ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

Comparison between Femoral and Superior Approach Central Venous Pressure Measurements in Critically Ill - Mechanically Ventilated Patients

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Manuscript Info

Manuscript History:

Received: 22 May 2014
Final Accepted: 25 April 2014
Published Online: May 2014

Key words:

Critically Ill Patients; Central Venous Pressure; Superior Approach; Femoral Vein

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Abstract

Central venous catheterization is one of the most commonly used invasive procedures in critically ill patients. Internal jugular and subclavian veins are the most frequently anatomical sites used for central venous catheter (CVC) insertion. However, access through the internal jugular or subclavian veins may lead to several substantial serious and life threatening complications such as pneumothorax, haemothorax, air embolism, arterial puncture, bleeding, dysrhythmias and thoracic duct injury. In contrast, femoral route is safe**,** standard and popular procedure as it avoids many of the potential peri-insertion and mechanical complications of the superior approach (internal jugular & subclavian veins. In addition, the femoral route is also considered by many to be the easiest site for central venous access and can be quickly learned by inexperienced operators. Ruesch (2002), (Alzeer et al,. 1998), (Gavin M. et al., 2000 & 2008). But, does the central venous pressure (CVP), monitored via the femoral route, correlate with that measured via the subclavian or internal jugular routes? In order to answer this question, this study was conducted; it was aimed to compare the measures of central venous pressure (CVP) at two different sites (superior approach and femoral approach).

Material and Methods: Prospective comparative cross - over design was used to conduct this study. Thirty consecutive adult mechanically ventilated patients admitted to intensive care unit (ICUs) from June to December 2011 and requiring femoral catheterization in addition to subclavian or internal jugular veins were recruited in this study. CVP was measured from both sites hourly for 6 consecutive hours. Positive end-expiratory pressure, mean airway pressure, and intra-abdominal pressure were recorded & measured simultaneously. **Results & Conclusions:** For 180-paired measurements obtained from superior approach veins and femoral vein were statistically analyzed using intra-class correlation coefficients (ICC). A statistically significant high correlation (ICC 0.868, p-value < 0.001) has been showed between the both sites. In addition, Bland and Altman Plot used for assessing agreement of femoral and superior approach. The mean difference between superior approach (subclavian and internal jugular) and femoral CVP was -1.64 mm Hg (95% CI -3.86 - 0.57). The difference was normally distributed around the mean with a standard deviation of 1.11 mm Hg. i.e., on an average, the femoral vein CVP measurements were higher than superior approach of 1.64 mm Hg.

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INTRODUCTION

Hemodynamic monitoring is a cornerstone in the care of the critically ill patient in the ICU. Within this context, hemodynamic monitoring is used to identify hemodynamic instability and its cause and to monitor the response to therapy. Pinsky (2007). Central Venous Pressure (CVP) measurement is a common procedure in the intensive care unit **(ICU).** It is a number that describing the pressure of the blood in the thoracic vena cava near the right atrium of the heart. It can be simplified that, CVP equals the right atrial pressure. CVP reflects the amount of the blood returning to the heart and the ability of the heart to pump the blood through the arterial system. It is a good approximation of the right atrial pressure, which is the major determinant of right ventricular end diastolic volume and right ventricular preload. Clinically, measurement of the CVP is used for two purposes (1) to gain information about cardiac function, and (2) to gain information about the adequacy of vascular volume. CVP can be measured via insertion of central catheter into the central vein. Mark (2005), (McGee et al., 2003), Ruesch (2002), Merrer (2001), Izakovic (2008).

The choice of the best central venous access for a particular patient is based on the rate and the severity of failures and complications. (Francois et al., 2003). The internal jugular and the subclavian veins are the most frequently anatomical sites used for CVC insertion. Indeed, there are substantial serious complications, sometimes life threatening, associated with both methods. These include pneumothorax, hemothorax, pulmonary embolism, arrhythmia, intra-cardiac positioning of the tip, thoracic duct laceration, damage to phrenic, vagus or recurrent laryngeal nerves or to the brachial plexus and inadvertent puncture of the carotid artery. However, cannulation of both internal jugular vein and subclavian veins are relatively safe but less so than femoral vein cannulation. They are recommended only for those who have experience with these techniques. Madger (2005), Reinhart (2004), Izakovic (2008).

