Validity and Reliability of Cardiac Output by Arterial Thermodilution and Arterial Pulse Contour Analysis Compared With Pulmonary Artery Thermodilution in Intensive Care Unit

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Abstract

Cardiac output measurement has a significat role in the critical care setting. The standard of mesurement currently is *via* pulmonary arterial catheter but it has some technical difficulties and serious complications. The authors performed a new method of measurement that used a catheter in a femoral artery. The results of both methods performed simultaneously in 10 surgical intensive care patients every 2 hours for 24 hours were compared. There was high correlation between the two methods, r = 0.97. The average difference of the cardiac output values was 0.46 l/min with standard deviation 0.56 l/min.

Key word : Cardiac Output, Thermodilution, Pulse Contour Analysis

WERAWATGANON T, PUNYATAVORN S, CHATKAEW P, BUNBURAPHONG P
J Med Assoc Thai 2003; 86 (Suppl 2): S323-S330

Pulmonary artery catheter is a monitoring device. It provides estimation of cardiac output (COpa) and cardiac preload pulmonary capillary wedge pressure (PCWP) which are very useful information for the management of critically ill patients(1,2). However, it is an invasive procedure and is associated with the risk of serious complications(3) such as ruptured pulmonary vessel(4), displacement(5,6), infection, pneumothorax, etc(7-13). The procedure is complicated and the monetary cost for this monitoring is also rather high. So it is reserved only for strongly indicated situations.

There have been many efforts to find other methods for cardiac output monitoring(14-26). One

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of the most promising methods to replace pulmonary artery catheter is arterial transpulmonary thermodilution (COart) and arterial pulse contour analysis(27-30). It is a new, less invasive and simple method to monitor the cardiovascular function. It requires a special thermistor-tipped catheter inserted in an artery, usually the femoral artery, to detect the temperature and pressure in the large artery. When 10-15 ml of cold saline was injected into a central venous line, the authors calculated the cardiac output from the

Table 1. Patients' characteristic.

Age	Diagnosis	Operation	Medical Problem	Medication
66	Esophageal cancer	Esophagectomy	Cirrhosis	Dopamine, adrenaline
88	Bladder cancer	Cystectomy	Wound infection	Adrenaline
59	Liver Cyst	Unroofed cyst	Hypernatremia	Dopamine, dobutamine, adrenaline
69	Triple vessels disease	Coronary bypass	Hypertension, paroxysmal SVT	Amiodarone, diltiazem, nitroglycerine
67	Triple vessels disease	Coronary bypass	Hypertension	Enarapril
68	Coronary artery disease	Coronary bypass	Diabetes mellitus	Dopamine, nitroprusside
59	Coronary artery disease	Coronary bypass	Diabetes mellitus	Dopamine, nitroprusside
40	Coronary artery disease	Off pump coronary bypass		Nitroprusside
53	Coronary artery disease	Coronary bypass	Diabetes mellitus	Diltiazem
77	Triple vessels disease	Coronary bypass	Hypertension	Nitroprusside, adrenaline

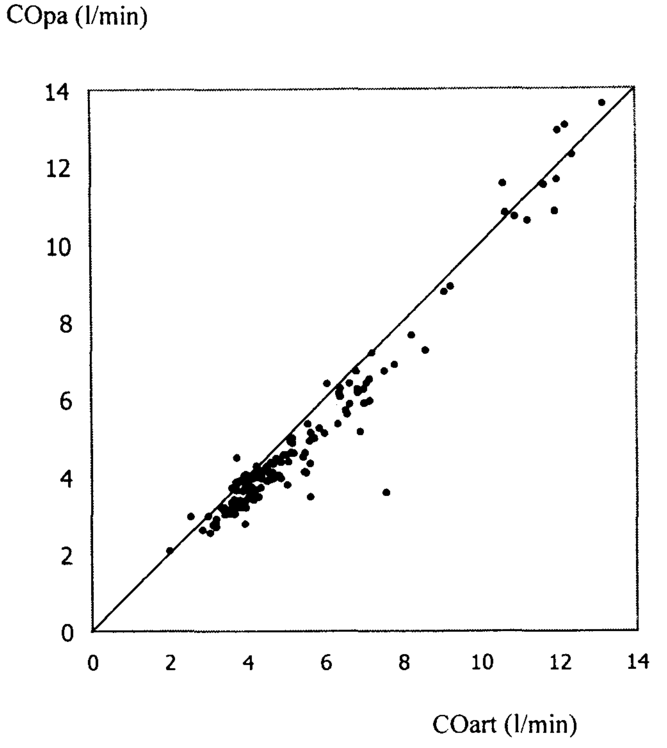

Fig. 1. COpa and COart plotted along the line of equality.

