Comparison of central venous and external jugular venous pressures during repair of proximal femoral fracture†

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Background. External jugular venous pressure (EJVP) is a close estimate of central venous pressure (CVP) in patients undergoing mechanical ventilation in the supine position, but the effects of spontaneous respiration and posture on this relationship are not known. In this study, we compared CVP with EJVP measurements in 36 patients undergoing repair of proximal femoral fracture breathing spontaneously in the supine or lateral positions.

Methods. A standard general anaesthetic was administered with patients breathing spontaneously via a laryngeal mask airway and i.v. fluids administered according to an algorithm guided by CVP measurements. CVP and EJVP catheters were placed on the right side of the neck where possible.

Results. In the supine position, 185 paired measurements of CVP and EJVP and 79 in the lateral position were recorded by a blinded observer during surgery. In the supine position, the mean difference between CVP and EJVP was $2.0 \pm 0.3$ mm Hg (limits of agreement $-2.6$ to $+1.9$ mm Hg, 95% confidence intervals for both upper and lower limits of agreement, respectively, were $-2.9$ to $-2.2$ and $+1.6$ to $+2.2$ mm Hg). In the lateral position, the mean difference was $-1.2$ mm Hg (limits of agreement $-5.8$ to $+3.8$ mm Hg, 95% confidence intervals $-6.8$ to $-4.5$ and $+2.7$ to $+4.9$ mm Hg).

Conclusions. These data suggest that EJVP is an acceptable estimate of CVP in the supine position. Agreement was poor in the lateral position but was stronger for estimates of trend rather than absolute values. This could be explained by the direct effects of posture.

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Hip fracture is common in the elderly population. In the UK, 66 000 operations for repair of proximal femoral fracture were performed in 1997–8, and mortality rates of up to 24% have been reported.1,2 Many patients have significant multi-system disease so that anaesthesia and surgery represent a considerable physiological challenge. Optimizing intraoperative fluid administration has been shown to improve outcome after femoral neck surgery,1–5 but invasive cardiovascular monitoring is seldom used to guide intraoperative fluid management. Central venous pressure (CVP) measurements are conventionally made via an internal jugular venous (IJV) catheter, but this technique is associated with a significant incidence of complications such as pneumothorax, arterial puncture, and arrhythmias. Several studies have demonstrated that fluid resuscitation guided by oesophageal Doppler monitoring leads to increased administration of i.v. fluids and reduces length of hospital stay.3–5 However, this technique is not available to many units for use on patients with hip fracture. Oesophageal Doppler monitoring also requires a period of training and is subject to inter-observer variation.6 It may be inaccurate in the presence of arrhythmias and usually requires tracheal intubation. Many patients presenting for hip fracture surgery can be managed using

Comparison of CVP and EJVP

Regional anaesthetic techniques and in those patients requiring general anaesthetic (GA) the laryngeal mask airway (LMA®) is frequently the preferred method of airway management so precluding the use of the oesophageal Doppler. External jugular venous pressure (EJVP) measurement is simple and uses equipment which is already available in most anaesthetic departments. An EJVP cannula will also facilitate the administration of drugs and infusions, and is associated with fewer complications than IJV cannulation. We have previously shown that EJVP values are close to CVP measured in mechanically ventilated patients undergoing major surgery in the supine position. However, cyclical changes in intrathoracic pressure may affect CVP (where the catheter tip is intrathoracic) and EJVP (where the catheter tip lies outside the thoracic cavity) to a different degree in patients breathing spontaneously. In addition, hip fracture surgery may be performed in the supine or lateral position, and the effects of posture on the relationship between EJVP and CVP are not known. The aim of this study was to compare EJVP with CVP in patients undergoing hip fracture surgery under GA with spontaneous respiration.

Methods

With local ethics committee approval and written informed patient consent, 40 ASA grade II–III patients presenting with a proximal femoral neck fracture were approached to participate in the study. All patients were aged >50 yr, were undergoing either hemi-arthroplasty or dynamic hip screw insertion, and were prepared for theatre in the normal way. The exclusion criteria were: perceived risk of regurgitation, poorly visible EJVP, non-consent, and contraindications to GA. Patients with an episode of acute heart failure in the 6 months preceding the study or dialysis-dependant renal failure were excluded.

