Comparison of central venous pressure and venous oxygen saturation from venous catheters placed in the superior vena cava or via a femoral vein: the numbers are not interchangeable

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ABSTRACT

Objective: To compare venous pressure and haemoglobin oxygen saturation measured from a catheter in the superior vena cava (SVC) with a catheter inserted via the femoral vein, and to assess the agreement of these measurements. To assess the effect of intra-abdominal pressure and intrathoracic pressures on these measurements.

Design, setting and participants: Prospective study of patients in an adult intensive care unit, Alfred Hospital, Melbourne, Australia.

Main outcome measures: Central venous pressure (CVP), femoral venous pressure (FVP), venous haemoglobin oxygen saturation in the SVC (SO_2C) and via the femoral vein (SO_2F), agreement between these measures using the Bland–Altman method, and the effect of intra-abdominal pressure and intrathoracic pressure.

Results: 43 patients were included; the mean bias for FVP – CVP was 1.05 mmHg (95% CI, 0.30–1.79 mmHg), with limits of agreement of –3.79 to 5.89 mmHg (95% CI, –5.08 to 7.18 mmHg). The bias for SO_2F – SO_2C was –3.21 (95% CI, –6.33 to –0.10), with limits of agreement of –22.43 to 16.01 (95% CI, –27.81 to 21.39). Intra-abdominal pressure had a significant ($P < 0.01$) effect on both the FVP and on the difference (FVP – CVP).

Conclusions: This study demonstrates poor agreement between CVP and FVP and between SO_2C and SO_2F and that the measurements taken from these two sites are not interchangeable clinically.

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Central venous catheters (CVCs) are used for infusion of irritant substances, inotropes and total parenteral nutrition. They also provide a way to measure various parameters that may be used to direct therapy in critically unwell patients, particularly in the intensive care or emergency department setting. In early goal-directed therapy for sepsis, the central venous pressure (CVP) and central venous oxygen saturation constitute essential parameters that require repeated assessment and optimisation.[1]

Currently, CVP is assessed by way of a transducer connected to a CVC whose tip lies in the superior vena cava (SVC) near the right atrium.[2] Central venous oxygen saturation is either measured on drawn blood from an SVC catheter or using specific catheters with inbuilt saturation monitors. CVCs are usually inserted via the internal jugular or subclavian vein, with or without ultrasound guidance.

There are risks associated with the insertion of "neck line" catheters, including carotid artery puncture, pneumothorax, air embolism and damage to adjacent structures such as the phrenic or recurrent laryngeal nerves or the thoracic duct.[2]

Femoral lines are technically easier to insert,[3] and pressure measurement from this site has been shown to accurately reflect the central venous pressure in children.[4] In an adult population, a study that examined long catheters inserted via the femoral vein to lie in the infra-diaphragmatic inferior vena cava (IVC) have also been shown to accurately reflect the SVC pressure.[5] Studies of the use of more standard length femoral catheters in adult patients also suggested that this agreement is accurate.[6-8]

We undertook a prospective study to examine the relationship of both venous pressure and haemoglobin oxygen saturation, measured via the femoral route and traditional neck line route in an adult intensive care population.

Methods

Before data collection, approval for the study was granted by the Alfred Hospital's Ethics Committee (approval no. 367-08). The measurements included in the study are monitored in the intensive care unit as part of routine clinical care, and as such a consent waiver was also granted. The study was undertaken over a 2-year period from December 2008, in the ICU of the Alfred Hospital, Melbourne, Australia, a 45-bed combined medical, surgical and trauma ICU.

Pressure measurements from the SVC (internal jugular vein or subclavian vein access) or from a catheter inserted via the femoral vein were taken using an Edwards Lifesciences pressure monitoring transducer set (Edwards Lifesciences, Irvine, Calif, USA) connected to a IntelliVue MP70 monitor (Philips Healthcare, Eindhoven, Netherlands). Enrolled patients had catheters in situ at both sites and pressure measurements were recorded simultaneously from the two sites using separate transducers.

