Correlation of Cardiac Output Measured by Thermodilution and Non-Invasive Continuous Monitoring

Thermodilution using a pulmonary artery catheter (PAC) has been considered the reference gold standard to measure cardiac output in critical patients. Consequently, new, less invasive technologies have been developed, with the advantage of providing continuous information. The validation of these methods was carried out by comparing them with thermodilution. Results are controversial due to their poor accuracy and concordance.

One of the least invasive techniques is the continuous monitoring by the plethysmographic analysis of the arterial pulse wave transit time (esCCO, Nihon Kohden, Tokyo, Japan). This technique provides real-time information on the transmission of blood pressure from the cardiac pre-ejection period during transit through large intrathoracic vessels, such as the aorta, and peripheral vessels - such as the radial artery - to generate the pulse wave in oximetry (references). It is a novel tool, and one of the few truly non-invasive systems for hemodynamic monitoring. It only requires usual elements for the monitoring of critical patients, such as electrocardiographic tracing, invasive or non-invasive blood pressure measurement, and pulse plethysmography.

Calibration of the equipment can be carried out by means of a calculation algorithm, which uses the patient's own data, such as weight, height and age, and blood pressure and pulse oximetry values. While it is a simple, innovative, and attractive method, different researchers have not found an adequate concordance with cardiac output measurement by thermodilution.

Our purpose was to compare cardiac output measurements by esCCO and by thermodilution. Our hypothesis was that both methods are not interchangeable.

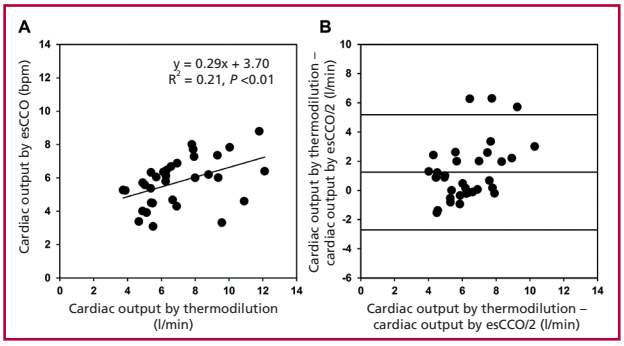

Fig. 1. A. Linear correlation between cardiac output by PAC and by esCCO. **B.** Bland-Altman plot of cardiac output by PAC and by esCCO.

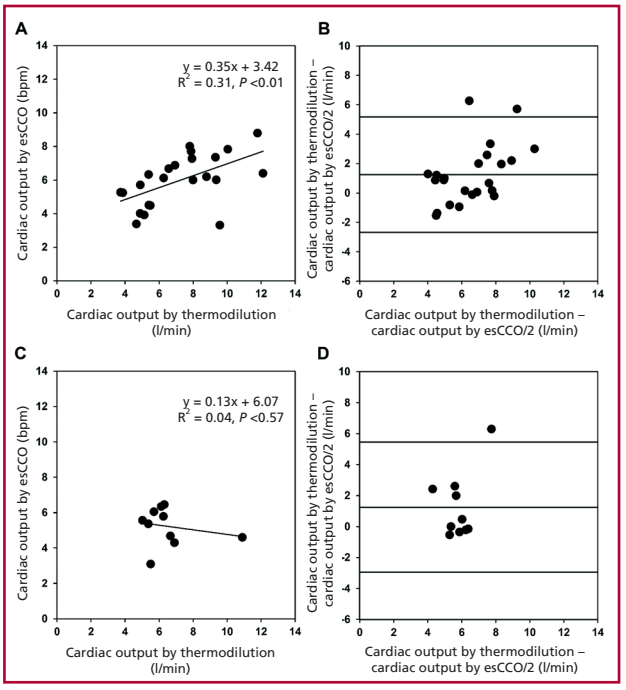

Fig. 2. A. Linear correlation between cardiac output measured by PAC vs. esCCO in patients with noradrenaline. **B.** Bland-Altman plot of cardiac output measured by PAC vs. esCCO in patients with noradrenaline. **C.** Linear correlation between cardiac output measured by PAC vs. esCCO in patients without noradrenaline. **D.** Bland-Altman plot of cardiac output measured by PAC vs. esCCO in patients without noradrenaline.

All patients requiring a pulmonary artery catheter were consecutively included. A multiparametric Nihon Kohden triton BSM 6300/6500 monitor (esCCO, Nihon Kohden, Tokyo, Japan) was used. Patients with arrhythmia, stent grafts, intra-aortic balloon counterpulsation, or cardiac pacemaker were excluded.