Anaesthesia was induced using propofol or etomidate at a dose sufficient to abolish the eye-lash reflex and maintained with a mixture of 66% nitrous oxide in oxygen and isoflurane 1–2%. An LMA was placed after induction of anaesthesia and spontaneous respiration maintained using a circle system. All patients received i.v. fentanyl 1 μg kg⁻¹ and in addition a ‘3 in 1’ femoral nerve block using 30 ml bupivacaine 0.25% was administered before the start of surgery.

After induction of anaesthesia, an 18 G 150 mm single lumen CVP catheter was sited via the right IJV (Abbocath, Abbott, Sligo, Ireland) and a 20 G 51 mm cannula (Abbocath) placed in the ipsilateral external jugular vein (EJV). The tip of the EJV catheter was palpated to ensure location in the EJV. All catheterizations were performed by experienced trainee anaesthetists using the anatomical landmark technique. Recruitment for this study commenced before the availability of ultrasound for guidance of central venous cannulation at our hospital. Both catheters were transduced via a three-way tap and a single transducer (Baxter Health Corporation, Deerfield, IL, USA). The position of the patient (supine vs lateral) was at the discretion of the surgeon. All patients received 15 ml kg⁻¹ h⁻¹ of 0.9% saline through a peripheral cannula as maintenance fluid during the procedure. Intraoperative fluid boluses were administered according to a predetermined algorithm based on CVP measurements. A bolus of 3 ml kg⁻¹ of 6% hetastarch was given over 10 min, if the CVP was <5 mm Hg or if the CVP was between 6 and 10 mm Hg, but the patient was hypotensive (systolic pressure was more than 40 mm Hg below baseline or below 90 mm Hg absolute value). Hypotension which did not resolve with the colloid bolus was treated with ephedrine 3 mg increments if heart rate was <90 beats min⁻¹ and phenylephrine 50 μg increments if heart rate was >90 beats min⁻¹. Paired measurements of EJVP and CVP were recorded in a random order at the end of each fluid bolus or every 10 min in the absence of fluid bolusing for the duration of the procedure. The observer was blinded to the catheter used for each reading. Before each set of paired measurements, the transducer was adjusted to an atmospheric pressure of zero and each catheter flushed to confirm patency. With each measurement, the investigator checked the venous pressure waveform for stability before asking the independent observer to record the displayed mean venous pressure. Because patients were breathing spontaneously, it was not feasible to measure mean pressure at end expiration reliably. No changes to patient position, fluid, or drug therapy were made during each set of paired measurements. Over time, CVP and EJVP measurements changed either spontaneously or in response to fluid boluses, and the changes between consecutive measurements were calculated as ΔCVP (CVP₁–CVP₂) and ΔEJVP (EJVP₁–EJVP₂). The term ‘trend value’ refers to the difference in the change in CVP and EJVP between readings, that is, ΔCVP–ΔEJVP. Postoperative chest X-ray confirmed correct placement of the CVP catheter in all patients.

Results

Forty patients were recruited to the study, but four patients were excluded because of failure to cannulate the EJV (two patients) or carotid artery puncture (two patients, both during attempted CVP cannulation) and so data from

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36 patients were analysed. Mean (range) age was 79 (58–99) yr; 10 patients were male. The surgical procedure was hemi-arthroplasty in 16 cases and dynamic hip screw in 24. The mean (SD) volume of i.v. fluid administered was 1935 (431) ml. Twenty-five patients were positioned supine and 11 were in the lateral position yielding 185 and 79 paired measurements, respectively. In most patients, both EJVP and CVP lines were sited in the right IJV. The different sides (evenly divided between supine and lateral groups). All CVP lines were sited in the right IJV. The mean (SD) duration of surgery and number of sequential readings were 93 (27) and 7 (2) min, respectively. No other complications related to venous cannulation were noted during the study.

Mean (SD) values for CVP and EJVP in the supine position were 8.3 (2.6) and 8.6 (2.8) mm Hg, respectively. In the lateral position, the corresponding readings were 9.2 (2.8) and 10.1 (2.9) mm Hg.

