Transpulmonary Thermodilution Cardiac Output Measurement Using the Axillary Artery in Critically Ill Patients

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Study Objective: To compare cardiac output (CO) as measured by the arterial thermodilution technique using only a central venous catheter and an arterial catheter inserted into the axillary artery, with conventional CO measurement with thermodilution using a pulmonary artery (PA) catheter (PAC).

Design: Prospective clinical study in which each patient served as his/her own control.

Setting: General ICU of a large tertiary-care teaching hospital.

Patients: 22 patients who required invasive hemodynamic monitoring in the ICU.

Interventions and Measurements: CO measurements made using the PAC (COpa) were compared to bolus arterial thermodilution measurements (COax). The significance of acute changes in the continuous CO measurements during acute hemodynamic episodes was observed.

Main Results: The correlation between the two techniques (COpa and COax) was $R^2 = 0.82$. There was a tendency for 5% overestimation of COpa by the COax. The SEM% (SEM/average CO) for COax and COpa was 2.6% and 3.2%, respectively. The bias between measurements was $0.27 \pm 0.67$ L/min, and the limits of agreement (mean difference $\pm 2$ SD) from minus 1.07 L/min to 1.63 L/min.

Conclusions: In critically ill patients, in whom the measurement of CO is required, arterial thermodilution, using a central vein and the axillary artery is accurate and reproducible. © 2002 by Elsevier Science Inc.

Keywords: Axillary artery, cardiac output, monitoring, pulmonary artery catheter, thermodilution.

Introduction

In many patients with hemodynamic instability or critical illness, it is important to measure cardiac output (CO) to assess perfusion to the various organs and tissues. The value of CO is also important in determining responsiveness to volume loading and to various hemodynamic maneuvers. The ideal “gold standard” method for the measurement of CO is still to be determined. Various
methods of measuring CO include use of the Fick equation, pulmonary artery (PA) thermodilution, acetylene gas rebreathing, and Doppler probes introduced into the esophagus, to name a few. The most common method of measuring CO involves the use of the pulmonary artery catheter (PAC), utilizing the thermodilution technique. However, in recent years, the use of PACs has become controversial.1

A relatively new technique of CO measurement is that of transpulmonary indicator dilution (TPID), or arterial thermodilution. In this method, a cold indicator solution is injected into a central vein and the temperature change is measured by a thermistor-tipped catheter inserted into a large artery.2 This technique can provide CO measurements without the need for a PAC, and is thus beneficial in many patients in whom the insertion of a PAC may be problematic or risky. A major advantage of this method is that because many patients in the ICU and the operating room require the use of central venous cannulation and an arterial catheter anyway, obtaining CO measurements in these patients may be achieved without additional invasive monitoring. Recently, the validity of this technique has been demonstrated in patients undergoing cardiac surgery,3,4 and critically ill patients.5

The technique of transpulmonary CO measurement requires the insertion of a thermistor-tipped catheter into a large artery, most commonly the femoral artery. In many patients who require invasive monitoring, the use of the femoral artery for cannulation is impractical; for example, in patients undergoing vascular surgery such as aortofemoral bypass, patients with severe atherosclerosis, or patients who undergo coronary artery bypass graft (CABG) but are expected to benefit from intraaortic balloon assist after surgery. We therefore examined the feasibility and accuracy of arterial thermodilution with axillary artery cannulation. We compared the CO measurements obtained with a new transpulmonary thermodilution system (PiCCO, Pulsion Medical Systems, Munich, Germany) through the axillary artery to conventional measurements using a PAC.

Materials and Methods

After approval of the Sheba Medical Center ethics committee and obtaining of informed consent, 22 ICU patients (ages 27 to 79 years) who required invasive monitoring with a PAC were entered into the study.

After insertion of the PAC (Swan-Ganz VIP, Baxter Health Care Corporation, Edwards Critical Care Division, CA) via the right jugular vein using a 8.5 Fr introducer (Arrow International, Reading, PA), the axillary artery was cannulated using a sterile technique with a 4F thermistor-tipped catheter (Pulsion Medical Systems AG, Munich, Germany). The axillary artery CO (COax) was then measured using an injectate of 0.2 mL/kg body weight iced water with the PiCCO device (Pulsion Medical System AG, Munich, Germany), the same bolus injection was used for the measurement of PAC thermodilution (COpa). Measurements were performed in triplicate, at least every 6 hours over each 24-hour period, or when deemed necessary by the attending physician.

