Invasive hemodynamic monitoring

(The thermodilution catheter)

By Jillaine Corp, R.N.

In our role as part of the operating room team we need to be acutely aware of the importance of hemodynamic monitoring and our responsibility in helping to prepare the critically ill patient for procedures leading up to these sometimes invasive techniques.

As with anything, when an individual understands the "whys and wherefores" of different procedures and techniques, it stimulates interest and enables us to be of better assistance in the events that lead up to the actual establishment of a system - the system in this case is hemodynamic monitoring - particularly thermodilution.

The perioperative role

This article will attempt to give an overview of the perioperative role of the operating room nurse in dealing with some invasive monitoring techniques. Included in this will be various hemodynamic methods of monitoring patients and the use of a thermodilution catheter as an aid in monitoring cardiac output.

"Monitoring is not merely a process of measurement or a collection of data; it involves the analysis and interpretation of the data which has been collected."[1] The purpose of monitoring is to:

(1) identify the problem
(2) determine severity
(3) evaluate therapy

By definition, hemodynamics is the study of the movements of the blood. Advanced hemodynamic monitoring is especially important in the perioperative period because:
(1) Traditional signs and symptoms of cardiovascular failure can be hidden by anaesthesia and surgery;
(2) Cardiovascular function is put under stress by anaesthetic and surgical procedures, therefore changing the levels of hemodynamics;
(3) Hemodynamically unstable patients often have several organ systems that are impaired.

Impairment or inadequate perfusion

It is necessary to be able to distinguish between impairment caused by inadequate perfusion and impairment caused by previous disease.

The ultimate concern in any therapeutic intervention is the maintenance of oxygenation via tissue perfusion. In the critically ill, attainment of this goal is sometimes complex and elusive.

Cardiac function must be continually evaluated and optimized. To do this, there must be a way to determine how well the heart is performing as a pump. Hemodynamic monitoring provides this information directly by the measurement of cardiac output and intracardiac pressures. During surgery low cardiac output states can be encountered. It is our responsibility as operating room nurses to have the therapeutic modalities available for the anaesthetist to intervene. Consequently, we must have a

---

About The Author

Jillaine Corp R.N. is an operating room nurse at the Peterborough Civic Hospital and is in charge of the vascular theatre. A graduate of the Peterborough Civic Hospital School of Nursing and the University of Alberta Post Graduate Course for Operating Room Nurses, Ms. Corp is membership chairperson for the O.R. Nurses Association of South Central Ontario.

Measuring cardiac output with the thermodilution technique

Thermodilution is the calculation of cardiac output (CO) using temperature change as the indicator. Cardiac output is a measure of how many litres of blood per minute the left or right ventricle ejects (the CO of the left ventricle is essentially the same as the right) and is measured in litres per minute (L/M).

The normal range for CO is from 4 to 8 L/M; 5 L/M is considered the norm.

Cardiac output (CO) is a product of the heart rate (HR), multiplied by stroke volume (SV):

$$CO = HR \times SV$$

Heart rate (HR) measures how many times per minute systole occurs, the systole being that part of the heart cycle in which the heart is in contraction; that is, the myocardial fibres are tightening and shortening.

Stroke volume is a measure of how many millilitres the ventricle ejects with each systole.

Any increase or decrease in SV or HR will have an affect on the cardiac output (CO). Three factors affect stoke volume:

- the contractability of the ventricle
- the preload or filling pressure
- the afterload or the resistance the ventricle must overcome in order to empty.

Cardiac Index

Patients vary in size, thus it is difficult to compare cardiac output from one patient to another. The CO for one patient may not meet the required criteria for another patient. In order to eliminate this size variable, a cardiac index (CI) is calculated along with the CO.

The CI is the patient's CO divided by his/her body surface area (BSA). This can be obtained from the Dubois Surface Chart:

$$CI = \frac{CO}{BSA}$$

The CI designates how many litres per minute per metre squared the heart ejects. The normal CI range is from 2.7 to 4.3 L/Min./m^2. It is important to determine both CO and CI. When they are not adequate, poor perfusion to body organs/tissue can be experienced.

working knowledge of the pharmacological and physiological principles involved. Some results of low cardiac output could be:

(1) tachycardia - abnormally rapid heart action, ie., heart rate over 100/min.
(2) bradycardia - abnormally slow heart action, ie., heart rate under 60/min.
(3) ischemia/infarction of all organ systems especially cerebral, myocardial, renal and hepatic.
(4) hypotension.

Cardiac output can be determined by using pulmonary artery catheters and hemodilution techniques.