temperature change in the large artery by using Stewart-Hamilton algorithm. Then the area under the arterial pressure curve can be calibrated with the acquired cardiac output parameter. When there is any further change in cardiac output, the arterial pressure curve will change and the area under the curve can be used to calculate the pulse contour cardiac output (PCCO) continuously every second. In addition to continuous cardiac output capability, it provides intrathoracic blood volume and extravascular lung water parameters calculated from temperature dissipation. The authors therefore, aimed to test the validity and reliability of this technique for cardiac output measurement with the gold standard technique using the pulmonary artery catheter to assess its usefulness in clinical practice.

MATERIAL AND METHOD

The study protocol was approved by the Ethical Committee of Faculty of Medicine, Chulalongkorn University. Ten critically ill adult patients in the surgical intensive care unit who required intensive cardiovascular function monitoring and who would have benefited from this hemodynamic parameter information were included in the study. Discussion with the patients or their responsible relatives and obtaining written informed consent were required for the study. The exclusion criteria were congenital and valvular heart disease.

Pulmonary artery catheter (Baxter, CA, USA) was placed *via* the right internal jugular vein and an arterial catheter (Pulsiocath™, PV2014L16, Germany) in the femoral artery by Seldinger's technique. After calibration, the cardiac output from pulse contour analysis was recorded. Then both catheters were processed to determine cardiac output simultaneously by thermodilution principle. Ten ml of cold saline, < 8°C was rapidly injected three times randomly spreading over the respiratory cycle. The average of these three

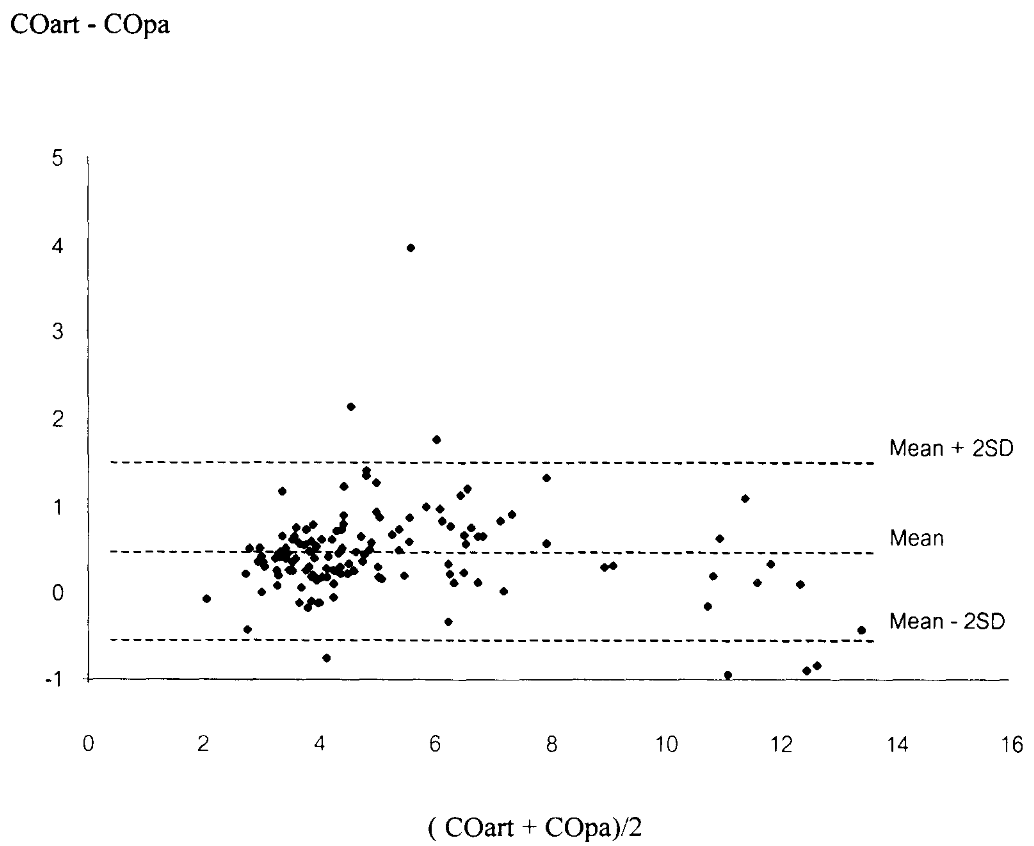

Fig. 2. The difference between COart and COpa was plotted against the average of the two measurements. The dotted lines are the mean of the difference and limits of agreement.

