Cardiac output estimation by visual inspection *vs* thermodilution during cardiac surgery

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Purpose: The objectives of this study were: 1) to compare the estimated cardiac output (CO) by visual inspection with objective measurements by thermodilution; 2) to compare the estimated systemic vascular resistance (SVR) with objective measurements by thermodilution; and 3) to assess whether management of the patient, based on subjective values, would have differed from the management of the patient based on the objective values.

Methods: A non-randomized, prospective, blinded study was conducted at a tertiary care university hospital. Following institutional ethics approval, 35 patients undergoing cardiac surgery, with pulmonary artery catheter (PAC) monitoring, were studied. Prior to the measurement of CO by thermodilution, but after separation from cardiac pulmonary bypass, the CO and SVR were estimated by the anaesthetist and the surgeon. Bland and Altman's method was used for statistical analysis.

Results: Surgeons' estimates of CO were comparable with the objectively measured thermodilution measures: in each case (100%), the difference between the subjective estimate and the objective measurement was less than two standard deviations from the mean difference of the two methods. Anaesthetists' estimates, by visual inspection, were also comparable with the objectively measured thermodilution values; 94.6% of cases. The surgeons' and anaesthetists' estimates of SVR were also comparable with the thermodilution measures in all cases. Management based on subjective values would have differed from those based on objective values in only 8.6% of cases.

Conclusion: An advantage of cardiac surgery is the ability to observe the heart and assess its performance visually. This study demonstrated that estimates of CO and SVR by clinical observation are comparable with the pulmonary artery catheter's derived values.

Objectif : Cette étude avait pour objectifs de: 1) comparer l'évaluation subjective du débit cardiaque (DC) avec la mesure objective par thermodilution; 2) comparer l'évaluation subjective de la résistance vasculaire systémique (RVS) avec la mesure objective par thermodilution; 3) vérifier si la prise en charge du patient basée sur les valeurs subjectives eut différé si elle avait été basée sur les valeurs objectives.

Méthodes : Cette étude sans randomisation, prospective et à l'aveugle a été menée dans un hôpital de soins tertiaires. Sanctionnée par le comité d'éthique, elle regroupait 35 patients opérés pour une chirurgie cardiaque et monitorés par un cathéter de l'artère pulmonaire. Avant la mesure du DC par thermodilution, après l'arrêt de la circulation extracorporelle, le DC et la RVS ont été évalués par l'anesthésiste et le chirurgien. La méthode statistique utilisée était celle de Bland et Altman.

Résultats : Les évaluations du DC par les chirurgiens étaient comparables aux mesures objectives obtenues par thermodilution : dans tous les cas (100%), la différence entre l'évaluation subjective et objective était inférieure à deux écarts-types de la différence moyenne entre les deux méthodes. Les valeurs des anesthésistes, obtenues visuellement, étaient aussi comparables avec les valeurs objectives obtenues par thermodilution dans 94,6% des cas. Dans tous les cas, les valeurs de la RVS déterminées à la fois par les chirurgiens et les anesthésistes étaient comparables aux valeurs obtenues par thermodilution. Sur la base des valeurs subjectives, la conduite adoptée n'aurait différé que dans 8,6% des cas sur celle des valeurs objectives.

Conclusion : Un des avantages de la chirurgie cardiaque consiste à ce qu'on peut voir le coeur et ainsi déterminer sa performance. Cette étude montre que les estimations du DC et de la RVS fournies par l'observation clinique sont comparables à celles que procurent les données obtenues par le cathétérisme de l'artère pulmonaire.

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STUDIES comparing thermodilution cardiac output (CO) with controlled *in vitro* measurements have revealed a 3% to 13% variability.[1] Factors which may alter the computed objective value include injection technique or injectate characteristics.[2] In addition, a considerable error may occur from the baseline temperature drift immediately after separation from cardiopulmonary bypass (CPB).[3] Respiratory variations in pulmonary artery temperature (>0.05°C), within 35 min after separation, may also contribute to errors of 15–50%.[4] Also, radial arterial pressures can underestimate central aortic pressures after CPB.[5] These errors in invasive monitoring during cardiac surgery should force physicians to place more emphasis on visual inspection of the heart during the critical period of weaning from CPB.

