Cardiothoracic Anesthesia, Respiration and Airway

Cardiac output by PulseCO™ is not interchangeable with thermodilution in patients undergoing OPCAB

[Objectif : Vérifier la fiabilité de l’évaluation du débit cardiaque par PulseCO™ par ordres de tension artérielle (PulseCO™) comparées à la thermodilution de bolus chez des patients devant subir un PACCB]

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During cardiac surgery, especially off-pump coronary artery bypass grafting (OPCAB), heart rate and arterial blood pressure change dynamically and sometimes dramatically. Under these conditions, a beat-by-beat cardiac output (CO) measurement is useful to understand hemodynamics.

The thermodilution technique of determining CO using a pulmonary artery catheter is standard. However, the thermodilution technique requires several stable cardiac beats to calculate CO from the temperature time curve. In contrast, the PulseCO™ (Lidco Ltd., London, UK) calculates CO from the arterial pressure waveform of a peripheral artery such as the radial artery using autocorrelation by nonlinear transformation of the input analogue arterial pressure. Therefore, the PulseCO™ can determine beat-by-beat CO. However, the arterial pressure waveform often changes during surgery because the arterial compliance changes according to sympathetic activity, intravascular blood volume, position, etc. These factors may induce miscalculation of the CO by PulseCO™ because of inaccurate estimation of pulse wave velocity. The purpose of the present study was to determine whether CO measured by the PulseCO™ is interchangeable with CO measured by the bolus thermodilution method with the Vigilance™ monitor (Edwards Lifesciences LLC, Irvine, CA, USA) in patients undergoing OPCAB.

Methods
Twenty-three patients scheduled to undergo OPCAB were enrolled in this study after obtaining informed consent to the institutionally approved protocol. Patients who suffered from aortic valve stenosis and regurgitation were excluded from the study. After premedication with oral diazepam 10 mg, anesthesia was induced with midazolam 0.15 mg·kg⁻¹ iv and fentanyl 10 µg·kg⁻¹ iv. Endotracheal intubation was facilitated with vecuronium 0.15 mg·kg⁻¹ iv. Anesthesia was maintained with midazolam, fentanyl and vecuronium. After induction, radial artery and pulmonary artery catheters (Edwards Lifesciences LLC, Irvine, CA, USA) with a 9 Fr introducer (Percutaneous Sheath Introducer Kit, Arrow International, Bernville, PA, USA) were inserted. CO was measured after induction to calibrate the PulseCO™ and, subsequently, after sternotomy, after opening the mediastinum and at the end of surgery. No vasopressor or vasodilator drugs were used until coronary artery bypass grafting was initiated. CO by the standard thermodilution method was measured using the Vigilance™ system. Other variables were measured by standard monitors (Life Scope 9™, Nihon Kohden, Tokyo, Japan). The PulseCO™ was connected to the patient monitor and analyzed the arterial pressure waveform to calculate CO. The PulseCO™ was initially calibrated with the value of CO measured by thermodilution, and no recalibration was performed during the study. For the thermodilution method, CO was measured three times by injection of 0.2 mL·kg⁻¹ saline of less than 5°C and the mean value was calculated.

Statistical analysis
Data are expressed as mean ± standard deviation (SD). Hemodynamic variables were analyzed by repeated measures analysis of variance with Bonferroni correction. Correlation between CO measured by the PulseCO™ and thermodilution was determined by linear regression analysis. The Blant-Altman plot was used to compare the bias (the mean of the differences) and limits of agreement (bias ± 2 SD of bias) between the two methods. A priori, a difference within the range of ± 0.5 L·min⁻¹ was considered clinically acceptable to support the conclusion that the two methods are interchangeable. A P-value < 0.05 was considered statistically significant.

