Peripheral venous pressure as an alternative to central venous pressure in patients undergoing laparoscopic colorectal surgery


1 Department of Anaesthesiology and Pain Medicine, Soonchunhyang University Hospital, College of Medicine, Soonchunhyang University, Bucheon Hospital, 1174 Jung-Dong, Wonmi-Gu, Bucheon-Si, Gyeonggi-Do, Republic of Korea
2 Department of Anaesthesiology and Pain Medicine, Soonchunhyang University Hospital, College of Medicine, Soonchunhyang University, Seoul, Republic of Korea
3 Quality Safety and Patient Experience Branch, Department of Health, Melbourne, VIC 3000, Australia

* Corresponding author. E-mail: aurelius@schmc.ac.kr

Editor’s key points
• The study evaluated if peripheral venous pressure (PVP) correlated with CVP during laparoscopic surgery.
• The PVP and CVP were measured in 42 patients.
• The correlation between PVP and CVP was strong; mean (95% confidence interval) bias being 0.9 (0.54–1.19) mm Hg.
• The study concludes that PVP may be used as an alternative to CVP during laparoscopy.

Background. Peripheral venous pressure (PVP) is strongly correlated with central venous pressure (CVP) during various surgeries. Laparoscopic surgery in the Trendelenburg position with pneumoperitoneum typically increases CVP. To determine whether PVP convincingly reflects changes in CVP, we evaluated the correlation between PVP and CVP in patients undergoing laparoscopic colorectal surgery.

Methods. Both CVP and PVP were measured simultaneously at predetermined time intervals during elective laparoscopic colorectal surgery in 42 patients without cardiac disease. The pairs of venous pressure measurements were analysed for correlation, and the Bland–Altman plots of repeated measures were used to evaluate the agreement between CVP and PVP.

Results. A total of 420 data pairs were obtained. The overall mean CVP was 11.3 (± 4.5) mm Hg, which was significantly lower than the measured PVP of mean 12.1 (± 4.5) mm Hg (P = 0.005). There was a strong positive correlation between overall CVP and PVP (correlation coefficient = 0.96, P < 0.0001). The mean bias (PVP–CVP) corrected for repeated measurements using random-effects modelling was 0.9 mm Hg [95% confidence interval (CI) 0.54–1.19 mm Hg] with 95% limits of agreement of −1.2 mm Hg (95% CI −1.75 to −0.62 mm Hg) to 2.9 mm Hg (95% CI 2.35–3.48 mm Hg).

Conclusions. PVP displays a strong correlation and agreement with CVP under the increased intrathoracic pressure of pneumoperitoneum in the Trendelenburg position and may be used as an alternative to CVP in patients without cardiac disease undergoing laparoscopic colorectal surgery.

Keywords: blood pressure, venous; central venous pressure; surgery, colorectal; surgery, laparoscopic

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Laparoscopic colorectal surgery has been increasingly performed for the surgical treatment of colorectal cancer because of its association with earlier recovery of bowel function, and the need for fewer analgesics, and shorter hospital stay compared with an open colectomy.1 Despite the minimal invasiveness of laparoscopic surgery, CO2 pneumoperitoneum and the Trendelenburg position used during the procedure induce haemodynamic alterations, including increased central venous pressure (CVP), pulmonary artery occlusion pressure, and mean arterial pressure (MAP).2–4 These haemodynamic changes are usually well tolerated in patients without cardiac disease (even in a steep Trendelenburg position of 40°), and a basic level of monitoring is typically adequate during the surgery. A central venous catheter is often inserted to measure CVP as a way to monitor the trend when assessing cardiac preload, given that this operation may be a long one. The usefulness of CVP measurements as guidance for fluid therapy has been demonstrated not only in improved survival in severe sepsis and septic shock but also in shortening the time to being medically fit for discharge in hip fracture patients.6,7 The CVP is influenced by not only the ventricular preload or contractility but also extra-cardiac factors such as intrathoracic pressure. High CVP values associated with the increased intrathoracic pressure during this surgery may be falsely
interpreted as intravascular volume overload or cardiac dysfunction. Furthermore, although infrequent, placement of a central venous catheter carries a risk of complications, such as unintended arterial puncture, haematoma, and pneumothorax.8

In the context of avoiding invasive intraoperative monitoring, peripheral venous pressure (PVP) monitoring has been tested as an alternative to CVP monitoring. Since the early 2000s, many investigators have shown a consistent and strong correlation between PVP and CVP during various types of surgery.9–12 As the majority of patients undergoing surgery have a peripheral i.v. catheter in place, monitoring PVP may contribute to reductions in costs, complications, and time to the onset of the operation. However, it has not yet been determined whether PVP convincingly reflects changes in CVP in cases of increased intrathoracic pressure, which is typically associated with pneumoperitoneum and the Trendelenburg position during laparoscopic colorectal surgery.