SVC pressure measurements were obtained through a Niagara 13.5 F× 15 cm short-term dialysis catheter (Bard Access Systems, Salt Lake City, Utah, USA), a Cook Medical 7 F× 20 cm Triple Lumen Central Venous Catheter (Cook Medical, Bloomington, Ind, USA), or a Cook Medical 10 F× 20 cm Five Lumen Central Venous Catheter. IVC pressure measurements were obtained through a Niagara 13.5 F× 24 cm short-term dialysis catheter (Bard Access Systems), a Cook Medical 7 F× 20 cm Triple Lumen Central Venous Catheter, or a Cook Medical 10 F× 20 cm Five Lumen Central Venous Catheter.

Clinical techniques

SVC and IVC pressure measurements were obtained according to the Bayside Health CVC protocol. Patients were positioned with the head slightly elevated (no greater than an estimated 30 degrees) to reduce the risk of ventilator-associated pneumonia, and the transducer was zeroed at the level of the phlebostatic axis.

Abdominal pressure measurements were taken using the Bayside Health protocol on measurement of intra-abdominal pressure. This involved instilling 100 mL of normal saline into the bladder through an indwelling urinary catheter. Measurements were taken with the transducer zeroed at the symphysis pubis.

Both spontaneously breathing patients and those supported by positive-pressure ventilation were included for data collection. Further measurements recorded included mean arterial blood pressure and fraction inspired oxygen. Peak inspiratory pressure, tidal volume and positive end expiratory pressures (PEEP) were recorded in all positive-pressure ventilated patients.

Venous samples were drawn from the two sites and analysed using a RAPIDLab 1265 blood gas machine (Siemens Healthcare Diagnostics, Deerfield, Ill, USA) for haemoglobin oxygen saturation.

Measurements were recorded by two observers, using exactly the same technique. Data collection was regularly undertaken with both observers present to ensure no discrepancies existed between the data collectors' techniques. Additionally, in an effort to reduce observer bias, data collectors were not aware of the research goals until data collection was complete.

Statistical analysis

All data were analysed using Stata, version 11 (StataCorp, College Station, Tex, USA). Agreement between measurements was assessed using the method outlined by Bland and Altman.[9] Limits of agreement were computed and reported with 95% confidence intervals. We used linear

Table 1. Venous pressure and oxygen saturation (mmHg) among 43 adult intensive care patients

Age (years)	Sex	FVP	CVP	SO_2F	SO_2C
58	F	5	7	61.1	58.8
63	F	6	6	66.0	68.1
80	M	8	6	77.8	76.2
31	M	7	7	52.4	67.1
85	M	10	5	60.8	57.6
46	M	6	9	80.0	70.6
64	M	10	5	72.9	73.9
34	M	10	6	—	—
65	M	10	7	66.4	73.9
62	M	8	10	—	—
17	F	9	9	58.9	67.5
54	M	11	9	70.1	82.0
62	M	10	11	55.0	68.0
35	M	11	10	76.2	73.0
79	M	10	11	49.6	58.7
20	F	12	10	72.5	52.8
50	M	11	11	55.9	45.7
57	F	12	10	84.7	82.8
79	M	12	11	58.6	58.6
62	M	12	11	74.1	79.3
70	M	14	10	72.6	83.9
65	M	12	12	67.5	62.8
79	M	12	12	64.5	75.1
71	M	16	10	65.4	76.3
59	M	12	14	62.5	70.9
35	M	14	13	88.3	80.4
91	M	16	12	72.4	84.3
83	M	17	12	60.8	47.9
78	M	15	14	67.3	75.7
49	F	16	14	71.3	85.6
64	M	16	15	70.0	73.3
64	M	18	14	70.5	82.3
83	F	16	16	51.3	67.2
59	M	18	16	56.5	65.9
62	M	20	15	—	—
55	F	18	17	77.5	71.1
69	M	16	20	75.2	75.0
21	M	17	19	81.7	70.6
64	M	17	19	62.5	65.1
42	M	18	19	—	—
63	M	20	18	52.7	47.5
69	M	19	19	27.8	54.1
55	M	20	21	68.9	75.8