The objectives of this study were: 1) to compare the estimated cardiac output (CO) by visual inspection (a subjective measure) with the standard thermodilution measure (an objective measurement); 2) to compare estimated systemic vascular resistance (SVR) similarly; and 3) to assess whether management of the patient, based on subjective values, would have differed from the management of the patient based on the objective values.

Methods

A non-randomized, prospective double blind study was conducted at a tertiary care university hospital. After institutional ethics approval, 35 patients undergoing coronary bypass or valvular surgery with Swan-Ganz pulmonary artery catheter (PAC) monitoring, were studied. The CO and SVR were measured via thermodilution (10 ml of room temperature normal saline injectate) after separation from CPB when baseline temperature drift was minimal. Two CO determinations were taken for each patient. Prior to taking the CO measure (objectively measured) after separation from CPB, the CO and SVR were estimated by the anaesthetist and the surgeon. Estimates were made to one significant digit for cardiac output. Estimates for SVR did not include significant digits. Clinicians were not blinded to arterial pressure or CVP. However, the anaesthetist and the surgeon were blinded to each other's estimates.

Following estimates of CO and SVR by visual inspection and measures by thermodilution, anaesthetists were given a standard questionnaire to determine whether their management, based on the objective thermodilution measurement, would have differed from that based on their subjective estimates.

Statistical Methods

The measurement methods were compared using Bland and Altman analysis.[6] The statistical analysis also included a two group (unpaired) t-test to evaluate any significant differences between the mean subjective estimates, for both the surgeons and the anaesthetists, and mean objective values. Statistical significance was determined at the 0.05 level.

Results

The mean age for the study patients was 64.1 ± 8.4 yr. There were 28 men, and 7 women. The mean height was 166.9 ± 12.5 cm, the mean weight was 88.1 ± 21.5 kg, and mean ejection fraction (EF) was 0.58 ± 0.1 (range –0.38 to 0.71).

Figure 1 shows the mean difference for the subjective estimates of CO for the surgeon as compared with the objective measures of the thermodilution measures. All data lie between ± 2 standard deviations of the mean difference. Figure 2 shows the mean difference for the subjective estimates of CO for the anaesthetists and the objective measures of the thermodilution method: 94% of the data lie between ± 2 standard deviations of this mean difference. Figures 3 and 4 pertain to SVR for the surgeons' and anaesthetists' estimates *vs* the thermodilution method respectively: 95.6% of the data lie between ± 2 SD in both instances. The table on page 128 shows the mean objective measures for CO and SVR and the mean subjective measures for CO and SVR, based on the surgeons' and the anaesthetists' estimates. There was no difference between the surgeons' mean estimate of CO and the thermodilution mean

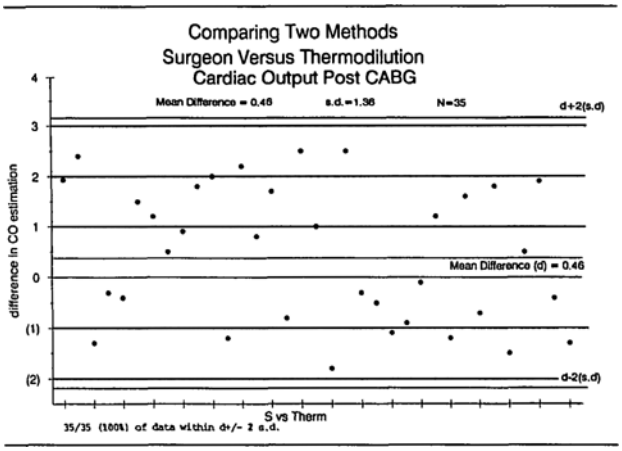

FIGURE 1 Comparison of the subjective surgeons' estimates for cardiac output and the objective measures of the PAC. All of the data are within ± 2SD of the mean difference for the two methods. (S *vs* Therm = Surgeon estimate *vs* Thermodilution method measure.)