Results
Fourteen males and nine females with a mean age of 68 ± 9 yr were controlled. Mean height and weight were 159 ± 9 cm and 61 ± 11 kg, respectively. Hemodynamic data are presented in Table I. Heart

<table>
<thead>
<tr>
<th></th>
<th>Control (calibration)</th>
<th>After sternotomy</th>
<th>After opening the mediastinum</th>
<th>At the end of surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate (min⁻¹)</td>
<td>57 ± 8</td>
<td>66 ± 16*</td>
<td>72 ± 12*</td>
<td>86 ± 14*</td>
</tr>
<tr>
<td>Mean arterial pressure (mmHg)</td>
<td>75 ± 12</td>
<td>74 ± 15</td>
<td>67 ± 12*</td>
<td>72 ± 12</td>
</tr>
<tr>
<td>Mean pulmonary artery pressure (mmHg)</td>
<td>16 ± 5</td>
<td>15 ± 4</td>
<td>14 ± 4</td>
<td>17 ± 4</td>
</tr>
<tr>
<td>Central venous pressure (mmHg)</td>
<td>7 ± 4</td>
<td>8 ± 4</td>
<td>6 ± 4</td>
<td>7 ± 3</td>
</tr>
<tr>
<td>Pulmonary vascular resistance (dyne·sec⁻¹·min⁻³)</td>
<td>1816 ± 820</td>
<td>1791 ± 631</td>
<td>1522 ± 598*</td>
<td>1250 ± 480*</td>
</tr>
<tr>
<td>Pulmonary vascular resistance (dyne·sec⁻¹·min⁻³)</td>
<td>374 ± 185</td>
<td>367 ± 139</td>
<td>293 ± 94*</td>
<td>286 ± 103*</td>
</tr>
</tbody>
</table>

Data are expressed as mean ± standard deviation; *P < 0.05 vs control (calibration).
rate increased after sternotomy, after opening the mediastinum and at the end of surgery \((P < 0.05)\). Mean arterial pressure decreased \((P < 0.05)\) after opening the mediastinum. Systemic and pulmonary vascular resistance were also lower \((P < 0.05)\) after opening the mediastinum and at the end of surgery compared to control values. The correlation coefficients \(R^2\) were relatively low between COs measured.
by the PulseCO™ and thermodilution (Figure 1). The bias was positive at every measurement (Table II, Figure 2). The limits of agreement exceeded the predetermined limits judged to be clinically acceptable.

**Discussion**

The main result from this study was the observation that PulseCO™ may overestimate CO in patients undergoing OPCAB, when compared to CO measured by thermodilution.

The method to determine CO from characteristics of the arterial pressure waveform is called the ‘pulse contour method’.3 Pulse contour methods use properties of the aorta and arterial system to determine an aortic flow from an arterial pressure waveform. However, aortic pathology and variations in the aortic sectional area present challenges in calibrating arterial pressure waveform in individual patients. Therefore, pulse contour methods require calibration by another method.2 Originally a lithium chloride indicator dilution technique was used to calibrate the PulseCO™ measurement.7,8 However, in the present study, the PulseCO™ was calibrated with CO measured by the bolus thermodilution method using a pulmonary artery catheter, because a lithium chloride indicator was not available for this purpose in Japan and the bolus thermodilution method is the current standard to measure CO.1 In the present study, CO measured after induction was the same between the two methods.

The PulseCO™ has previously been reported to be a useful CO monitor after cardiac surgery.9 However, in the present study, correlation coefficients between CO measured by the PulseCO™ and thermodilution were smaller, moreover, and bias was relatively larger than documents in previous studies.2,10 The observed bias from 0.30 to 0.76 L·min⁻¹ and limits of agreement exceeding ± 0.5 L·min⁻¹ suggest that the PulseCO™ overestimates CO measured by thermodilution in patients undergoing OPCAB.

The PulseCO™ algorithm uses aortic flow velocity to calculate CO from the mean arterial pressure.3 However, velocity may change by alteration of cardiac and/or arterial compliance, even when mean arterial pressure remains the same. In cardiac surgery, cardiac compliance changes markedly due to the alteration of intrathoracic pressure by sternotomy and opening the mediastinum. In addition, arterial compliance may be altered by vasoactive drugs (e.g., phenylephrine, dopamine, nitroglycerine) or body temperature. However, the PulseCO™ cannot continuously measure the arterial compliance. Therefore, the PulseCO™ has the potential to miscalculate CO due to ‘drift’ and may need several calibrations to measure CO during surgery. In our study, we calibrated the PulseCO™ only once, reflecting how it is generally used in the clinical setting.

We conclude that CO measurement by PulseCO™ is not interchangeable with CO measured by thermodilution in patients undergoing OPCAB.

**References**