FVP = femoral venous pressure. CVP = central venous pressure. SO_2F = femoral haemoglobin oxygen saturation. SO_2C = central haemoglobin oxygen saturation. — = no data.

regression to assess the effect of intra-abdominal pressure and thoracic pressures on FVP and difference between FVP and CVP. Results were reported as parameter estimate (PE) with standard error (SE). A two-sided *P* of 0.05 was considered statistically significant.

Results

Forty-three critically ill adult patients were recruited with CVCs in situ via both the femoral and neck route. Data for the patients studied are shown in Table 1.

Venous pressure

Venous pressures ranged from 5.00 to 21.00 mmHg, with a median of 12.00 mmHg and a mean of 12.66 mmHg (SD, 4.28 mmHg).

Using the Bland–Altman method, the difference between FVP and CVP was plotted against the mean of these values (Figure 1). Overall, the mean difference between FVP and CVP was 1.05 mmHg (SD, 2.42 mmHg), giving limits of agreement for our data of – 3.79 to 5.89 mmHg. The standard error for the mean was 0.37, which gives a 95% confidence interval for the bias of 0.30 to 1.79 mmHg. The standard error of the limits of agreement is 0.639. Using a *t* distribution with 42 degrees of freedom, this gives confidence intervals for the lower limit of agreement as –5.08 to –2.50 mmHg, and for the upper limit of agreement as 4.60 to 7.18 mmHg.

We also examined the effect of intra-abdominal pressure (as measured by bladder pressure) on these two measurements. We obtained intra-abdominal pressure values between 4 and 22 mmHg. We found a statistically significant increase in the FVP (PE, 0.498; SE, 0.154; $P = 0.003$), and the difference (FVP – CVP) with increasing intra-abdominal pressure (PE, 0.264; SE, 0.091; $P = 0.007$). This effect is demonstrated graphically in Figure 2.

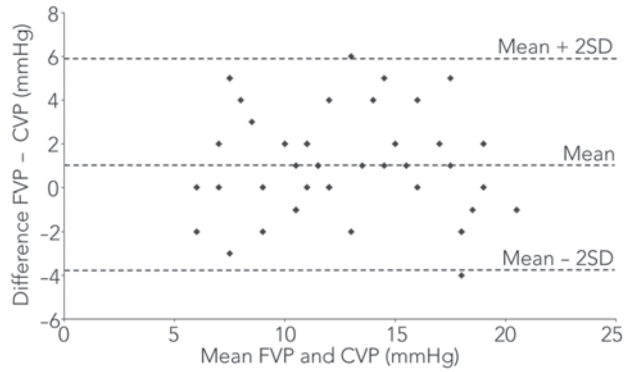
We also determined intra-thoracic pressure measurements among ventilated patients. These factors did not appear to affect the relationship of FVP to CVP for the values measured in our study (PEEP, 5–18 mmHg; peak inspiratory pressure, 13–45 mmHg).

Venous oxygen saturation

Using the Bland–Altman method, the difference between femoral haemoglobin oxygen saturation (SO_2F) and central haemoglobin oxygen saturation (SO_2C) were plotted against their means (Figure 3).