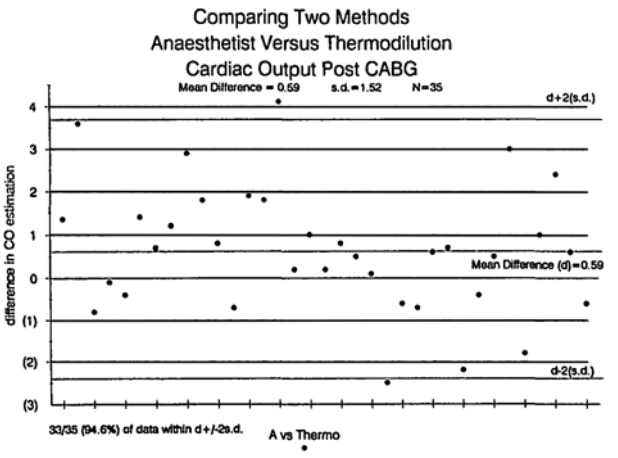

FIGURE 2 Comparison of the subjective anaesthetists' estimates for cardiac output and the objective measures of the PAC (A vs Therm). 94.6% of the data are within ± 2 SD of the mean difference for the two methods.

(A *vs* Therm = Anaesthetist estimate *vs* Thermodilution method measure.)

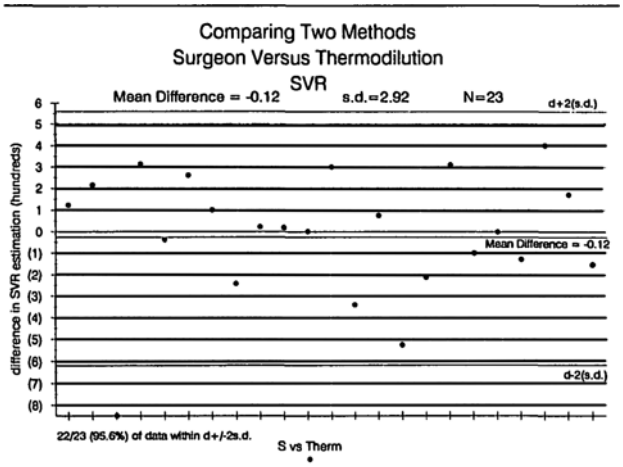

FIGURE 3 Comparison of the subjective surgeons' estimates for SVR and the objective measures of the PAC. 95.6% of the data are within ± 2 SD of the mean difference for the two methods.

(S *vs* Therm = Surgeon estimate *vs* Thermodilution method measure.)

measure (P=0.12). Similarly, there was no difference in the thermodilution mean measure and the anaesthetists' mean estimate of cardiac output (P=0.06). There was no difference in the mean thermodilution measure for SVR and surgeons' mean estimate of SVR (P=0.83) and similarly, no difference in the mean thermodilution measure of SVR and the anaesthetists' mean estimate of SVR (P=0.79).

Clinical management based on subjective values would have differed from those based on objective values in (3/35) 8.6% of cases.

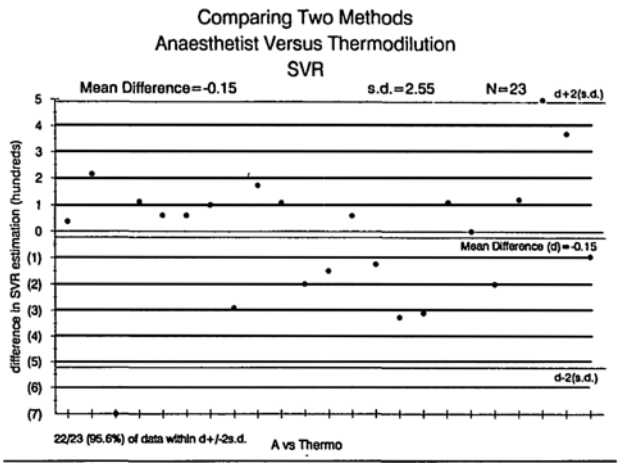

FIGURE 4 Comparison of the subjective anaesthetists' estimates for SVR and the objective measures of the PAC. 95.6% of the data are within ± 2 SD of the mean difference for the two methods of measuring SVR.

(A *vs* Therm = Anaesthetist estimate *vs* Thermodilution method measure.)