Cardial output measurements

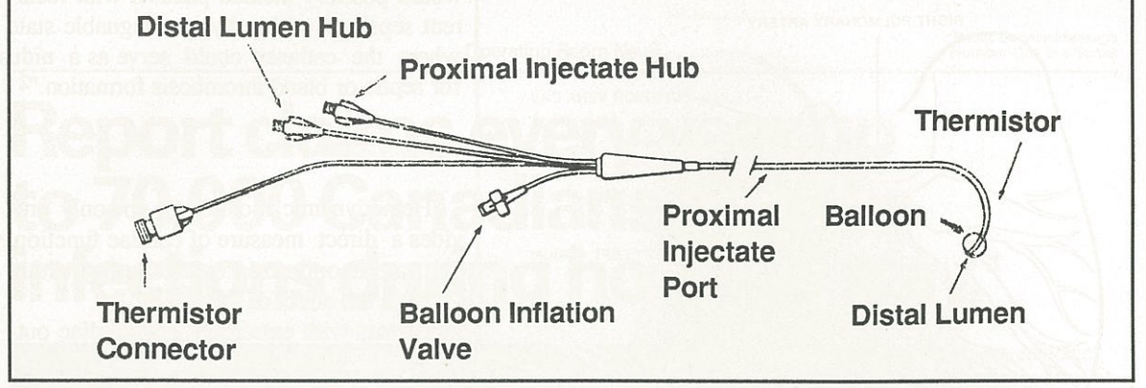
"The pressures generated by the heart cause blood to flow. The amount of blood pumped during one minute by a ventricle is called cardiac output."[2] Cardiac output is a function of heart rate and heart stroke volume. **(See box above)**

The thermodilution catheter is widely used for assessment of the cardiovascular system and cardiac output of the critically ill patient. These catheters provide the instrumentation for the detection of the temperature change necessary for cardiac output determination. Additional capabilities include intracardiac pressure measurement, blood sampling, and solution infusion. The thermodilution catheter is also a helpful adjunct in the diagnosis of ventricular septal defects, mitral regurgitation and cardiac tamponade. The use of pressure monitoring permits more accurate evaluation of and more precise therapy for the critically ill patient.

Thermodilution Technique

The process of thermodilution involves the measurement of the cardiac output by injecting a sterile solution, at a lower than body temperature, into the venous (typically right atrium) system.

Whether or not the injectate is cooled should be taken into consideration when preparing for the initial thermodilution set-up as time could be a factor in preparing for the anaesthetic set-up. (It takes approximately an extra 45 minutes when



A thermodilution (pulmonary artery) catheter

preparing the iced injectate). The procedure for cardiac output determination is the same when using iced or room temperature injectate.

"With minimal handling of the barrel of the syringe, (so as to not inadvertently warm injectate) the contents are rapidly injected as a bolus into the proximal catheter lumen, which empties into either the superior or the inferior vena cava near the right atrium or directly into the right atrium itself **(See illustration following page).** The injectate becomes thoroughly mixed with the blood by the time it reaches the pulmonary artery. The resulting blood/injectate mixture is cooler than blood alone. This temperature change is sensed by a small temperature transducer called a thermistor." 2

This thermistor is embedded in the catheter wall a short distance from the distal end. The proximal end is connected via an appropriate cable, to the recording instrument or computer. An average of three cardiac output measurements is recommended, thus allowing for the possibility of technical error.

Possible technical errors

Errors in measuring cardiac output by thermodilution can be caused by the following:

(1) the injectate gaining heat from the catheter;
(2) by warming of the syringe by handling before injection
(3) other technical errors can involve the volume of injectate and the timing of injection.

The common consequence in all of these is that they can cause the cardiac output measurement to increase or decrease. Also, thermodilution cardiac output should not be determined while cautery is applied because the electrical noise will erroneously affect the pulmonary artery baseline temperature.

