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Experience of using a non-invasive pulse-wave transit time-based cardiac output monitoring in patients undergoing robot-assisted surgery with pneumoperitoneum in a head-down position

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ABSTRACT

Background: Estimated continuous cardiac output (esCCO) is a non-invasive technique for monitoring continuous cardiac output (CCO) that is based on pulse-wave transit time. In this study, we report the use of CCO monitoring for patients undergoing robot-assisted surgery with pneumoperitoneum in a head-down position.

Method: Thirteen patients undergoing radical robot-assisted prostatectomy under general anesthesia were enrolled. Intraoperatively, esCCO and arterial pressure-based cardiac output (APCO) were simultaneously recorded. The association between esCCO and APCO was then evaluated using correlation analysis and Bland-Altman analysis. The trending ability of esCCO was evaluated by 4-quadrant plot analysis.

Results: The correlation coefficient between esCCO and APCO was 0.54 ($P < 0.0001$). According to the Bland-Altman plot, the bias and precision values were 1.38 and 0.79 L/min, respectively. The concordance analysis showed the concordance rate of 92.3%.

Conclusion: These results indicate that esCCO is capable of tracking hemodynamic changes associated with pneumoperitoneum in the head-down position.

Keywords: continuous cardiac output, head-down position, pnuemoperitoneum

Introduction

Tissue hypoperfusion is an important factor associated with postoperative complications[1),2)]. Both perioperative dehydration and presence of excess fluid can increase postoperative complications, leading to longer hospital stays and increased hospitalization costs[3)]. Goal-directed therapy using infusion control and inotropic drug administration has reduced the time required for gastrointestinal tract function recovery after surgery[4)]. Thus, appropriate management of hemodynamics is required during the perioperative period, for which various minimally invasive hemodynamic monitors have been developed recently.

Estimated continuous cardiac output (esCCO) is a non-invasive method for continuous cardiac output (CO) measurement[5),6)]. Based on pulse wave transit time technology, esCCO measures continuous cardiac output (CCO) noninvasively using electrocardiogram (ECG), pulse oximetry, noninvasive blood pressure monitoring, and patient demographic information. Several studies have shown its usefulness in abdominal surgery, thoracic surgery, and the intensive care setting[7), 8)].

Pneumoperitoneum and the head-down position affects hemodynamics[9)], but there has been no reports of using esCCO under these conditions. In this study, we used esCCO in the head-down position and laparoscopic surgery and compared esCCO with arterial pressure-based cardiac output (APCO).

Materials and Methods

Patients

In the present study, 13 patients with American Society of Anesthesiology physical status classification 1-2 undergoing radical robot-assisted prostatectomy under general anesthesia at Yamagata University Hospital (Yamagata, Japan) from November 2015 to February 2016 were enrolled. Patients were excluded if they were diagnosed with marked cardiac arrhythmias. The study protocol and informed consent form were approved by the institutional review board of Yamagata University Hospital (No. 354). All patients provided written informed consent to participate in this study.

Anesthesia and surgery

All patients were cannulated via the radial artery with a 22G catheter to monitor arterial blood pressure. Anesthesia was induced with target controlled infusion (TCI) 3 μg/ml of propofol, 0.3 μg/kg/min of remifentanil, and 0.6 mg/kg rocuronium bromide. Ventilation was controlled to maintain normocapnia with a tidal volume of 8 ml/kg (ideal body weight) with 40% oxygen in air. In addition, 5 cmH_2O positive end-expiratory pressure was applied. Propofol and remifentanil doses were adjusted so that the mean blood pressure was 65 mmHg or more, and the bispectral index value was 40-60. Rocuronium bromide was continuously administered until the end of abdominal insufflation, and a muscle relaxation monitor confirmed that sufficient muscle relaxation was obtained. The head-down position was set at 26 degrees with an angle gauge, and pneumoperitoneum pressure was set at 12-15 mmHg.