values of cardiac output was used for the analysis. Data from the measurements were provided for the physician who was responsible for each patient's management so that adjustment of treatment for the benefit of the patient was possible. The data collection was repeated every two hours for 24 hours. Before each subsequent thermodilution, the authors recorded the cardiac output from arterial pulse contour analysis (PCCO) twice one minute apart. The two values of PCCO were compared to show the repeatability of measurement and the last value of PCCO was used to show the agreement with the standard thermodilution measurement. Complications from both methods were looked for and recorded.

Statistical analysis

By using the SPSS version 9.0 statistical software, the correlation of the data was calculated and displayed in a scatter graph. The bias of the data from transpulmonary thermodilution and arterial pulse contour analysis were evaluated with the concurrent data from the pulmonary artery catheter using the Bland and Altman method[31]. The bias was calculated as the mean difference between the two measurements. The upper and lower limits of agreement were calculated as ± 2 SD of the bias. The range was expected to include 95 per cent of the difference between the two methods. The precision of the bias was assessed by using 95 per cent confidence intervals.

RESULTS

The authors recruited 3 patients from the general surgical intensive care unit and 7 patients from the cardiac surgical intensive care unit (Table 1). The means ± SD of age, weight, and height were 64.6 ± 13.1 yr, 61.3 ± 11.5 kg and 162.0 ± 9.6 cm, respectively.

There were 130 pairs of measurements between COpa and COart. The COpa range was 2.1-13.6 l/min and COart range was 2.0-13.2 l/min. The pairs of data were plotted along the line of equality (Fig. 1) for previewing the degree of agreement between the measurements. There was high correlation between the two methods, Pearson's correlation coefficient, r =