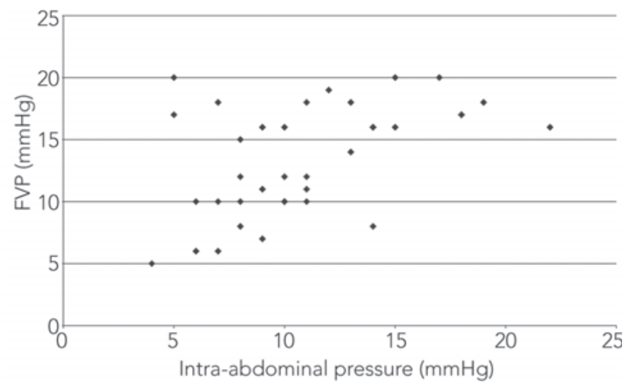
The mean difference was –3.21, with a 95% confidence interval for the bias of –6.33 to –0.10. Limits of agreement for our data were –22.43 to 16.01. Again, extrapolating to the population gives confidence intervals for the lower limit of agreement of –27.81 to –17.04 and for the upper limit of

Figure 1. Bland–Altman plot of the difference between FVP and CVP



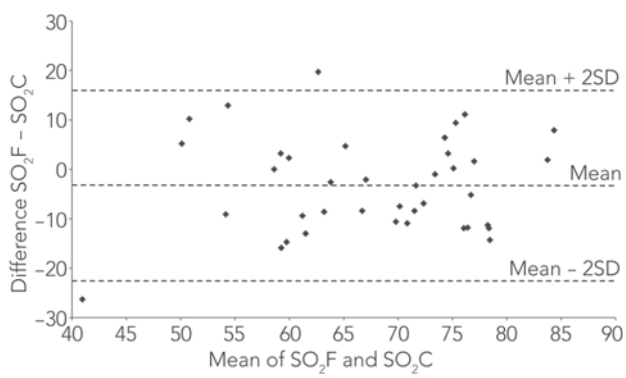
FVP = femoral venous pressure. CVP = central venous pressure.

Figure 2. Bland–Altman plot of the effect of intra-abdominal pressure on FVP



FVP = femoral venous pressure.

Figure 3. Bland–Altman plot of the difference between SO_2F and SO_2C



SO_2C = venous haemoglobin oxygen saturation in the superior vena cava.
SO_2F = venous haemoglobin oxygen saturation via the femoral vein.

agreement of 10.62 to 21.39. Intra-abdominal and intrathoracic pressure measurements did not affect the relationship of SO_2F to SO_2C.

Discussion

This prospective study set out to determine whether measurements of venous pressure and saturation taken from catheters inserted into a femoral vein could be used in place of measurements from a "central line" (catheter placed in the SVC via either the subclavian or internal jugular vein). We found poor agreement for these measurements, suggesting that these values should not be used interchangeably.

The duration of central venous access required means patients often undergo "change of lines" during their intensive care stay, and having the option of the femoral route gives two additional sites for inserting these catheters. Furthermore, in certain situations use of the femoral route may be considered safer, such as in patients requiring ventilation with high pressures or in patients with coagulopathy. Femoral access carries no risk of pneumothorax and the vessels are directly compressible in the event of haemorrhage. X-ray confirmation of catheter position is not required. The femoral route is not without its disadvantages, however, namely, increased rates of catheter-related sepsis[10] and lower limb venous thrombosis.[11]

Previous studies have suggested that there is a sufficiently close agreement between CVP and FVP to allow catheters inserted via the femoral route to be considered "central" for venous pressure monitoring. Our study failed to demonstrate this close agreement, despite a larger number of enrolled patients. Indeed, the limits of agreement suggest that the value measured at the groin may vary by as much as 7 mmHg. Considering that in early goal-directed therapy for sepsis, the target for CVP is 8–12 mmHg,[1] this difference may make the reading uninterpretable as an end point for therapy.