Monitor

We connected the esCCO system to a pulse oximeter and an ECG unit and obtained esCCO. ECG and pulse oximetry wave data, as well as pulse wave transit time, were obtained using a BSM-9101 bedside monitor (Nihon Kohden, Tokyo, Japan) and transmitted to a personal computer with a c-compiled program for esCCO calculation. APCO was measured using FloTrac-Sensor software V4 (Edwards Lifesciences, Irvine, CA). The esCCO was calibrated before induction of anesthesia using ECG, pulse oximetry, non-invasive brachial blood pressure monitoring, and patient information (age, sex, height, and weight). After induction of general anesthesia, esCCO and APCO were measured simultaneously.

Statistical analysis

Data are presented as mean ± standard deviation (SD). Correlation analysis and Bland-Altman analysis were performed to examine correlations between esCCO and APCO. A 4-quadrant plot analysis of ⊿APCO and ⊿esCCO was performed to evaluate the trending ability of esCCO. Values for ⊿APCO and ⊿esCCO were calculated from the start of the events (head-down, pneumoperitoneum, head-down + pneumoperitoneum, pressure change, supine position, and medication administration [ephedrine, phenylephrine, nicardipine]), and after 10 min. We excluded the central zone data of the 4-quadrant plot with ⊿CO < 0.6 L/min. Based on the 4-quadrant plot analysis, the concordance rate of two methods was calculated. Statistical significance was set at a P value (P) < 0.05.

Statistical analyses were performed using Microsoft Excel 2013 (Microsoft Corporation One Microsoft Way Redmond, WA 98052-7329 USA) and IBM SPSS Statistics 20.0.0 (SPSS Inc., Chicago, IL, USA) software programs.

Result

Patient demographics are shown in Table1. Results of correlation analysis and Bland-Altman analysis are presented in Figure 1. The difference between esCCO and APCO was 1.38 ± 0.79 L/min

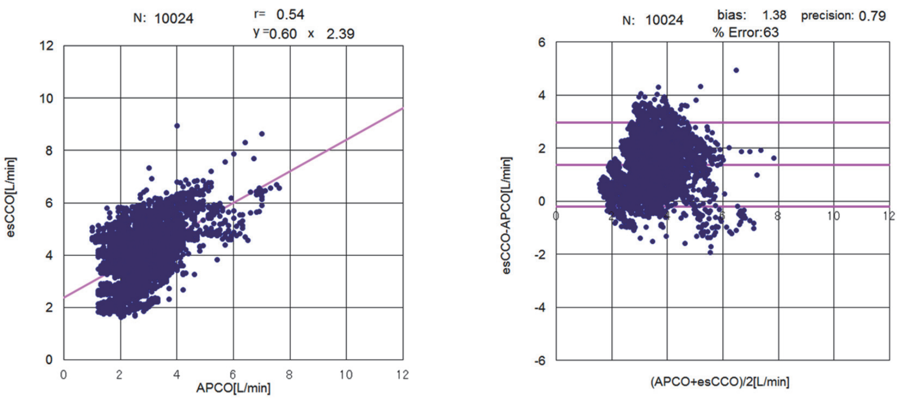

Figure 1. Correlation between arterial pressure cardiac output (APCO) and estimated continuous cardiac output (esCCO; left), and Bland-Altman plot (right).

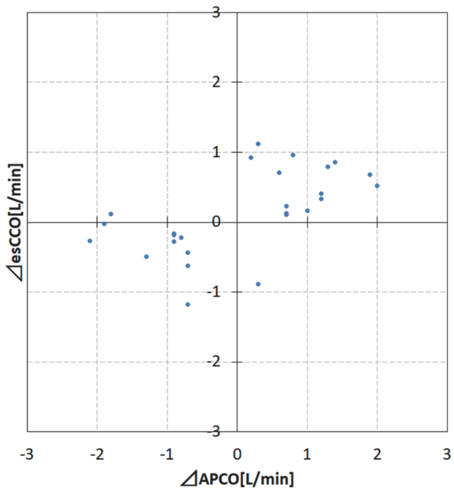

Figure 2. A 4-quadrant plot of ⊿APCO and ⊿esCCO.

