Can Estimated Continuous Cardiac Output Be Used in the Same Manner as Arterial Pressure-Based Cardiac Output?

Estimated continuous cardiac output (esCCO) is a new parameter for estimating cardiac output (CO) and stroke volume (SV) and continuously displaying biological information using pulse waves obtained with a pulse oximeter and electrocardiogram and blood pressure*. *Either invasive or non-invasive measurement can be used for blood pressure.
I herein report on evaluation of the precision and trackability of esCCO and the feasibility of fluid management using esCCO.

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1. Introduction

Estimated continuous cardiac output (esCCO) is a technology for calculating cardiac output (CO) non-invasively and continuously using pulse wave transmit time (PWTT). PWTT is the transmit time of the pulse pressure waveform generated when blood from the left ventricle is released. Defining the start point as the electrocardiogram (ECG) R-wave and the end point as the rise point where the differentiated pulse oximeter wave reaches 30% of its peak amplitude, Nihon Kohden independently defined PWTT as the time from the start point to the end point. PWTT is comprised of the pre-ejection period (PEP) up to release of blood to the aortae, the time from the aortae to the radial artery (PWTT1), and the time from the radial artery to the fingertip (PWTT2). PEP is affected by the contractile force of the heart, and PWTT2 is affected by peripheral vascular resistance. For esCCO, calculation of CO is begun by performing calibration using patient characteristics. During calibration, pulse pressure is calculated from blood pressure, and CO is calculated using the formula esCCO = (K × PP) × HR. After calibration, CO is calculated non-invasively and continuously by means of continuous measurement of PWTT based on the formula esCCO = K × (α × PWTT + β) × HR (α: constant, β and K: constants determined by patient).[1] According to the latest Enhanced Recovery After Surgery (ERAS) Society Recommendations (2018),[2] high-risk patients require proper adjustment of individual Frank-Starling curves using a minimally invasive cardiac output measurement device,[3,4] improvement of intravascular volume and circulating blood volume while evaluating the degree of dehydration is recommended for fluid therapy.[5] Arterial pressure-based cardiac output (APCO) is often used, but esCCO can be used without the risk of securing the radial artery and at a lower cost as compared with APCO. The advantages of being able to use esCCO in the same manner as APCO are substantial.

2. Comparison of stroke volume index calculated using esCCO and stroke volume index calculated using APCO with the thermodilution method as the standard

We previously compared the precision of esCCO and the precision of APCO in kidney transplant patients with a history of cardiovascular events, using CO measured by the thermodilution method with a pulmonary artery catheter as the standard,[6] and reported that the precision of CO calculated with esCCO was comparable to that of CO calculated with APCO. These data were reanalyzed, and the precision of stroke volume index (SVI) calculated using esCCO (esSVI) and SVI calculated using APCO (APSVI) was compared with that of SVI calculated using the thermodilution method (ISVI).[7] Calibration was carried out using patient information and radial pulse pressure. The correlation coefficient of esSVI and ISVI was 0.68, the bias was -3.0 cc/m^2, and the precision was 8.8 cc/m^2 (percentage error: 33.5%) (Fig. 1). The correlation coefficient of APSVI and ISVI was 0.51, the bias was 0.9 cc/m^2, and the precision was 11.2 cc/m^2 (percentage error: 42.6%) (Fig. 2). Like CO, the precision of esSVI was comparable to that of APSVI.