There are several possible explanations for the lack of agreement in our results compared with previous studies. Yung and Butt studied a paediatric population, with a mean age of 33 months. It may be that the smaller distances involved from catheter tip to right atrium reduced the observed difference in pressure readings from the two sites.[4] In a study by Joynt and colleagues, which comprised adult patients, the catheter was advanced to lie in the inferior vena cava close to the right atrium.[5] Their results suggested close agreement between the measurements, perhaps also because the distances involved were small.[5]

In terms of statistical analyses, our method differed from previous studies in that a single pair of measurements was taken from each patient; Yung and Butt took a mean of two reading from each site before the Bland–Altman analysis, which would reduce any apparent difference in their readings. Ho and colleagues took numerous readings (140 paired readings) from fewer patients ($n = 20$) and applied the Bland–Altman method to the dataset, again reducing the apparent difference without increasing n;[6] this was also true of the study by Joynt et al (133 paired measurements, $n = 19$).[5] Dillon and colleagues showed close agreement in 22 ventilated adult patients (162 paired measurements; $n = 22$) and further that this agreement was not affected by the type of mechanical ventilation (normal and inverse ratio ventilation).[7]

The original statistical article by Bland and Altman discusses a method of assessing agreement when multiple measurements are taken from the same participant, but this was not applied in the previous articles, and as a result the limits of agreement they reported may be artificially small.[9]

Pacheco and colleagues compared the venous pressure at the two sites in heart surgery patients.[8] They also took multiple measures from their sample of 60 patients (720 paired measurements; $n = 60$) and applied the Bland–Altman analysis to their data without correcting for multiple measures. Interestingly, despite the larger sample size, and the lack of correction for multiple measures, their reported limits of agreement were wider (–10.3 to 6.5 mmHg), which is in keeping with our findings.[8]

Lastly, data collectors in our study were not aware of the research intentions until data collection was complete, in an effort to reduce observer bias. It is not clear whether this was employed for the data collection process in the previous studies.

In addition, we found that rising intra-abdominal pressure significantly increased the measured FVP as well as the difference between FVP and CVP, potentially further reducing the accuracy of this measurement in certain clinical scenarios.

Venous oxygen saturation

Venous oxygen saturation is an important parameter in the implementation of early goal-directed therapy for sepsis. Our results suggest that there is poor agreement between the values obtained centrally (SO_2C) and via the femoral route (SO_2F), with wide limits of agreement for the difference in these measurements (– 27.81 to 21.39). In the clinical setting of a septic patient being managed as per early goal-directed therapy, a central venous SO_2 less than 70% could result in a blood transfusion, institution of inotropic support, or indeed intubation, ventilation and paralysis. If the measurement is taken from a femoral venous catheter, the target of 70% may actually correspond to values approaching 40% or above 90%. Similar results have been found by Davison and colleagues in a North American ICU.[12]

The differences measured may reflect a restricted "view" of tissue oxygen extraction by the femoral venous catheter, in that the blood sampled from this site is essentially venous return from the lower limb(s) and to some extent the pelvis (depending on the length of the catheter relative to the external iliac vein), and is unlikely to reflect tissue oxygen extraction for the systemic circulation as measured by the mixed venous oxygen saturation.

Femoral catheter length

As mentioned above, Joynt and colleagues showed good agreement when using catheters inserted via the femoral vein, when their tips lie close to the right atrium.[5] One potentially confounding variable we identified in our study was the use of femoral catheters of differing lengths; this was also true for the previous studies looking at the comparison of venous pressure.[4,6-8] For both venous saturation and venous pressure measurements, longer catheters may provide closer agreement than shorter catheters, simply as a consequence of their proximity to the right atrium.

As part of a post-hoc analysis, when we divided our data into two groups based on femoral catheter length, we found a smaller bias (0.43 mmHg for 24 cm v 1.63 mmHg for < 24 cm) as well as narrower limits of agreement (–3.07 to 3.93 mmHg for 24 cm v – 4.04 to 7.31 mmHg for < 24 cm). This effect was not seen for venous haemoglobin saturation.

Conclusion

The femoral vein is a useful additional site for central access but the results of our study suggest that this route should be reserved for indications other than the assessment of the physiological parameters of central venous pressure and central venous oxygen saturation. Measurements from this site may be useful as a single value or a trend measurement, but normal physiological and pathological ranges have not been established and require further study.

Competing interests

None declared.

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