In contrast, femoral route is safe**,** standard and popular procedure as it avoids many of the potential peri-insertion, mechanical complications of the internal jugular and subclavian routes and at the same time, the femoral route is also considered by many to be the easiest site for central venous access and can be quickly learned by inexperienced operators. Femoral venous cannulation is frequently used in patients with limited venous access, such as burns or long stay patients, patients with severe coagulopathy, severe respiratory distress, or difficult head and neck anatomy**.** Few significant complications are associated with femoral vein cannulation such as increased risk of lower limb deep venous thrombosis, and a small increase in infectious complications. The most potentially complication of femoral rout is inadvertent penetration of the peritoneal cavity or rectum. This complication can be avoided by ensuring the site of insertion is below the inguinal ligament and the needle is not directed to posteriorly or inserted too deeply. In addition to bleeding from inadvertent arterial puncture that is more easily controlled by manual pressure because the site is directly compressible than the other sites. David (2003), Roberto (2007), (Eisen et al., 2006), Joynt (2000).

Material and Methods:

A prospective comparative – cross over study design was used to conduct this study. Thirty consecutive adult mechanically ventilated patients admitted to intensive care units requiring femoral catheterization in addition to superior approach catheterization (subclavian or internal jugular vein) were recruited in this study. Patients were excluded from the study if the Positive End Expiratory Pressure (PEEP) was higher than 10 mmHg, patient had lung diseases that might contribute to increasing the airway pressure such as pulmonary edema, pneumothorax, and those patients who had intra-abdominal pathology (ascites, femoral vein thrombosis) and if the intraabdominal pressure was higher than 12 mmHg (normal IAP) (Kimball et al., 2007).

The study was conducted over the course of 6 months in the Intensive Care Units (ICUs) of the Main University Hospital in Alexandria. Permission to conduct the research was obtained from the authority figures in the hospital & in the intensive care units after explanation of the research aim and methodology. After having the study explained, a verbal consent was obtained from the patient or the relative. Tool was develop by the researcher and was checked for content validity by five professors from critical care nursing and critical care medicine. A pilot study was conducted on five patients order to test the clarity, validity and applicability of the tool.

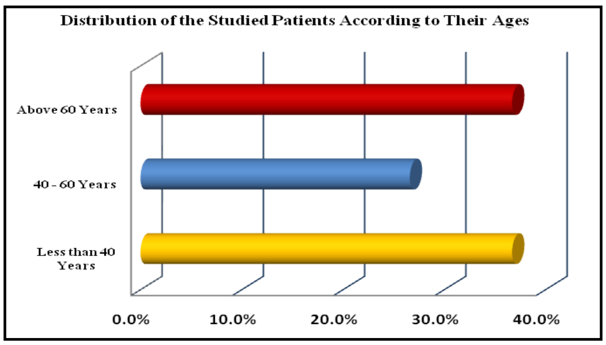
In addition to the superior approach catheter that was in place, catheter was inserted into femoral vein by the ICU physician with the assistance of the critical care nurse. The femoral catheter was placed in the inferior vena cava close the right atrium blindly based on the anatomical landmark of the femoral vein. Catheter tip was positioned within the inferior vena cava, close to the right atrium. The catheter placement was confirmed (and repositioned it if necessary) by chest radiography before CVP measurements were made. CVP and intraabdominal measurements were performed by the critical care nurse who was assigned to the patient. For the duration of the study, all patients were placed in the supine position with a maximum head-up-tilt of 15 degree. Patient position and the ventilator settings were not changed for the duration of the study.

