Session 4. High arterial line pressure, poor venous return, venous air lock.

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Clinical Problems:
1. The perfusionist notes that the pressure in the arterial line going from the heart-lung machine to the patient is elevated.
   a. What is the “arterial line pressure”? What is its significance? Should it be monitored continuously in all patients during CPB? If so, why?
   b. What is the differential diagnosis of high arterial line pressure
   c. What is the role of the perfusionist, surgeon, anesthesiologist and “scrubbed nurse or technician” in evaluating and managing this problem?
   d. How would you “trouble-shoot” this problem and manage it?

2. The perfusionist is experiencing poor venous return from the patient into the heart-lung machine.
   a. What might be the cause of this?
   b. What regulates/determines the amount of venous return during CPB?
   c. What is the significance of poor venous return?
   d. What is the role of the perfusionist, surgeon, anesthesiologist and “scrubbed nurse or technician” in evaluating and managing this problem?
   e. How would you “trouble-shoot” this problem and manage it?

3. An “air-lock” is noted in the venous line going from the patient to the heart-lung machine.
   a. What is meant by an “air-lock”
   b. What is its significance
   c. How is it dealt with?

Suggested reading:

Discussion

High arterial line pressure

This refers to the pressure in the arterial line which runs from the heart-lung machine to the patient (in distinction to the pressure being monitoring in the patient’s arterial system via a line in the radial artery or elsewhere.) “Arterial line pressure” should be monitored in all patients immediately after connecting the arterial line from the heart-lung machine to the arterial cannula after it has been placed in the patient’s arterial system, and continuously throughout CPB. Immediately after connecting the arterial line to the arterial cannula which has been place in the aorta (or elsewhere) the “arterial line pressure” should be compared to the reading from the systemic arterial pressure line(i.e., in the radial or other arteries). The “arterial line pressure” should be pulsatile and have similar mean pressure.) The pressure port for the “arterial line pressure” is usually just proximal to the bubble trap/arterial microfilter. There should be an alarm on this pressure monitor which indicates over-pressure and some groups servo this into the arterial pump to slow it down or turn if off if excessive pressure is detected.

The differential diagnoses of high “arterial line pressure” include systemic arterial hypertension, placement of the arterial cannula into a branch vessel (e.g., innominate, left carotid, or left subclavian), intramural placement of the arterial cannula, aortic dissection, tip of arterial cannula abutting the wall of the aorta, kinking of the arterial line, clamp still on the arterial line, too small an arterial cannula, obstruction of the arterial microfilter/bubble trap, and excessive flow through the cannula (due to error in calibration or function of the arterial pump.)

Arterial pump flow should be reduced to lower the pressure until cause is discovered and corrected. Coming off bypass, if feasible, until the problem is resolved, should be considered. The entire course of the arterial line from heart-lung machine to patient should be examined. Noting the arterial pressure in the radial or brachial artery could provide clue to cannulation of one of the arch vessels, depending upon which arch vessel has been cannulated and which radial/brachial artery is being monitored. Checking and repositioning the tip of the arterial cannula should be considered. Visual examination of the aorta at the cannulation site by the surgeon for evidence of dissection, and examination of the aorta by TEE and epiaortic aortic scanning should be used to rule out dissection. This is particularly important when arterial inflow (cannulation) is via the femoral artery.
Low venous return

Usually venous drainage is provided by gravity drainage employing the siphon principle. A siphon requires that the drainage tubes be filled with fluid/blood at all times, i.e., that there is no large amount of air in the tubing (see discussion of air-lock below). The factors that influence the amount of venous return during gravity drainage are as follows:

- Pressure in the central veins or right atrium (CVP, RAP)
- Volume of blood in the systemic venous system
- Venous tone (influenced by sympathetic system and vasoactive hormones or drugs including anesthetic agents)
- Height difference between the patient (OR table) and the level of fluid in the venous reservoir.

- Resistance and any obstruction in the venous cannulae and the tubing leading from the patient to the venous reservoir.

The significance of low venous return are that it reduces the amount of flow which can be provided by the heart-lung machine (systemic blood flow), may lead to distension of the heart and compromise working conditions of the surgeon, and could result in an increase in the venous pressure.

Elevated venous pressure compromises perfusion of various organs especially since mean arterial pressure during CPB is often relatively low (50-60 mm Hg). This is of particular concern regarding cerebral blood flow. Thus it is critical that the pressure in the SVC cephalad to the tip of the SCV cannula (when bicaval cannulation is being employed) be monitored during CPB especially after the snare has been tightened around the SVC surrounding the cannula in the SVC. Note that the opening of the catheter through which SVC pressure is being measured must be cephalad to the tip of the SCV cannula. This may not be true if one is measuring the pressure in the CVP port of a PAC or from the tip of a CVP cannula which is in the RA or at the junction of the SVC with the RA. Use of the side arm of the central venous introducer may be required. One can determine that the cephalic SVC pressure is being monitored by having the surgeon briefy occlude the SVC cannula while on CPB after snaring the SVC (first warning the perfusionist that venous drainage may briefly decline) and documenting that the SVC pressure rises.