The aim of this study was to evaluate the relationship between PVP and CVP in patients undergoing laparoscopic colorectal surgery and the potential use of PVP as an alternative to CVP during the surgery.

Methods

After obtaining approval from the Institutional Review Board of Soonchunhyang University Bucheon Hospital (Bucheon-City, Republic of Korea) and written informed consent from each patient, 46 consecutive patients, ASA I–II, undergoing elective laparoscopic colorectal surgery were assessed for eligibility for this study from June 2009 to May 2010. The exclusion criteria were significant cardiac disease (ejection fraction <40%, unstable angina, or valvular disease), failure to place a peripheral or right internal jugular venous catheter, existence of artificial arterio-venous fistula for haemodialysis, and pre-existing vascular anomalies of the central venous system.

All patients received i.m. glycopyrrolate 0.2 mg as premedication 30 min before arrival at the operating theatre. Upon arrival, patients were monitored using a three-lead ECG, pulse oximetry, and non-invasive arterial pressure measurement (Solar 8000; GE, Milwaukee, WI, USA). Anaesthesia was induced and maintained with propofol (effect site concentration, 3–5 μg ml

1;

Schnider pharmacokinetic model) and remifentanil (3–5 ng ml

1; Minto model) using a target-controlled infusion device (OchestraTM; Fresenius Kabi, France). After loss of consciousness, a bolus of 0.6 mg kg

1 rocuronium was administered to facilitate tracheal intubation. To maintain an end-tidal carbon dioxide concentration between 4.7 and 5.3 kPa, the patients' lungs were mechanically ventilated with 60% oxygen at a flow rate of 4 litre min

1 with a constant tidal volume of 8 ml kg

1 (predicted body weight),13 by adjusting the ventilatory frequency throughout surgery without positive end-expiratory pressure. After induction, a 22 G arterial catheter (Angiocath PlusTM; Becton Dickinson Korea, Gumi-City, Republic of Korea) was inserted into a radial artery to continuously monitor arterial pressure. A 7 Fr triple-lumen central venous catheter (CS-25703-E; Arrow International, Reading, PA, USA) was inserted via the right internal jugular vein, and the distal port was used to measure CVP. I.V. placement of the catheter was confirmed by aspirating blood from all of the three ports. The central venous catheter was secured 13–14 cm from the skin, as suggested by Ryu and colleagues,14 and the catheter tip position was confirmed by chest radiography after operation. PVP was measured using a 25 mm, 22 G cannula (Becton Dickinson Korea), inserted in either vein of the dorsum of the hand or forearm on the morning of surgery. All catheters were connected to a continuous pressure monitoring kit (PX3X3; Edwards Life Sciences, Irvine, CA, USA) via 150 cm-long rigid pressure tubing filled with saline. The transducer was set to zero at the level of the right atrium, ~4 cm below the fourth intercostal space, and was adjusted to this level depending on the patient's position (Trendelenburg or tilt to left or right). Patients were positioned in the lithotomy position, with the hips flexed at 40–70° from the trunk and the thighs abducted 30–45°. One arm was placed alongside the patient on the operating table, depending on the type of operation performed (right arm in descending, sigmoid, or rectal cancer). PVP was measured at the other arm, which was placed on an arm board abducted to 90° to avoid the possibility of leaning or compression by the surgeon. After a skin incision, pneumoperitoneum was established with an intra-abdominal pressure of 12–14 mm Hg through the umbilical port, using an open (Hasson) technique. After exploring the abdominal cavity, three additional trocars were inserted into the usual sites, depending on the type of surgery. At least 1 min after the establishment of pneumoperitoneum, the patient was placed in the Trendelenburg position (20–30°). The operation was performed with the patient in this position, and the patient's position was adjusted (head down or left/right tilt) when the surgeon requested. After evacuating the carbon dioxide, the specimen was removed through a minimal incision at the appropriate port site while still in the Trendelenburg position. The abdominal wall was closed in the supine position at the end of the operation. The patient was transferred to the post-anaesthesia care unit after tracheal extubation. All operations were performed by the same surgeon and the same anaesthetist managed the anaesthetic.