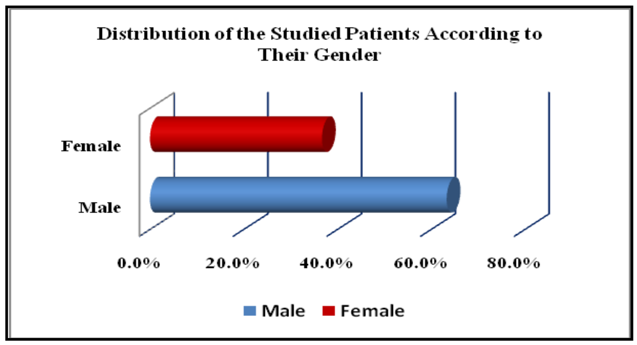
Simultaneous measurements of femoral and superior approach CVP were made with the same disposable electronic transducer or manual manometer and with the same nurse at hourly intervals. CVP was measured from both sites hourly for 6 consecutive hours. The transducer or manometer was fixed at the level of the right atrium (junction of midaxillary line and the fourth intercostal space). Six pairs of measurements were made from each patient. Positive end-expiratory pressure and mean airway pressure, obtained from the ventilator readout (Drger- Evita XL ventilator)), and intra-abdominal pressure, obtained from an indwelling urinary catheter (Fr.14) were measured at the time of venous pressure comparison.

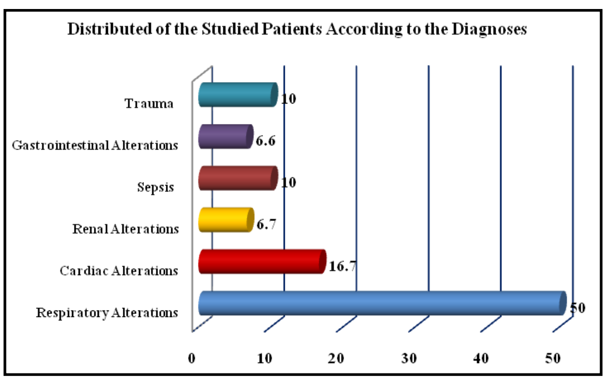
Results & Discussion:

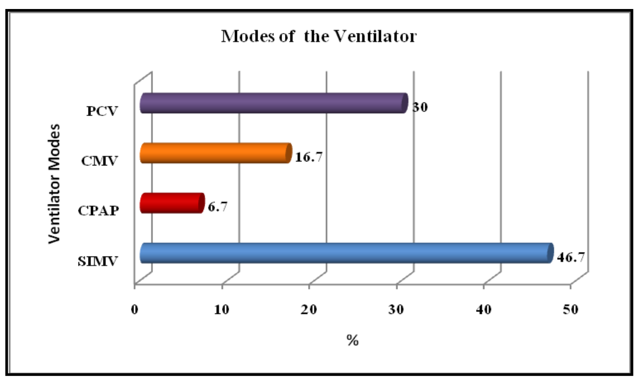
Results were presented as mean± standard deviation for continuous variables and number (%) for counts. Bland and Altman method was used to compare the paired measurements of superior approach and femoral CVP. Identity plot was used to check the perfect agreement between the paired measurements. It is obtained as a scatter plot of the two measurements along with the line y = x. Intra-class, correlation was also calculated to estimate correlation between the paired measurements. Correlation analysis were used to identify the relationship between difference in superior approach CVP and femoral CVP measurements and the positive end expiratory pressure (PEEP), mean airway pressure (MAP) and intra-abdominal pressure (IAP).

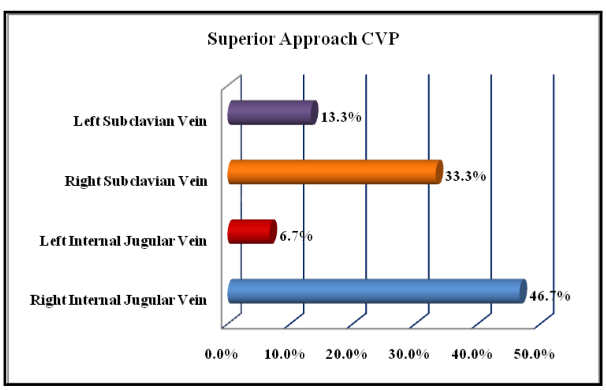
1. PATIENT DEMOGRAPHICS AND CHARACTERISTICS