If venous return decreases markedly and suddenly and is not immediately recognized by the perfusionist, there is risk of the venous reservoir going dry and pumping air into the patient (This is less likely with use of collapsible venous reservoirs and centrifugal pumps.) Many teams include a level sensing device on the venous reservoir to alarm if the level gets too low, and may even slow or turn off the arterial pump. Air-bubble monitors on the arterial line which again may be directed to turn off the arterial pump may also prevent this disaster. The surgeon should warn the perfusionist anytime he/she does something that may suddenly reduce venous drainage (e.g., lift up the heart, readjust the venous lines, clamp a venous line.)

Based upon the factors that influence venous return during gravity drainage mentioned above, the differential diagnosis of low venous return include low blood volume in the patient (low volume before initiating CPB, autologous priming of the extra-corporeal circuit, and unappreciated loss of blood during CPB). Low central venous blood volume may manifest itself by “chattering” of the venous cannula (periodic occlusion of the venous cannulae due to the periodic collapsing of the walls of the right atrium
and/or central veins around the openings in the venous cannulae). Low venous return may be the first sign of blood loss due to aortic dissection. Hidden blood loss can also occur in the pleural cavities and at sites of peripheral cannulation (arterial or venous). Blood may be lost off of the field onto the drapes or onto the floor and not be appreciated. Redistribution of crystalloid prime and excessive urine output or fluid removal by ultrafiltration may lead to low blood volume. Other causes of decreased venous return include increased venous capacitance (administration of veno-dilators and inhalation agents), malposition of the tips of the venous cannulae (may be in hepatic, azygous or subclavian veins), kinking of the venous cannulae, obstruction by a PAC balloon, too small of venous cannulae, clamps still on the venous lines, long and narrow venous lines, and low difference between the height of the patient (OR Table height) and the venous reservoir.) Manipulation of the heart by the surgeon, especially elevating the heart to examine or perform coronary anastomosis to vessels on the back of the heart (PDA and circumflex vessels) often compromises venous return especially from the SVC if a two stage cavo-atrial cannula is used. Both adequacy of venous return, and SVC pressure should be monitored when the heart is elevated in this manner. Thorough examination of the operative field (by the surgeon and the anesthesiologist) and of the entire course of the venous cannulas and lines from patient to the heart-lung machine (by the perfusionist, surgeon and the anesthesiologist ) are essential in trouble shooting this problem. Collaboration between the anesthesiologist and perfusionist can be particularly helpful.

The advantage of the passive gravity system over the augmented venous system (e.g., employing vacuum or a pump to withdraw the venous blood from the patient) is that it tends to automatically adjust the venous return to that available from the systemic venous system.

**Augmented venous drainage**[by vacuum applied to a hard-shell venous reservoir or with use of a centrifugal (“kinetic”) pump] is used to overcome the problem of limited venous return with gravity drainage associated with use of long narrow venous cannulae and/or lines, or the desire to elevate the venous reservoir closer to the level of the patient. These conditions are encountered with peripheral venous cannulation, limited access surgery and with the effort to lessen the prime of the extracorporeal circuit. While augmented venous drainage overcomes some of the causes of limited venous return they impose other risks. These include increase risk of air aspiration, more difficult balancing of arterial flow versus the patient’s effective blood volume, and requirement of the perfusionist to carefully monitor the degree of negative pressure being applied to the venous cannula. Reduced venous return can still occur for many of the reasons listed above. In addition, when using vacuum augmented venous return, when the venous reservoir is closed (as it must be to apply vacuum), if no or inadequate vacuum is applied, venous return may be reduced, or cease, or, in the worse case, reverse flow can occur with risk of pushing air into the right heart.

**Venous air lock**

This is a hazard when using gravity drainage (which requires that the venous lines be full of fluid/blood.) If a considerable amount of air gets into the venous line (usually due to dislodgement of a venous cannula or one of its side-holes out of the vein or atrium) this will break the siphon and venous drainage will cease immediately. This is an emergency!
The arterial pump must be stopped (resulting in no systemic blood flow) and the venous line clamped near its entrance into the venous reservoir of the heart lung machine and the air lock eliminated as rapidly as possible. After the venous cannula problem has been corrected it may be possible to refill the venous line with blood by sequentially elevating the venous drainage tubing above the level which contains blood, starting at the patient and progressively moving towards the heart-lung machine, causing the air to progressively move towards the heart-lung machine. When most of the venous tubing is full of blood down to near the venous reservoir, the clamp on the venous line at the level of the heart-lung machine may be briefly released and the air will enter the venous reservoir, and then gravity drainage and CPB can be resumed.

Alternately the venous line can be disconnected from the venous cannula, both the venous line and the venous cannula can then be refilled with blood or saline, reconnected, and then CPB resumed.