The measurements of CVP and PVP were recorded during the end-expiratory phase, at a predetermined set of 10 time points: T1, when the patient was anaesthetized before the surgical incision; T2, 1 min after the skin incision; T3, 1 min after surgical pneumoperitoneum with an intra-abdominal pressure of 12–14 mm Hg after the placement of the four trocars; T4, 1 min; T5, 10 min; T6, 30 min; T7, 60 min, and T8, 120 min after placing the patient in the Trendelenburg position under pneumoperitoneum; T9, 1 min after specimen removal and desufflation while still in the Trendelenburg position; and T10, at the end of the
surgery, with the patient in the supine position. The MAP, heart rate (HR), nasopharyngeal temperature, and peak airway pressure were also recorded at these time points.

**Statistical analysis**

Descriptive statistics of the variables are presented as means (SD) unless otherwise stated. Data analysis was performed using Student’s t-test, Pearson’s correlation coefficient, and linear regression. As CVP and PVP were measured repeatedly, we used a Bland–Altman analysis for repeated measurements, as suggested by Myles and Cui. The random-effects model was used to calculate the within-subject variance for each patient, mean measurements for each patient over time, mean measurements between the two methods, and mean measurements for each method over time. An agreement was evaluated by calculating the mean difference (bias) and standard deviation of the differences. The limit of agreement was calculated as a bias ± 2 SD. The precision of the estimated limit of agreement was provided by a 95% confidence interval (CI). Any changes in variables during the study period were analysed by repeated measurements of analysis of variance using the Bonferroni test for post hoc comparisons. Statistical analysis was performed using the software program SPSS version 14.0 (SPSS, Chicago, IL, USA) and Stata version 10 (StataCorp, College Station, TX, USA). Values of P<0.05 were considered to indicate statistical significance.

**Results**

In this study, no patient met the exclusion criteria, but two patients who refused to participate were excluded. Consequently, 44 patients were enrolled (23 males and 21 females), with a mean age of 59.1 yr (range, 33–84). Of the 44 patients enrolled, two were excluded owing to conversion to open surgery or failure to complete the surgery due to extensive peritoneal seeding of cancer. Thus, data from the remaining 42 patients with a total of 420 pairs of measurements were included in the analysis. All central venous catheterizations were successfully performed without complications. All patients remained in normothermia. Patients’ characteristics and operative data are presented in Table 1.

The overall mean CVP was 11.3 (SD 4.5) mm Hg, which was significantly lower than that of the PVP, which was 12.1 (4.5) mm Hg (P<0.005). The regression equation was PVP = 0.96 (CVP) + 1.35, indicating a strong positive correlation between overall CVP and PVP (correlation coefficient = 0.96, P<0.0001; Fig. 1). The mean bias (PVP–CVP) corrected for repeated measurements using the random-effects model was 0.9 mm Hg (95% CI 0.54–1.19 mm Hg) with 95% limits of agreement of −1.2 (95 CI −1.75 to −0.62 mm Hg) to 2.9 (95% CI 2.35–3.48 mm Hg) (Fig. 2). The mean bias significantly decreased when patients were in the Trendelenburg position under pneumoperitoneum (Table 2). The mean venous pressure [(CVP+PVP)/2] had a moderately strong, positive correlation (r=0.61, P<0.0001) with peak airway pressure (Fig. 3a), and the mean bias had a weak negative correlation (r=−0.19, P<0.0001) (Fig. 3b).

The CVP, PVP, and MAP increased during pneumoperitoneum in the Trendelenburg position and returned to baseline values at the end of surgery (P<0.001) (Supplementary Fig. S1). The HR did not differ significantly from the baseline value during the study period (Supplementary Fig. S2).

**Discussion**

The current study demonstrated high agreement between CVP and PVP, suggesting that PVP monitoring can replace CVP monitoring in patients undergoing laparoscopic colorectal surgery under conditions of pneumoperitoneum and

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**Table 1** Patients’ characteristics and operative data. Data are presented as mean (SD) or n