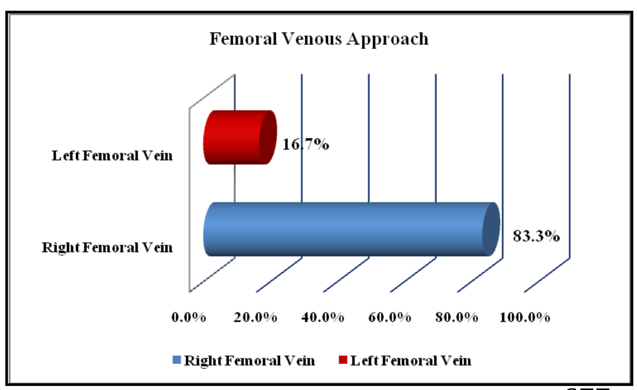












Regarding to the patients' demographics and characteristics, it can be observed that, median age of the study group was 49 years (ranged from 18 – 80 years), almost 63% of patients were male, and fifty percent of the study sample was diagnosed as respiratory alterations. Moreover, synchronized intermittent mandatory ventilation (SIMV) was the highest documented ventilator mode. Right internal jugular vein was the highest site chosen for intrathoracic central catheter insertion and right femoral vein was higher than left one in the intraabdominal.

2. AGREEMENT BETWEEN SUPERIOR APPROACH CVP AND FEMORAL CVP

Table 2.1: Summary of the Mean ± SD of the Superior Approach CVP and Femoral CVP

Anatomical Site	Mean ± SD	Min. - Max
Superior Approach CVP	10.5 ± 2.62	6 - 18
Femoral CVP	12.2 ± 2.71	7 - 19

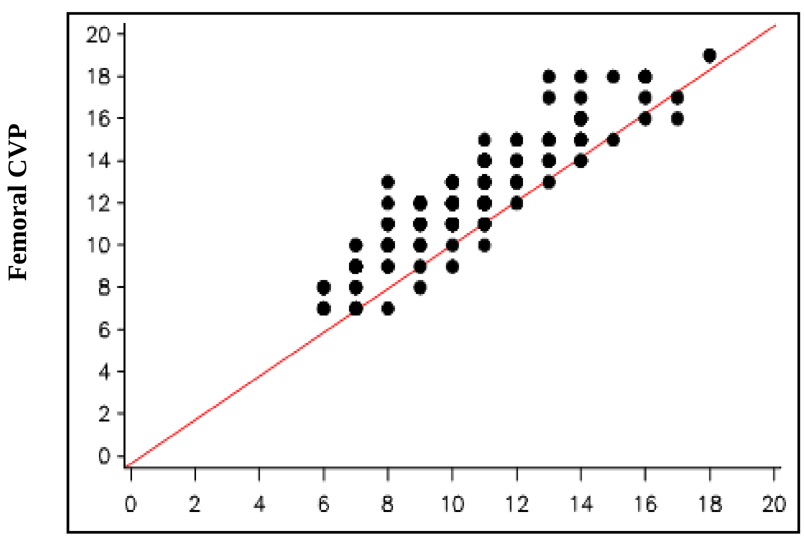
Table 2.1: provided the summary of 180 measurements of superior approach CVP and femoral CVP. The mean ± SD of the superior approach CVP was 10.5 (2.6) and the mean ± SD of femoral CVP was 12.2 (2.7).

2.2 Correlation between Superior Approach CVP and Femoral CVP

Correlation between the two methods was assessed using intra-class correlation coefficient (ICC), which describes how strongly units in the same group resemble each other. A statistically significant high correlation (ICC 0.868, p-value < 0.001) has been showed between superior approach CVP and femoral CVP.

2.3. Identity Plots for Assessing Perfect Agreement

The ability of femoral CVP to reflect the superior approach CVP was assessed by identity plots of femoral CVP against superior approach CVP. In figure1.1 (combined – 180 paired measurements) and figure 2.2 (for each measurement occasions), most of the paired measurements showed departure from the line of perfect agreement (indicated by a diagonal red line). Hence, it was concluded only a basic agreement between femoral CVP and superior approach CVP.