Data were examined for differences between CVP and EJVP at each time point (absolute values) and these data are shown in Figure 1 A and B for patients in the supine position. In the supine position, mean bias was 0 mm Hg (limits of agreement −2.9 to +2.9 mm Hg, 95% confidence intervals −2.0 to +2.0 mm Hg) (Fig. 1A). In the lateral position, mean difference between absolute CVP and EJVP was −0.3 mm Hg (limits of agreement −2.0 to +1.4 mm Hg, 95% confidence intervals −2.2 to +2.3 mm Hg) (Fig. 1B).

Agreement between corresponding ΔCVP and ΔEJVP measurements is shown in Figure 2 A and B. For trend values in the supine position, mean difference between ΔCVP and ΔEJVP was 0.0 mm Hg (limits of agreement −1.7 to +1.7 mm Hg, 95% confidence intervals −2.3 to +2.3 mm Hg) (Fig. 2A). For trend values in the lateral position, mean difference between ΔCVP and ΔEJVP was −0.1 mm Hg (limits of agreement −1.4 to +1.1 mm Hg, 95% confidence intervals −2.9 to +2.7 mm Hg) (Fig. 2B).

Data were also examined excluding patients with catheters on different sides of the neck. In the supine position, mean difference between absolute CVP and EJVP was −0.2 mm Hg (limits of agreement −2.0 to +1.7 mm Hg, 95% confidence intervals −2.4 to +1.4 mm Hg). In the lateral position,
mean difference was $-1.2 \text{ mm Hg}$ (limits of agreement $-6.0$ to $+3.6 \text{ mm Hg}$, 95% confidence intervals $-7.4$ to $-4.3$ and $+1.9$ to $+4.9 \text{ mm Hg}$). For trend values in the supine position, mean difference between $\Delta \text{CVP}$ and $\Delta \text{EJVP}$ was $0.0 \text{ mm Hg}$ (limits of agreement $-2.3$ to $+2.3 \text{ mm Hg}$, 95% confidence intervals $-2.9$ to $-1.7$ and $+1.7$ to $+2.9 \text{ mm Hg}$). For trend values in the lateral position, mean difference between $\Delta \text{CVP}$ and $\Delta \text{EJVP}$ was $0.0 \text{ mm Hg}$ (limits of agreement $-2.2$ to $+2.3 \text{ mm Hg}$, 95% confidence intervals $-3.0$ to $-1.4$ and $+1.7$ to $+2.9 \text{ mm Hg}$).

**Discussion**

In this study, we found a high level of agreement between CVP and EJVP measurements in spontaneously breathing patients undergoing surgery for proximal fracture in the supine position, over a wide range of venous pressures ($-2$ to $+18 \text{ mm Hg}$). Mean bias in both supine and lateral positions was $<1.5 \text{ mm Hg}$, though for some patients, particularly in the lateral group, the disparity was much greater than this. However, in both the supine and lateral positions, the mean bias for trend values was low, with limits of agreement of $+3$ and $-3 \text{ mm Hg}$. The numbers of patients in whom catheters were sited on opposite sides of the neck was small and insufficient to make meaningful statistical comparisons. Exclusion of patients with cannulae on different sides of the neck had a negligible effect on the limits of agreement in both supine and lateral position (decreases of $<1 \text{ mm Hg}$ noted). This would suggest that in the lateral position, the wider limits of agreement are independent of whether cannulae are sited on opposite sides of the neck.