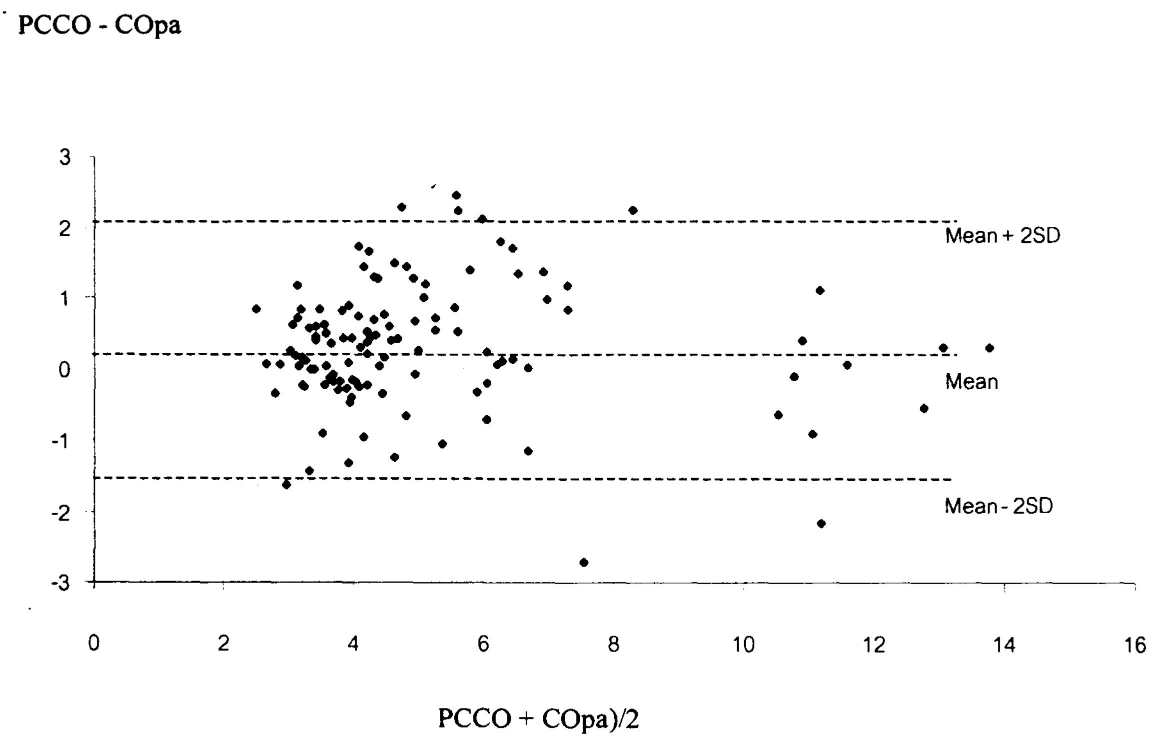

Fig. 3. The difference between PCCO and COpa was plotted against the average of the two measurements. The dotted lines are the mean of the difference and limits of agreement.

0.97. The mean difference between COart and COpa bias was 0.46 l/min and SD was 0.56 l/min. So the limit of agreement was between - 0.65 to 1.56 l/min (Fig. 2), whereas, the 95 per cent confidence interval of the mean difference was 0.36-0.56 l/min.

The agreement between PCCO and COpa after calibration for 2 hours was fair. The mean ± SD of bias was 0.29 ± 0.94 l/min and the limit of agreement was between -1.58 and 2.16 l/min. (Fig. 3)

The mean difference between two PCCO measuring one minute apart was 0.0057 l/min with 95 per cent confidence interval from -0.076 to 0.065 l/min and SD equaled 0.40 l/min. (Fig. 4)

The mean difference between two COpa values measured one minute apart was 0.03 l/min with SD equaled 0.67 l/min.

The outlier that had the highest difference of various methods of cardiac output measurements occurred in a patient during an attack of paroxysmal supraventricular tachycardia (SVT) with ventricular rate 150 beats/min at the time cardiac output being measured.

There was difficulty while inserting the femoral artery catheter in two patients who required replacement of the guide wire. There were problems obtaining PCWP measurement after 4-6 hours of the study but in four patients the pressure curves and the radiologic images confirmed that the catheter tips were still in the pulmonary artery. No other catheter-related complications were found during the study period.

DISCUSSION

The thermodilution cardiac output measurements from the pulmonary artery catheter and femoral catheter were highly correlated with r = 0.97. On average, COart was higher than COpa approximately 0.46 l/min. This result agreed with the range found in previous studies. For example, Della Rocca found that the mean bias between COart and COpa was 0.15 (2SD of differences between methods = 1.74) l/min (32), whereas, the authors' two standard deviation was 1.12 l/min. Some small differences between the studies might come from the variation among different groups

