Update:

Monitoring Cardiac Outputs

by Kenneth N. Hicks, CBET, and Kevin Lynch, RRT, CPFT

Since the article by Swan, Ganz, et al,[1] was published in 1970, the use of pulmonary artery catheters for the determination of cardiac pressures has come to be a routine part of critical care medicine. Probably the biggest advance in Swan-Ganz catheters was the addition of a thermal thermistor for determining cardiac output (CO). As with any other medical intervention, there are questions concerning this very invasive procedure.

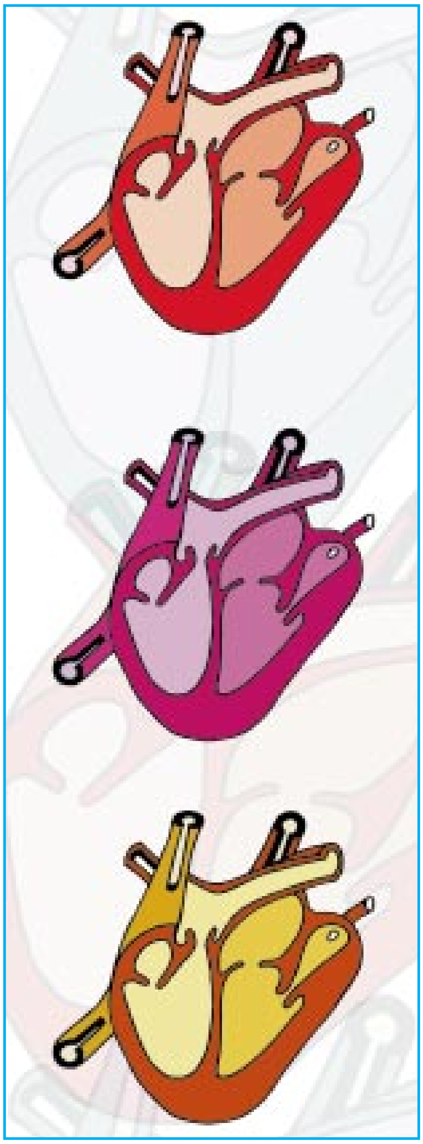
A review of the medical journals lists a number of complications with pulmonary artery catheters, such as infection,[2] intracardiac knotting,[3] catheter perforation of the pulmonary artery causing cardiac tamponade,[4] hemorrhage,[5] ventricular arrhythmia,[6] and complete heart block.[7] The incidence of these complications is low but must be kept in mind.

There have never been any prospective studies showing the benefit/risk of pulmonary artery catheterization. David Spodick, MD, FCCP, in his recent paper in *CHEST*, ably pointed this out.[8] There are many ways to determine CO; however, only a few are clinically viable, and even fewer are currently accepted. Increased attention is currently going to the lesser-invasive and lesser-sedated methods. This article reviews the various indications for monitoring and the methods available.

Some of the indications for monitoring include management of PEEP and volume therapy, distinguishing between cardiogenic and non-cardiogenic pulmonary edema, unresponsive congestive heart failure, diagnosis and monitoring of pulmonary hypertension, major cardiac surgery, and complicated myocardial infarction.[9-10] Trying to diagnose problems or predict trends of cardiopulmonary status would be difficult without the input of these various methods.

Fick Method — This has been the standard to which most methods are compared. The Fick Method is complex for clinical applications since metabolics must be considered to arrive at accurate values (invasive catheter). The cost of equipment and time required to make measurements are usually undesirable; consequently, it is not widely used clinically. No other method compares to the accuracy of the Fick Method, which is why it is usually the method of choice for research.

Thermodilution — This method is commonly used in the operating room and intensive care unit envi-



ronments. The major disadvantage to this method is a catheter must be inserted in the right heart and pulmonary artery. Placement is critical but has become a common well-learned technique.

Thermodilution has several advantages, which include very accurate data due to the measurement technique, and little or no artifact from other systemic or monitoring systems. This is a very good method for the operative and immediate postoperative patient where cardiac function requires monitoring. Measurement is performed by periodically injecting a known volume and temperature (usually 10 cc at less than 25 degrees Celsius) fluid proximal to the right ventricle. The temperature gradient is constantly monitored at the pulmonary artery, and CO can be determined by integrating the temperature curve.