TABLE Confidence intervals and P-values for mean differences (actual-estimated) in CO and SVR.

	Cardiac output ($L \cdot min^{-1}$)	*SVR* ($dyn \cdot sec \cdot cm^{-5}$)
Thermodilution	6.1 ± 1.6	787 ± 208
Anaesthetist	5.5 ± 1.3	771 ± 185
estimate	95% CI = −1.32–0.04	95% CI = −133–102
	P = 0.063	P = 0.790
Surgeon	5.6 ± 1.1	775 ± 177
estimate	95% CI = −1.16–0.14	95% CI = −127–103
	P = 0.12	P = 0.83

Discussion

An advantage of cardiac surgery is the ability to observe the heart and assess its performance visually. Most often the right ventricle is in view. One is able to observe and estimate its distention, preload, and contractility.

This study shows adequate estimation of CO by visual inspection when compared with the PAC. As suggested by Bland and Altman,[6] when comparing two measurement methods, taking the mean difference between the 'standard' (thermodilution) measure and the 'test' (subjective estimates made by the surgeons and the anaesthetists) measure, plotting it and then plotting the difference between these measures for each patient, around the mean difference, is the method of choice for assessing their comparability. This plot will demonstrate acceptable comparability between measurement techniques when 95%–100% of the points fall between ± 2 SD of the mean difference.[6] In this study, the anaesthetists' and surgeons' estimates were within

± 2 SD of the mean difference of the PAC, for CO, for 94% and 100% of the patients respectively. The anaesthetists' and surgeons' estimates were within ± 2 SD from the mean difference of the PAC, for SVR, for 95.6% of the patients. In addition to this Bland and Altman analysis, there were no differences found between the subjective and thermodilution measures of CO and SVR using the standard t-test.

In our institution, it is routine management to insert a PAC in all patients having cardiac surgery. With increasing financial constraints placed on medical care, we need to evaluate the utility of our practice critically. Although, the PAC is considered to be the gold standard, it has also been shown to be associated with large variability.[1,3]

Mangano[7] found that the central venous pressure (CVP) correlated well (r=0.89) with pulmonary capillary wedge pressure (PCWP) in patients with ejection fractions >0.50 without angiographically demonstrable ventricular dyssynergy preoperatively. Although survey studies in postoperative and intensive care units have demonstrated that PAC data appear to change therapy in 30–62% of cases,[8,9] the clinical importance with respect to improving outcome is unclear. Some institutions do not employ the PAC catheter routinely during CABG surgery. At these institutions, visual inspection may be important for correct patient management post bypass. Bashein *et al.* reported that in their institution, patients with: 1) EF >40–50%, 2) absence of a history of congestive heart failure, and 3) normal arterial blood pressure response to exercise testing, were well monitored with central venous pressures rather than PAC catheters.[10]

Tuman *et al.* demonstrated, in a controlled prospectively non-randomized study of 1094 patients, that there were no differences in outcome (length of ICU stay, postoperative myocardial infarction, in-hospital death, major haemodynamic changes, and important noncardiac changes) between patients undergoing coronary artery surgery managed with elective PAC (n=537) or with CVP (n=557).[11] The authors concluded that PA catheterization does not play a major role in influencing outcome after cardiac surgery, and that even high-risk cardiac surgical patients may safely be managed without routine PA catheterization.[11] Bashein *et al.* managed to save an estimated US $216,000 in hospital and professional fees over a three-year period, by not routinely inserting a PAC preoperatively.[10]

Conclusion

In many patients, the trachea is now extubated within six to eight hours postoperatively at which time the PAC is removed. With the emphasis on early extubation, the amount of time that the PAC is able to give informative data post-operatively is decreasing. Our study demonstrated that for the majority of patients there was no difference between the anaesthetists' estimates, of CO and SVR, and the objective measures obtained by the PAC, the proven gold standard. This was also true for the difference between the surgeons' estimates for CO and SVR and the PAC. Furthermore, the intraoperative management based on subjective estimates would have changed in only 8.6% of cases once the objective measure was observed. In conclusion, this study supports the notion that continued emphasis should be placed on visual inspection of the patient's heart during cardiac surgery.

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