Table 1. Patients demographics

Age (years)	63.6±5.8
Height (cm)	166.5±7.2
Weight (kg)	64.7±10.8
BMI (kg/m^2)	23.2±2.6
BSA (m^2)	1.72±0.17
Sex Male	13

Values are presented as mean±standard deviation or n.
BMI, body mass index; BSA, body surface area.

with a linear correlation between two (r = 0.54, n = 10024, P < 0.0001). The percentage error was 63%. A 4-quadrant plot is presented in Figure 2. The concordance analysis showed a concordance rate of 92.3%.

Discussion

We used esCCO in operative patients during pneumoperitoneum in the head-down position and compared the results obtained with those of APCO. We used APCO as a reference monitor. APCO is commonly used for measuring CO values during the perioperative period and uses arterial pressure waveform analysis to calculate CO. A previous study found clinically acceptable agreement between APCO and pulmonary artery catheter standard bolus thermodilution (PAC)[10]. Moreover, comparison of APCO and esCCO at the same time with intermittent bolus thermodilution CO in kidney transplant patients showed that the trending ability of esCCO is comparable with APCO[11]. Because PAC was too invasive for patients in this study, we chose APCO as a reference monitor. If esCCO could capture changes in cardiac output during pneumoperitoneum in the head-down position as well as APCO, we considered it could be used clinically.

The value measured by esCCO tended to be

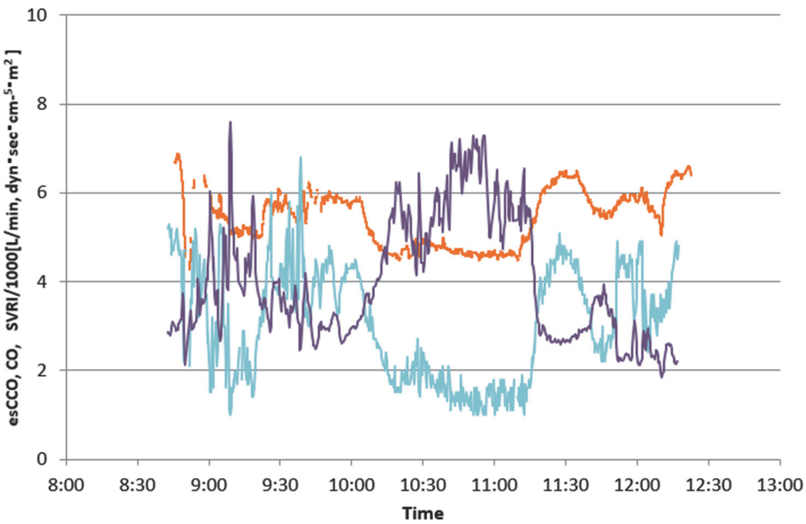

Figure 3. Trend graph of estimated continuous cardiac output (esCCO, orange line), arterial pressure cardiac output (APCO, blue line), and systemic vascular resistance index (SVRI, purple line) in one case.

higher than that by APCO. The Bland-Altman results show that the compatibility of esCCO and APCO was not very good. A previous study reported that the reliability of APCO decreases when the systemic vascular resistance index (SVRI) is < 1200 or ≥ 2500[12]. In contrast, esCCO may be relatively accurate even in the presence of changes in systemic vascular resistance[13),14]. The SVRI when measuring esCCO and APCO in one case in this study is presented in Figure 3. In patients with pneumoperitoneum, the SVRI is high; therefore; the reliability of the APCO value may be low, resulting in an increased difference between esCCO and APCO values.

The trending ability of esCCO at each event was acceptable. We evaluated the change 10 min after the event. The time interval at which changes should be measured was based on a prior study of fluid responsiveness[15]. We set exclusion zones at 0.6 L/min. According to Peyton et al.[16], a concordance rate of 90% to 95% shows reliable trending ability for 0.5 to 1.0 L/min, or a 15% change. Our finding of 92.3% concordance in this study indicates that the data is reliable. In situations resulting in a change in hemodynamics, it is important to follow the trend. Our experience suggests that esCCO can track hemodynamic changes as well as APCO.

In our study, the participants were all men and the sample size was small. Radical robot-assisted prostatectomy surgery was performed at a constant head low angle, and the operation time and blood loss were almost constant. In order to limit variability, we selectively enrolled patients undergoing radical robot-assisted prostatectomy surgery. Therefore, further research may be needed to validate the trending ability of esCCO in patients of varying demographics and in different surgical situations.

