arterial cannula appears to depend on the linear velocity and therefore the internal resistance of the cannula at a given blood flow,^{10,11} it is necessary to construct a reference table of cannula gradients for each size and type of aortic cannula used. This table could be constructed for infant, pediatric, and adult extra-corporeal circuits and cannula by retaining the CPB apparatus with the aortic cannula and pressure recorder after a case and recirculating the remaining blood through an open basin. With the aortic cannula mounted level with the pressure transducer and above the blood level of the basin, the flow rate may be varied in 500 ml/min steps and the resultant mean line pressure recorded. All the cannulae suitable for adult, pediatric and infant circuits may thus be tested with their respective circuits. The results so

TABLE 1
Example of a Table of Cannula Gradients, Blood
Htc 20%, Temperature 37°C

Blood Flow ml/min	Pressure	Gradient mmHg				
5 000						69
4 500						61
4 000				72		50
3 500			93	50		41
3 000			72	41		30
2 500			53	30		24
2 000		115	36	20		
1 500		67	22	14		
1 000	115	33	13			
500	30	12				
	10 Fr	14 Fr	18 Fr	21 Fr	24 Fr	
	Argyle THI* Angled Aortic Cannula					

*Sherwood Medical

obtained, may be tabulated for future reference (Table 1).¹¹

Should the mean line pressure exceed the mean radial artery pressure during total bypass by more than 1.5 times the calculated gradient for the arterial cannula in use at any given flow rate, there is a problem. An excessively high line pressure, possibly transient, with a low radial pressure, falling venous pressure and lowering of volume in the heart-lung machine at the start of bypass indicates the possibility of aortic dissection. The aorta itself may feel tense to the surgeon.

Elevated line pressure with unusually marked sympathetic radial pressure pulsations during bypass indicates malpositioning of the arterial cannula tip in the aortic arch. Under those conditions blood flow may thus be preferentially directed into the aortic arch vessels, or the cannula tip may be lodged in one of those vessels. If taped vena caval catheters are being used for venous return there may be a rise in superior vena caval pressure. There may also be an unusually marked visual difference in oxygen saturation between the blood in the superior vena caval cannula and that of the inferior vena caval cannula suggesting excessively disproportionate blood flow to the superior vena cava.⁷

Because it is possible to alter the positioning of the aortic cannula during cross-clamping of the aorta, it

is important to watch the line pressure at this time. The aortic cannula, especially the angled type, may turn 180° in the aorta and be caught in the aortic clamp.⁶ Almost instantaneous reaction in stopping the pump is necessary. Failure to react immediately may result in blow-off of the arterial line.⁸ All connectors in the arterial line should be tied with nylon ties except the connector at the aortic cannula. If blow-off of the arterial line occurs it will then be within the sterile field, at a high point in the circuit, and the problem can thus be easily and quickly solved.

Conclusion

Although the techniques mentioned are not new, arterial line pressure monitoring in conjunction with arterial and venous pressure monitoring give the perfusionist more control over the perfusion. Any line pressure measurement system is preferable to none, but the ideal system includes a pressure transducer and a dynamic line pressure display with a digital meter for mean line pressure.

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