Cardiac output was also measured with a pulmonary artery catheter. The average of three measurements made by injecting isotonic saline at room temperature was considered.

Cardiac output measurements by both methods were correlated by the least squares method, and their concordance was evaluated by the Bland and Altman method.

A total of 33 measurements were performed in 17 patients. The correlation between cardiac output measured by thermodilution and by esCCO was poor but significant. The esCCO systematically underestimated the thermodilution values, and the 95% concordance limits were 7.9 l/min (Figure 1). Correlation was not significant in patients treated with noradrenalin (Figure 2).

Our main finding has been that esCCO measure-

ments are poorly correlated with thermodilution measurements, and underestimate them. In addition, we have found that concordance limits between the two methods are broad, therefore, they are not interchangeable.

Previously, other authors, such as Ishiara or Yamada, had found different results. However, in those cases, the initial calibration of the esCCO system had been performed based on the cardiac output provided by thermodilution, and not by the automatic exclusion algorithm with the data from the patient's hemodynamic trend.

Thereafter, a new algorithm was developed to perform the calibration of the equipment based on patient data. The most attractive feature of this non-invasive method is precisely that it does not require the patient's instrumentation, but if the data provided by the calibration algorithm are not comparable to those of the Swan Ganz, the method would lose all its benefit.

Recently, Takashi found an error of -0.4 ± 1.1 l/min in kidney-transplant patients, even though the calibration of the device had been performed with the calibration algorithm along with patient data, and not based on the data provided by PAC.

Conversely, other authors have concluded that, while non-invasive features of this new technology and the ability for continuous cardiac output measurement make it attractive when using current algorithms, the error level is too high and questions the usefulness of the method for decision-making.

Critchley and Critchley had previously stipulated that, for a minimally invasive method to be acceptable, it should have an error <30%; however, that limit is too wide, as adding the intrinsic error of the Swan Ganz would increase it by 45%.

It is also interesting to highlight the possible influence of systemic vascular resistance on esCCO measurements as previously pointed out by other authors; however, this is not fully understood, and its true role is unknown.

Another factor to be considered is the use of vasopressors in our population. The use of noradrenaline has been described as one of the elements interfering with the plethysmographic variability index; in our work, correlation improved significantly in patients without noradrenaline compared with those receiving vasopressors (R^2 0.3 vs. 0.02) (Figure 2).

The small number of patients was the main limitation of our work. On the other hand, most patients were undergoing postoperative liver transplantation. In these patients, changes in systemic the hemodynamics and vascular resistances of the different territories after surgery could impact on cardiac output.

Despite these limitations, we can confirm that in this population the esCCO system was not able to assess cardiac output values.

Conflicts of interest
None declared.

(See authors' conflicts of interest forms on the website/ Supplementary material).

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Polymorphic Ventricular Tachycardia and Long QT Syndrome Associated with Clarithromycin Therapy

We report the case of a 73 year-old female patient, allergic to penicillin, ex-smoker, with a history of hypertension (HT), chronic obstructive pulmonary disease (COPD), anticoagulated paroxysmal atrial fibrillation (AF), and a VVIR permanent pacemaker (PMK) implantation in the last year due to cardiogenic syncope in the context of brady-tachycardia syndrome.

The patient was admitted to hospital due to hypertensive acute pulmonary edema (APE), with adequate response to diuretic therapy and intravenous (IV) vasodilator. Moreover, the patient presented with a clinical condition consistent with exacerbated COPD, for which treatment with IV clarithromycin was started at a dose of 500 mg every 12 hours. The ECG on admittance revealed: sinus rhythm, heart rate (HR) 75 bpm, QRS axis between –30° and –60°, P wave 80 ms, PR interval 160 ms, QRS 160 ms, QTc 391 ms and complete left bundle branch block image.

Seventy two hours after admission, the patient developed multiple episodes of nonsustained polymorphic ventricular tachycardia (nsVT) with hemodynamic decompensation, manifested with presyncope (Figure 1). Surface ECG revealed PMK rhythm alternating with own sinus rhythm, complete left bundle branch block image at HR of 75 bpm, polymorphic ventricular extrasystoles (VE) with R-on-T phenomenon, fusion and pseudofusion beats, and prolonged QT interval with QTc of 671 ms (Figure 2).

It was decided to stop clarithromycin therapy; ten hours later the QT interval was normalized and the