The results of this study were presented at the Japan Association for Clinical Monitoring Congress in 2016.

Conclusion

We evaluated esCCO in head-down position and laparoscopic surgery. We find that esCCO was able to track hemodynamic changes associated with pneumoperitoneum and in the head-down position.

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References

1. Bennett-Guerrero E, Welsby I, Dunn TJ, et al. : The use of a postoperative morbidity survey to evaluate patients with prolonged hospitalization after routine, moderate-risk, elective surgery. Anesth Analg 1999; 89: 514-519
2. Gan TJ, Mythen MG: Does peroperative gut-mucosa hypoperfusion cause postoperative nausea and vomiting? Lancet 1995; 345: 1123-1124
3. Krell RW, Glrotti ME, Dimick JB: Extended length of stay after surgery: complications, inefficient practice or sick patients? JAMA Surg 2014; 149: 815-820
4. Corcoran T, Rhodes JE, Clarke S, Myles PS, Ho KM: Perioperative fluid management strategies in major surgery: a stratified meta-analysis. Anesth Analg 2012; 114: 640-651
5. Sugo Y, Sakai T, Terao M, Ukawa T, Ochiai R: The comparison of a novel continuous cardiac output monitor based on pulse wave transit time and echo Doppler during exercise. Conf Proc IEEE Eng Med Biol Soc 2012; 2012: 236-239
6. Sugo Y, Ukawa T, Takeda S, Ishihara H, Kazama T, Takeda J: A novel continuous cardiac output monitor based on pulse wave transit time. Conf Proc IEEE Eng Med Biol Soc 2010; 2010: 2853-2856
7. Terada T, Maemura Y, Yoshida A, Muto R, Ochiai R: Evaluation of the estimated continuous cardiac output monitoring system in adults and children undergoing kidney transplant surgery: a pilot study. J Clin Monit Comput 2014; 28: 95-99
8. Yamada T, Tsutsui M, Sugo Y, Akazawa T, Sato N, Yamashita K, Ishihara H, Takeda J: Multicenter study verifying a method of noninvasive continuous cardiac output measurement using pulse wave transit time: a comparison with intermittent bolus thermodilution cardiac output. Anesth Analg 2012; 115: 82-87
9. Darlong V, Kunhabdulla NP, Pandey R, Punj CJ, Garg R, Kumar R: Hemodynamic changes during robotic radical prostatectomy. Saudi Journal of Anaesthesia 2012; 6; 213-218
10. Cannesson M: Comparison of FloTrac cardiac output monitoring system in patients undergoing coronary artery bypass grafting with pulmonary artery cardiac output measurements. Eur J Anaesthesiol 2007; 24: 832-839
11. Terada T, Oiwa A, Maemura Y, Samuna R, Kessoku S, Ochiai R: Comparison of the ability of two continuous cardiac output monitors to measure trends in cardiac output: estimated continuous cardiac output measured by modified pulse wave transit time and an arterial pulse contour-based cardiac output device. J clin Monit Comput 2016; 30: 621-627
12. Suehiro K, Tanaka K, Funao T, Matsuura T, Mori T, Nishikawa K: Systemic vascular resistance has an impact on the reliability of the Vigileo-Flotrac system in measuring cardiac output and tracking cardiac output changes. Br J Anaesth 2013; 111: 170-177
13. Ishihara H, Okawa H, Tanabe K,Tsubo T, Sugo Y, Akiyama T, Takeda S: A new non-invasive continuous cardiac output trend solely utilizing routine cardiovascular monitors. J Clin Monit Comput 2004; 18: 313-320
14. Ochiai R, Takeda J, Hosaka H, Sugo Y, Tanaka R, Soma T: The relationship between modified pulse wave transit time and cardiovascular changes in isoflurane anesthetized dogs. J Clin Monit Comput 1999; 15: 493-501
15. Vincent JL, Weil MH: Fluid challenge revisited. Crit Care Med 2006; 34: 1333-1337
16. Peyton PJ, Chong SW: Minimally invasive measurement of cardiac output during surgery and critical care: a meta-analysis of accuracy and precision. Anesthesiology 2010; 113: 1220-1235