A variation of this technique, continuous cardiac output (CCO), has been adopted for the same environment. This method uses the same principles; but instead of injecting a cold fluid, the catheter incorporates a continuous heating element that heats the blood proximal to the right ventricle. The integral of the temperature curve is used to calculate CO. Cost arguably overcomes any benefits of CCO over traditional thermodilution CO.

Thoracic Impedance — This method measures normal expansion and contraction of the thoracic cavity to determine CO. This method is noninvasive, since it only involves the placement of external electrodes; and it is very economical. It can be used effectively for follow-up cardiac events without the costs of analgesia or anesthesia to sedate the patient. Currently, clinical acceptance has been slow due to the lack of artifact rejection by this technique. Any movement like non-resting respiratory, mechanical ventilation, abdominal motion, or manipulation of patient, decreases the ability of this method to provide clinically accurate CO values. An example of this type of device would be the new BioZSystem by Cardiodynamics.

Transesophageal Echo-cardiograph — This method uses ultrasound to determine flow in the descending aorta via introduction of an ultra sound probe into the esophagus. CO is calculated by the descending aorta diameter, and blood flow is measured by the Doppler effect of the ultrasound-returned echoes. Advantages of this system include visual mapping of other thoracic areas using complex FFT math functions that are displayed as real time images of the cardiac area. This allows physicians to view heart valve motions and blood flow regurgitations in real time on a display. Cost and complexity of this technique, along with the need to sedate the patient, are some of the major disadvantages.

A variation of this technique is the esophageal Doppler monitor, an example being the CardioQ developed by Deltex. These function in the exact same way as the transesophageal echocardiography (TEE), except that no visual images depicting vascular contour are provided. This helps remove some of the disadvantage of cost and complexity; however, placement is still as critical as it is with the TEE. One of the biggest advantages of the system is the small size of the Doppler probe, approximately the same size as an 18 French nasal gastric tube. Esophageal problems may contraindicate its use.

Transthoracic Echo-cardiograph — This method uses ultrasound on the outside of the thoracic area. This method is noninvasive and does not require sedation of the patient, which is a major advantage. Complexity, however, is a major disadvantage. A clinician must manipulate the ultrasound transducer to acquire left ventricular internal diameter for diastole and systole. Therefore, accuracy is also often compromised due to the operator's ability and quality of the ultrasound signal returned from the patient via potential patient-related abnormalities (or obesity). This method is costly and time consuming, which is probably why it is not practiced very widely.

Fick Partial Re-breathing — This method is one of the newest methods available. Many advantages show great promise for this technique. Low cost, less invasive, and ease of use are the major advantages. This technique uses carbon dioxide (CO_2) rebreathing by the patient and is based on a stable arterial CO_2. The machine looks at the difference in end-tidal carbon dioxide levels when rebreathing CO_2 and nonrebreathing CO_2, which allows the computation of CO. However, even though this method is considered a noninvasive technique, intubation and mechanical ventilation are usually necessary. Further refinement of this technique should help it gain clinical acceptance. The NICO system from Novametrix would be an example of this technology.

Summary

Other techniques exist for CO, such as dye injection, but the techniques discussed here are the most accepted. Several methods have advantages over others; but, unfortunately, no method is ideal for all situations. Highest consideration should be given to providing high-quality care to the patient, with his comfort being a close second. Patient comfort should outweigh some cost and a little accuracy when non-diagnostic use is concerned.

Clinicians should consider the contraindications for each method and potential risk in not performing CO measurements. Many other physiological indicators offer information about cardiac function. Don't overlook them when evaluating the CO numbers given by any technique. The respiratory therapist and critical care nurse will have new equipment choices to add to their armamentarium.

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EDITOR'S NOTE

The equipment referred to are mentioned only as examples of new technology. The authors and Baylor University Medical Center are not endorsing the use of any particular piece of equipment in this article.

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