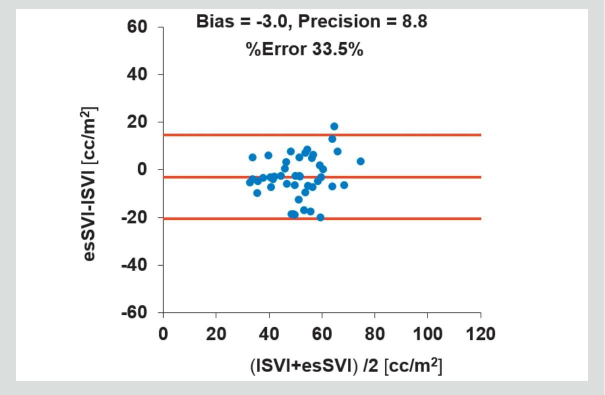

Figure 1 Bland-Altman analysis of esSVI and ISVI

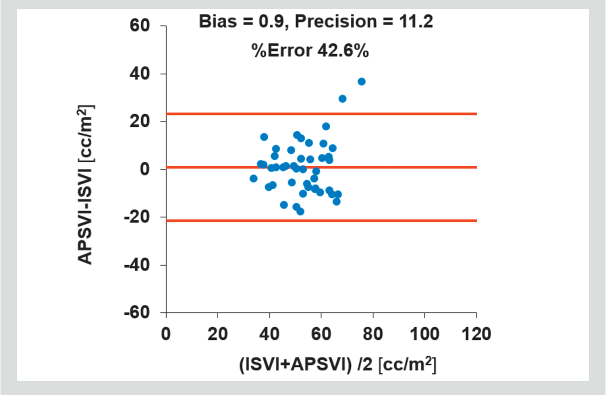

Figure 2 Bland-Altman analysis of APSVI and ISVI

3. Evaluation of trackability of esCCO using APCO as the standard

Next, we investigated the trackability of esCCO in non-cardiac surgery without a change of position, using APCO as the standard.[8] Improving intravascular volume and circulating blood volume while evaluating the degree of dehydration is recommended when performing fluid therapy in high-risk patients. APCO is often used for this purpose, and fluid responsiveness is used to evaluate it. If it can be demonstrated that esCCO has trackability comparable to that of APCO, it could serve as a useful parameter in clinical practice. APCO is considered to be more precise[9,10] than pulmonary artery catheter as long as there are no major changes in hemodynamics and the fluid volume is not excessive. In our research, we compared systemic vascular resistance index (SVRI),[10] which is said to have good APCO precision, using only data within the range of 1200-2500 dyn·sec·m^2/cm^{-5}, and assumed a central venous pressure of 11 mmHg when measuring SVRI. We found a mean angular bias of 3.5°, a radial limit of agreement of 28.3°, and trackability that trended well (Fig. 3).

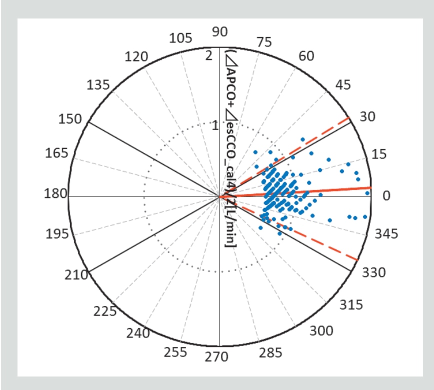

Figure 3 Polar plot of esCCO and APCO

Discussion

We were able to confirm that SVI calculated using esCCO was not inferior to SVI calculated using APCO as compared with the thermodilution method. SVI is often employed as an index of volume load, and it is used as the standard for fluid responsiveness. As such, it is used as a parameter for circulation management. Moreover, the trackability of esCCO trended well with APCO as a control. There has been a report of a comparison of the thermodilution method and esCCO in patients requiring a pulmonary artery catheter, and a report of a study that found no correlation or trackability.[11,12,13] However, these reports involved studies in ICU patients and severe cases,[12,13] i.e., patients with markedly unstable hemodynamics following cardiac surgery,[13] for instance. Although it has been reported that PWTT may accurately measure SV despite changes in vascular resistance since it includes factors that reflect cardiac function and peripheral vascular resistance, such as PEP and PWTT2,[14] the precision of esCCO may decrease in situations where hemodynamics are markedly unstable. The present results showed that SVI calculated using esCCO was equally precise as SVI calculated using APCO, and it was also found to trend well with APCO in terms of trackability. This suggests that it may be possible to use esCCO in clinical practice. Due to its non-invasive nature, it could be used in various settings, such as fluid management in the outpatient setting, in the examination room, and before and after surgery.

Summary

Having more clinical indicators such as cardiac output (stroke volume) in addition to blood pressure and pulse for preoperative and postoperative management is effective for circulation management including safe fluid management of patients. Moreover, the ability to perform non-invasive measurement lends itself to a wide range of applications. However, the characteristics of the parameter need to be fully understood in order to maximize the effectiveness of the parameter.

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