<table>
<thead>
<tr>
<th>Gender (M/F)</th>
<th>22/20</th>
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<tbody>
<tr>
<td>Age (yr)</td>
<td>59.4 (12.6)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>161.5 (8.9)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>61.1 (10.2)</td>
</tr>
<tr>
<td>ASA (I/II)</td>
<td>19/23</td>
</tr>
<tr>
<td>I.V. site (hand/forearm)</td>
<td>18/24</td>
</tr>
<tr>
<td>Operation time (min)</td>
<td>250.6 (73.6)</td>
</tr>
<tr>
<td>Anaesthesia time (min)</td>
<td>311.2 (74.2)</td>
</tr>
<tr>
<td>Blood loss (ml)</td>
<td>215 (146)</td>
</tr>
<tr>
<td>Urine output (ml)</td>
<td>551 (525)</td>
</tr>
<tr>
<td>Fluid administered (ml)</td>
<td>1351 (690)</td>
</tr>
<tr>
<td>Crystalloid</td>
<td>482 (145)</td>
</tr>
<tr>
<td>Colloid</td>
<td>1351 (690)</td>
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<tr>
<td>Types of operation</td>
<td></td>
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<tr>
<td>Low anterior resection</td>
<td>18</td>
</tr>
<tr>
<td>Anterior resection</td>
<td>16</td>
</tr>
<tr>
<td>Right hemicolec tomy</td>
<td>5</td>
</tr>
<tr>
<td>Left hemicolec tomy</td>
<td>2</td>
</tr>
<tr>
<td>Abdominal perineal resection</td>
<td>1</td>
</tr>
</tbody>
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![Fig 1 Scatter plot of PVP and CVP from 420 pairs of 42 subjects.](https://academic.oup.com/bja/article-abstract/106/3/305/322746)
while in the Trendelenburg position. A low mean bias of 0.9 mm Hg, with limits of agreement of -1.2 and 2.9 mm Hg, has been demonstrated in this study. Additionally, we found that the difference between CVP and PVP tended to decrease with an increasing peak airway pressure, as evidenced by the negative correlation coefficient (-0.19). The clinical implication of the present study is that PVP has a strong correlation with CVP in a clinical setting during increased intrathoracic pressure.

A previous study demonstrated a strong correlation between CVP and PVP in patients undergoing spine surgery in the prone position. This is consistent with our observations. It has been suggested that an increase in CVP results from increased intrathoracic pressure related to the pneumoperitoneum and head tilt, rather than from changes in the intrathoracic blood volume. However, it has not been reported whether an increase in CVP is associated with an increase in PVP during laparoscopic surgery.

Recent studies dealing with the effects of pneumoperitoneum and the Trendelenburg position on the haemodynamic consequences and cerebral oxygenation during robot-assisted laparoscopic radical prostatectomy have shown that CVP increases significantly and remains stable during the steep head-down position and pneumoperitoneum, and returns to baseline on resuming the supine position. This is consistent with our observations. It has been suggested that an increase in CVP results from increased intrathoracic pressure related to the pneumoperitoneum and head tilt, rather than from changes in the intrathoracic blood volume. However, it has not been reported whether an increase in CVP is associated with an increase in PVP during laparoscopic surgery.

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Table 2: Bias and limits of agreement (95% CI) between PVP and CVP. ULOA, upper limits of agreement; LLOA, lower limits of agreement; T1, when the patient was anaesthetized before the surgical incision; T2, 1 min after the skin incision; T3, 1 min after maintaining pneumoperitoneum with an intra-abdominal pressure of 12–14 mm Hg after the placement of the four trocars; T4–T8, the patient in the Trendelenburg position under pneumoperitoneum; T9, 1 min after specimen removal and desufflation while still in the Trendelenburg position; T10, at the end of the surgery, with the patient in the supine position. *P<0.05 vs T1, †P<0.05 vs T2

<table>
<thead>
<tr>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
<th>T6</th>
<th>T7</th>
<th>T8</th>
<th>T9</th>
<th>T10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bias</td>
<td>1.21 (0.89, 1.54)</td>
<td>1.19 (0.83, 1.55)</td>
<td>0.67 (0.26, 1.10)</td>
<td>0.76 (0.46, 1.07)</td>
<td>0.55* (0.20, 0.90)</td>
<td>0.62 (0.23, 1.01)</td>
<td>0.55† (0.18, 0.92)</td>
<td>0.88 (0.45, 1.31)</td>
<td>1.00 (0.60, 1.46)</td>
</tr>
<tr>
<td>ULOA</td>
<td>3.27 (2.71, 3.83)</td>
<td>3.45 (2.83, 4.07)</td>
<td>3.36 (2.62, 4.10)</td>
<td>2.67 (2.16, 3.22)</td>
<td>2.76 (2.16, 3.37)</td>
<td>3.07 (2.40, 3.74)</td>
<td>2.89 (2.25, 3.53)</td>
<td>3.59 (2.85, 4.33)</td>
<td>3.52 (2.83, 4.22)</td>
</tr>
<tr>
<td>LLOA</td>
<td>-0.84 (−1.40, −0.28)</td>
<td>-1.07 (−1.69, −0.45)</td>
<td>-2.03 (−2.76, −1.29)</td>
<td>-1.17 (−1.69, −0.64)</td>
<td>-1.67 (−2.28, −1.06)</td>
<td>-1.83 (−2.50, −1.16)</td>
<td>-1.79 (−2.43, −1.15)</td>
<td>-1.83 (−2.57, −1.09)</td>
<td>-1.52 (−2.22, −0.83)</td>
</tr>
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</table>

Fig 2: The Bland–Altman plot of the difference between CVP and PVP against the mean value of CVP and PVP in the 42 study subjects.
demonstrated the use of PVP as an alternative to CVP in cases of increased intrathoracic pressure from extrinsic forces (e.g. the prone position) transmitted to the abdomen. The smaller mean bias (0.67 mm Hg, T4–8) in our study may be attributable to the consistent intrathoracic pressure during the laparoscopic procedure.