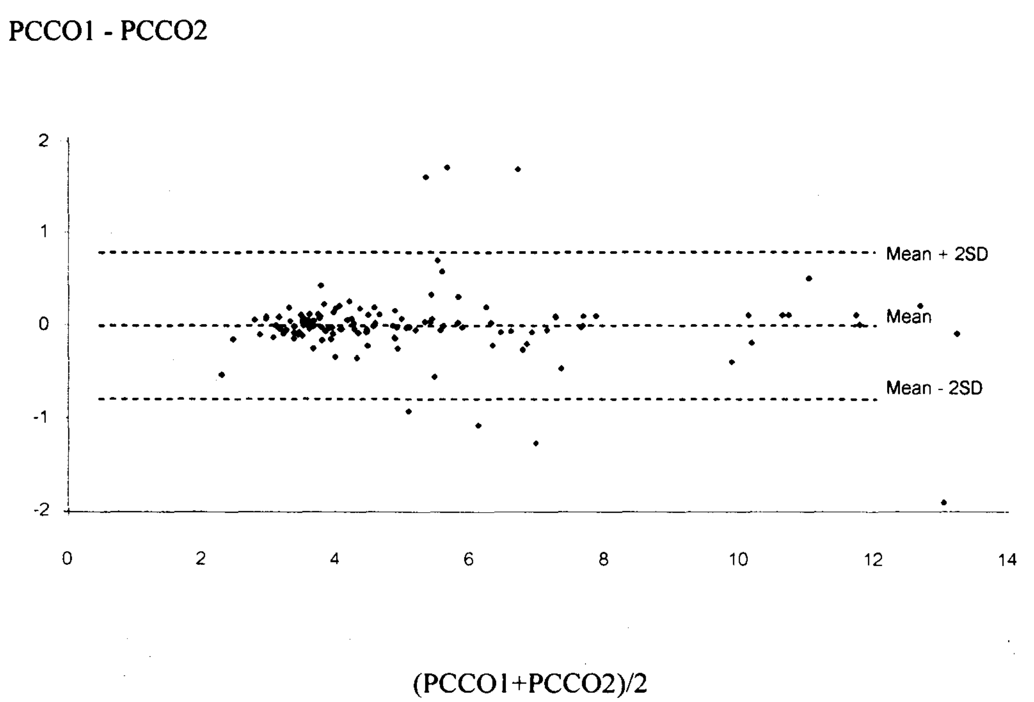

Fig. 4. The difference between two values of PCCO measured one minute apart was plotted against the average of the two measurements. The dotted lines are the mean of the difference and limits of agreement.

of patients. The authors studied critical patients in the surgical intensive care unit who had a high variation of cardiac output ranging from 2.1 to 13.6 l/min.

For the pulse contour cardiac output, the agreement with COpa was fair. The mean of bias was 0.29 l/min (2SD = 1.88 l/min) which was a little higher than previous studies(32,33). For example, Rauch found that the mean bias between PCCO and COpa was -0.14 (2SD of differences between methods = 1.16) l/min (33). The authors used the PCCO that had been calibrated 2 hours previously for comparison because the manufacture recommended calibration at this interval in unstable patients.

When the repeatability of PCCO was assessed by comparing the values obtained one minute apart, the authors found acceptable repeatability with mean of difference nearly zero and SD 0.40 l/min, 95 per cent of differences was expected to be less than the two standard deviations.

One of the limitations of the present study was some outliers found during some measurements, especially in patients with arrhythmia. In real clinical practice, if obtained a value that was out of range from the previous measurement was obtained, there should be a repeat for a new measurement. Discarding these outlier values would improve the agreement(31).

Another limitation was the gold standard of the cardiac output measurement for comparison. The cardiac output from pulmonary artery thermodilution was chosen because it was the most commonly used method in clinical practice and in most of the previous studies(29, 32-35). The mean difference between two consecutive COpa measurements showed some variation (mean difference = 0.03 l/min, SD = 0.67 l/min). The authors tried to improve the reliability and validity by using the average of three measurements spread over the respiratory cycle.

In conclusion, the new measurement, both COart and PCCO, had acceptable agreement with the standard method and could be a good alternative for monitoring cardiac output of adults in the intensive care unit. Further work should be conducted to study whether it could improve the patients' outcome and the usefulness of other parameters especially extravascular lung water, intrathoracic blood volume, and global end diastolic volume in clinical practice.

ACKNOWLEDGEMENT

The authors would like to thank Zovic company for equipment support in the study.

(Received for publication on April 21 2003)

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ความถูกต้องและความน่าเชื่อถือของการวัดปริมาณเลือดที่ออกจากหัวใจโดยการวิเคราะห์ความเปลี่ยนแปลงของอุณหภูมิและความดันในหลอดเลือดแดง

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พรเลิศ ฉัตรแก้ว, พบ, ปวีณา บุญบูรพงศ์, พบ**

การวัดปริมาณเลือดที่ออกจากหัวใจมีประโยชน์ในการดูแลผู้ป่วยในภาวะวิกฤต การวัดด้วยวิธีมาตรฐานคือใส่สายเข้าหลอดเลือดไปยังปอดทำได้ยากและอาจมีภาวะแทรกซ้อนที่อันตราย เราจึงทำการวัดด้วยวิธีใหม่โดยใส่สายเข้าหลอดเลือดแดงที่ขาเปรียบเทียบกับวิธีเดิม ศึกษาผู้ป่วยในหออภิบาลผู้ป่วยหนักจำนวน 10 ราย วัดด้วยวิธีทั้งสองพร้อมกันทุกสองชั่วโมงเป็นเวลา 24 ชั่วโมง พบว่ามีความสัมพันธ์กันถึง 0.97 และมีความแตกต่างกันเฉลี่ย 0.46 ลิตร/นาที ส่วนเบี่ยงเบนมาตรฐาน 0.56 ลิตร/นาที ซึ่งแสดงว่ามีค่าใกล้เคียงกันยอมรับได้ สามารถใช้แทนการวัดด้วยวิธีมาตรฐานได้ดี

คำสำคัญ : ปริมาณเลือดที่ออกจากหัวใจ, อุณหภูมิในหลอดเลือดแดง, ความดันในหลอดเลือดแดง

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