Previous comparisons between CVP and EJVP measurements have suggested that the two methods show reasonable similarity, but older studies have been small, unblinded, or used single pairs of static measurements, rather than calculating limits of agreement across a range of absolute values. Our group demonstrated an acceptable level of agreement between CVP and EJVP in mechanically ventilated patients undergoing elective major surgery. We noted that mean EJVP is on average slightly higher than mean CVP and that the EJVP trace is relatively dampened, perhaps because of the presence of valves in the EJV. Mean CVP and EJVP values in mechanically ventilated patients were higher than in this study ($9.2$ and $9.5$ vs $8.3$ and $8.6 \text{ mm Hg}$, respectively) which probably reflects increased mean airway and PEEP in patients receiving positive pressure ventilation. Patients in the current study were also older (median age $79$ vs $66 \text{ yr}$) which may have affected both CVP and EJVP because of changes in lung compliance secondary to age or respiratory disease. We had anticipated that the disparity between EJVP and CVP would be greater in patients breathing spontaneously, but our results did not confirm this. In fact, the limits of agreement for absolute and trend values in the supine position were closer in the current study than previously demonstrated in patients undergoing positive pressure ventilation ($-2.6$ to $+1.9 \text{ mm Hg}$ for absolute values, compared with $-3.6$ to $+3.0 \text{ mm Hg}$ in the previous study). This suggests that the effects of intrathoracic pressure on the relationship between EJVP and CVP during spontaneous breathing are small.

Ultrasound-guided venous access was not widely available in our hospital when this study was devised and performed. It is known that the presence of the LMA may distort laryngeal anatomy and the normal position of the jugular vein relative to the carotid artery. One of the disadvantages of IJV cannulation is arterial puncture which occurred in two of the 40 patients. A decreased complication rate with IJV cannulation would alter the risk/benefit ratio of central venous cannulation compared with EJV cannulation and use of ultrasound for CVP insertion may be relevant to this. However, EJV cannulation is a useful option in certain patients, and the purpose of this study was simply to establish the level of agreement between EJVP and CVP.

In eight patients, we were unable to cannulate the right EJV. This may reflect our relative inexperience at external EJV cannulation compared with IJV cannulation. Factors contributing to difficult EJV cannulation include small size (EJV diameter is inversely proportional to IJV diameter), valves, hypovolaemia, and suboptimal neck positioning. The existence of a unilateral EJV has been reported but is probably rare.

We recognize that simple pressure measurements may not accurately reflect preload or end-diastolic volumes in all patients. Right heart pressures are affected by many other factors including ventricular function or impairment and vascular tone. I.V. fluid bolusing may produce variable effects on CVP values which depend on the intravascular volume, cardiac function, and neuroendocrine activity. An increase in CVP of $3 \text{ mm Hg}$ or more suggests the limits of vascular compliance have been reached. Various dynamic indices of preload such as stroke volume variation and pulse pressure variation have been suggested to be superior to pressure measurements for guiding fluid management. Some of these indices have been validated in sedated patients undergoing mechanical ventilation, where cyclical changes in intrathoracic and transpulmonary pressures are predictable. However, swings in intrathoracic pressure during spontaneous ventilation are less consistent and alterations in the interaction between intrathoracic pressure and right heart may mask preload dependence. Recent data suggest that dynamic indices do have some limitations as a guide to fluid therapy in patients breathing spontaneously. Conversely, others have shown that a decrease of $\geq 1 \text{ mm Hg}$ in right atrial pressure accurately predicts fluid responsiveness in most patients, so the role of right-sided heart pressure measurements in guiding fluid therapy cannot be discounted.
accuracy of EJVP with CVP measurements rather than compare it against dynamic measures of preload.

The advantages of EJVP monitoring are that it is less invasive and avoids some of the risks of CVP cannulation; it uses currently available equipment and can be used in the awake patient. Although not specifically assessed, our clinical impression during the study was that it is less painful than CVP cannulation in the awake patient. The point at which the limits of agreement between a new method of measurement and the standard technique move point at which the limits of agreement between a new clinical impression during the study was that it is less invasive and avoids some of the risks of CVP cannulation; it uses currently available equipment and can be used in the awake patient. Although not specifically assessed, our clinical impression during the study was that it is less painful than CVP cannulation in the awake patient. The point at which the limits of agreement between a new method of measurement and the standard technique move.

We conclude that in anaesthetized patients breathing spontaneously via an LMA, EJVP gives an acceptable estimate of CVP in the supine position. When used in the lateral position, the mean bias was also low, but the wider limits of agreement suggest that the anaesthetist should be cautious in interpreting absolute values. In either lateral or supine positions, there was good agreement between both techniques for trend values.

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