Several studies have demonstrated that the difference between CVP and PVP varies with the value of CVP. In nine patients undergoing orthotopic liver transplantation, a weaker correlation between PVP and CVP was evident at low CVP. Another study showed that when CVP increased, the difference between PVP and CVP tended to decrease; when the measured CVP was ≥13 mm Hg, the difference between PVP and CVP was less than 1 mm Hg. These findings concur with our study, in which the difference between venous pressures decreased at high CVP. The difference between these studies and our study was the source of the change in CVP (i.e. primarily intrathoracic pressure vs intravascular volume). The reason for the decrease in PVP–CVP in our study is that the increase in intramural CVP, on establishing pneumoperitoneum, exerts a backward force on the veins, impeding blood flow from the veins into the right atrium, rendering the peripheral veins more patent. As the CVP increases still further on assuming the Trendelenburg position, the transmission of central pressure increases consistently, causing a corresponding increase in PVP; as a consequence, the difference between the two pressures is decreased. Our results add evidence for a decrease in PVP–CVP when CVP increases, regardless of the cause.

Here, we measured PVP at a more peripheral site (vein on either the dorsum of the hand or forearm) and used a smaller-diameter venous catheter, compared with previous studies. There was no difference in the mean PVP measured at the dorsum of the hand vs the forearm [11.9 (SD 2.6) vs 12.2 (2.4) mm Hg], which is consistent with previously reported results that the site of the peripheral venous catheter does not interfere with the agreement between CVP and PVP. The use of a smaller catheter during routine preoperative peripheral venous catheterization may be helpful in decreasing pain.

Our study differs from previous studies comparing CVP and PVP, in that we used a modified Bland–Altman plot for the analysis. An analysis based on pooling the 420 paired measurements of CVP and PVP using the original Bland–Altman method ignores the repeated nature of the data. Therefore, we included the baseline and mean measurements over time for each patient, and the mean measurements between the two methods for each time point to fit a random-effects model, as proposed by Myles and Cui.

A recent systematic review demonstrated a very poor relationship between CVP and blood volume, and an inability to predict the haemodynamic response to fluid challenge. The CVP measured during the pneumoperitoneum do not seem to reflect accurate preload status or to guide resuscitation. As this study assessed the agreement of CVP with PVP, no conclusion can be drawn about the usefulness of venous pressure monitoring in terms of fluid management in this type of surgery. We recognize that measurements of the ‘static’ cardiac filling pressure cannot accurately reflect preload or fluid responsiveness. It may be more useful to monitor ‘dynamic’ parameter, such as pulse pressure variation, to detect hypovolaemia and guide fluid therapy during laparoscopic surgery. However, as there is no single parameter that can guide fluid therapy in all circumstances, CVP monitoring may still help to evaluate volume status, to guide replacement therapy, when considered together with other clinical variables, such as blood pressure, HR, and urine output. Given that the changes in CVP and PVP are strongly correlated, predictable, and consistent over time during uncomplicated laparoscopic colorectal surgery, the trends in PVP may be useful for monitoring the intravascular volume status and fluid management. Further studies are needed to determine the clinical usefulness of PVP as a trend monitor for evaluating the intravascular volume in this patient population.

Some limitations of the current study need to be noticed. As we did not measure ventricular end-diastolic volume...
using either transoesophageal echocardiogram or pulmonary artery catheter, we cannot rule out the contribution of venous return, which may increase during pneumoperitoneum and in the Trendelenburg position, when measuring CVP. Additionally, it is not clear whether our data are applicable to cardiac patients undergoing this surgery.

In conclusion, we demonstrated that PVP reflects CVP in cases of increased intrathoracic pressure under pneumoperitoneum in the Trendelenburg position and that it can be used as an alternative to CVP in patients without cardiac disease undergoing laparoscopic colorectal surgery.

Supplementary material
Supplementary material is available at British Journal of Anaesthesia online.

Conflict of interest
None declared.

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