Correlation coefficient of COax versus COpa was calculated using Pearson’s linear regression analysis. The association between corresponding CO values was assessed according to the recommendations of Bland and Altman.6 The mean of the differences between values thereby provides a measure of the bias or systemic error between two methods. The standard deviation (SD) of the differences, also denoted as SD of bias (precision value), represents the variability between the different techniques, bias ± 2 SD of bias denoting the “limits of agreement.” The reproducibility of each one of the measurements was evaluated by examining the standard deviation of repeated measurements of CO done during a stable period. The percent standard error of the mean (%SEM: SEM/average CO) was calculated for each study for conditions of one and three measurements per determination.7 In addition, the direction of change between consecutive measurements in both methods was compared to indicate the ability of the COax to indicate the same change shown by the COpa.

Results

A total of 190 measurements were performed in 20 patients (4 to 16 measurements per patient, mean 9.5). Two patients were excluded from the study due to failure of axillary artery cannulation. In one patient, the study was stopped after four measurements due to axillary catheter failure. The mean COax was 6.56 ± 1.57 L/min and the mean COpa was 6.29 ± 1.56 L/min. The correlation coefficient between the two measurements was 0.82 (R2) (Figure 1), the precision (bias, mean difference) between measurements 0.27 ± 0.67 L/min, and the limits of agreement (mean difference ± 2 SD) from −1.07 L/min to 1.63 L/min (Figure 2).
The SEM%, (SEM/average CO) for COax and COpa was 2.6% and 3.2%, respectively, for measurement in triplicate and 4.45 and 5.66, respectively, for a single injection measurement.

Table 1 demonstrates the direction of change between measurements using the two techniques. Of 168 measurement pairs, 135 showed the same direction in change. In 33 measurement pairs, the two methods demonstrated a change in different direction.

There were no complications due to the axillary arterial cannulation.

Discussion
The position that the PAC has traditionally held in the armamentarium of the ICU clinician as the major monitoring tool for hemodynamic management is changing significantly. It has been shown that many clinicians who are using the PAC are not familiar with it. Connors et al. showed that mortality is increased in patients who are monitored with this tool.

A relatively new technique for CO monitoring is arterial thermodilution. This technique is used for bolus measurements of CO, and it uses a thermistor placed in a large artery, usually the femoral artery. A bolus of cold indicator is injected into the right atrium, is mixed with the flowing blood in the right ventricle, and thus the relative change in temperature reflects the CO flowing through the cardiovascular system. This action enables measurement of the CO even though the temperature change is measured in a relatively small portion of the systemic blood flow; in our patients, in one arm.

Because the flow of the injectate occurs through a larger volume of distribution than with conventional thermodilution using a PAC, a larger injectate bolus is required, and only ice cold injectate can be used. The current system requires that an injectate volume of 0.2 mL/kg be used. Development of the system is expected to reduce the required injectate volume, as well as enable use of room temperature injectate.

The technique has been validated in many studies and has been found to correlate well with a CO measurement obtained with a PAC. The arterial thermodilution measurements tend to overestimate the PAC CO measurements by approximately 5% to 10% due to the increased indicator loss when using this method.

Although the most frequently used artery for monitoring blood pressure is the radial artery, the use of a large artery such as the femoral artery is not uncommon. In some patients, however, the use of the femoral artery is precluded for various reasons. In these patients, the use of the axillary artery is an option.

The use of the axillary artery for arterial catheter cannulation is well established. In contrast to the brachial artery, the axillary artery is not an end artery, and there are adequate collateral arteries in the shoulder, which prevent ischemic damage to the arm even in the event of thrombosis due to the catheter. In our group of 22 patients, there were no complications of axillary artery catheterization. As with any other vascular catheter, attention should be paid to the possibility of trauma to the artery, and in prolonged catheterization, the possibility of intravascular infection should be considered.

In conclusion, we find that in critically ill patients, accurate CO measurements can be obtained using the transpulmonary technique using the axillary artery, reliably, with a 5% tendency to overestimate the CO obtained with PA thermodilution.

| COpa | ↑ | ↓ | ↑ | ↓ | — | — | ↑ | ↓ | — |
| COax | ↑ | ↓ | ↑ | ↑ | ↑ | ↓ | — | — | — |
| Measurements | 64 | 70 | 9 | 9 | 3 | 1 | 7 | 4 | 1 |

↑ = increase in CO, ↓ = decrease in CO, — = no change in CO.

References