Although we, as O.R. nurses, are not directly involved with the interpretation of the cardiac outputs, we should be aware of the external forces that may inappropriately influence them. Other errors could be caused by:

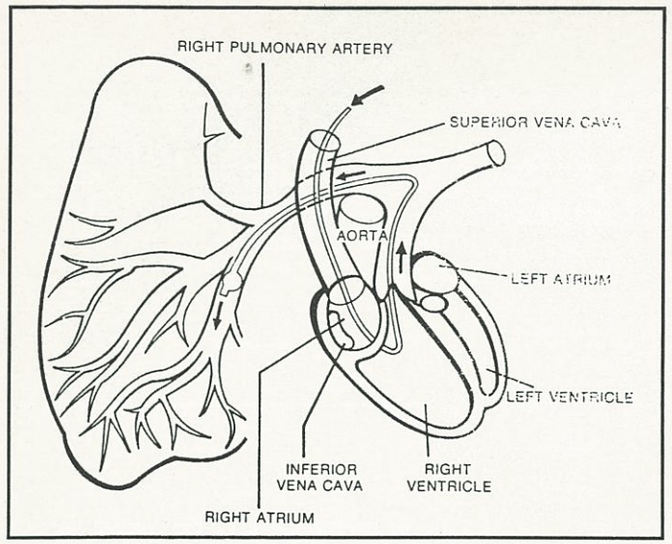
(1) poor injection techniques
(2) improper positioning of the "thermistor"
(3) variations in the cardiac rate or rhythm (for this reason ECG should be recorded during cardiac output determination)
(4) patient movement or change in position
(5) change of patient temperature
(6) change in hemodynamic state (more readily identified if pressures are recorded before and after each set of cardiac output determinations)
(7) volume of injectate-decreased volume will give a falsely high reading
(8) timing of injectate - since the ratio of venous return is changed by respiration it will alter the pulmonary artery temperature - depending on when injection is made a different cardiac output will result.

Considerations for set-up

When preparing for hemodynamic monitoring short extension tubings are advised as there is less chance of hidden areas of air bubbles. Also, disposable domes may overpressurize the transducer, resulting in constant negative drift during surgery. To prevent this, alternate snugging and loosening of the dome on transducer is advised.

A word about technique

To prevent accidental intra-arterial injections, extension tubes and stopcocks should be labeled. Always be alert and watch for clots and air bubbles in



Pulmonary artery catheter insertion

lines. Keep stopcocks capped and sterile. Disconnection may lead to hemorrhage or air embolism, so it is recommended that only LUER-LOK connectors be used. Be sure to keep catheters and lines visible.

To prevent nosocomial infection, sterile prep and gloves should be used. This helps protect both patient and anaesthetist from potentially fatal illnesses.

Take time for safety

An important part of our role in the mechanics of monitoring patients is to bear in mind that the patient has been connected safely and reversibly to a piece of equipment. As more invasive monitoring techniques are used, along with more electronic surgical instrumentation, the risk of patient morbidity related to electrical shock increases. "The utilization of non-invasive modalities whenever possible will further reduce the risk of increasing morbidity or mortality from the monitoring process itself. This may be due to electrical hazards, or other dangers such as infection."[1]

The need for regular routine inspection and maintenance is essential in order to ensure that monitoring equipment functions reliably, accurately, and safely. Cost allowance for this must be included as part of the hospital budget. Neglect of this policy invites legal action, with far greater costs.

Contraindications

"There are no absolute contraindications to the use of floatation catheters - such as those used in thermodilution monitoring. Relative contraindications would possibly include patients with recurrent sepsis or with a hyper-coaguable state where the catheter could serve as a nidus for septic or bland thrombosis formation."[2]

Conclusion

Hemodynamic monitoring not only provides a direct measure of cardiac function, but care is optimized by measuring within minutes the effect of therapy.

Patients with extremely low cardiac output are likely to be the ones who depend the most upon accurate invasive hemodynamic monitoring. Regardless of calculations, we must always be aware of the patient, not numbers at the end of cables. ■

References

(1) Hope, C., Morrison, D., "Understanding and selecting monitoring equipment in anaesthesia and intensive care," *Canadian Anaesthetists' Society Journal,* Volume 33, Number 5, September, 1986.

(2) "Understanding hemodynamic measurements made with the Swan-Ganz® catheter," Edwards Laboratories, Division of American Hospital Supply Corporation (Baxter Canada), May, 1979.

Bibliography

(1) Hug, Carl Jr. M.D., PHD., "Management of hemodynamic instability complicated by hypotension," American Society of Anesthesiologists, annual refresher course lectures and annual meeting, October, 1984.

(2) Nadeau, S., Noble W., "Limitations of cardiac output measurements by thermodilution," *Canadian Anaesthetists' Society Journal,* Volume 33, Number 6, November, 1986.

(3) Bedford, Robert, M.D. "Prevention and treatment of complications of invasive hemodynamic monitoring," American Society of Anesthesiologists, annual refresher course lectures and annual meeting, October, 1985.

Acknowledgement

Dr. J. Chirico, staff anaesthetist, Peterborough Civic Hospital, Peterborough, Ontario.