Superior Approach CVP

Figure 1.1

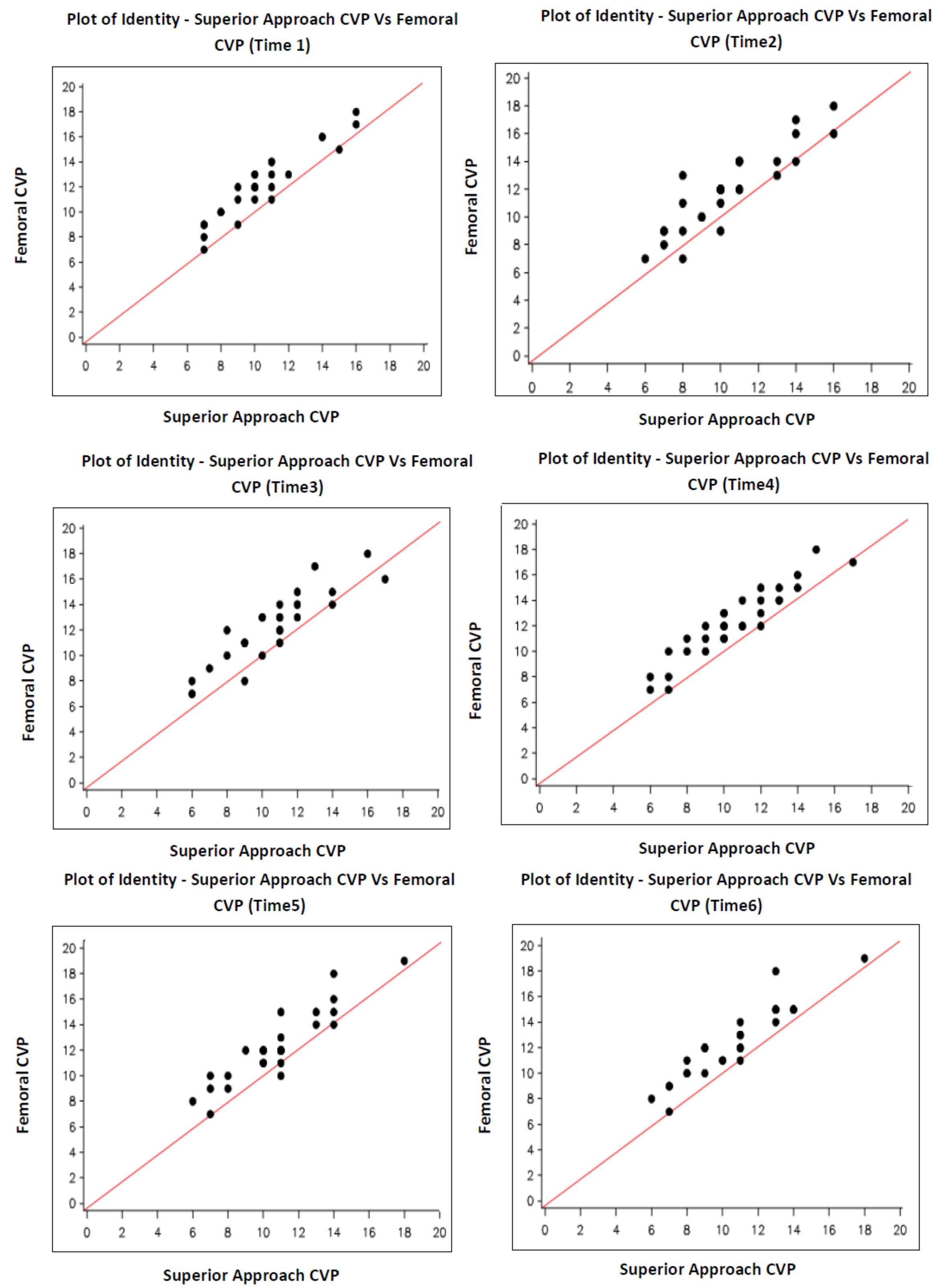


Figure 2.2: Plot of Identity for each Measurement Occasions (Hour 1 to 6)

Bland and Altman Plot for Assessing Agreement

Paired measurements of superior approach CVP and femoral CVP were further compared by the method of Bland and Altman (figure 2.3). The mean difference between superior approach CVP and femoral CVP was -1.64 mm Hg (95% CI -3.86 - 0.57). The difference was normally distributed around the mean with a standard deviation of 1.11 mm Hg. i.e., on an average, the femoral CVP measurements were higher than superior approach CVP of 1.64 mm Hg. The limit of agreement was therefore -3.90 – 0.80 mm Hg.

Bland-Altman Plot comparing Femoral CVP and Superior Approach CVP

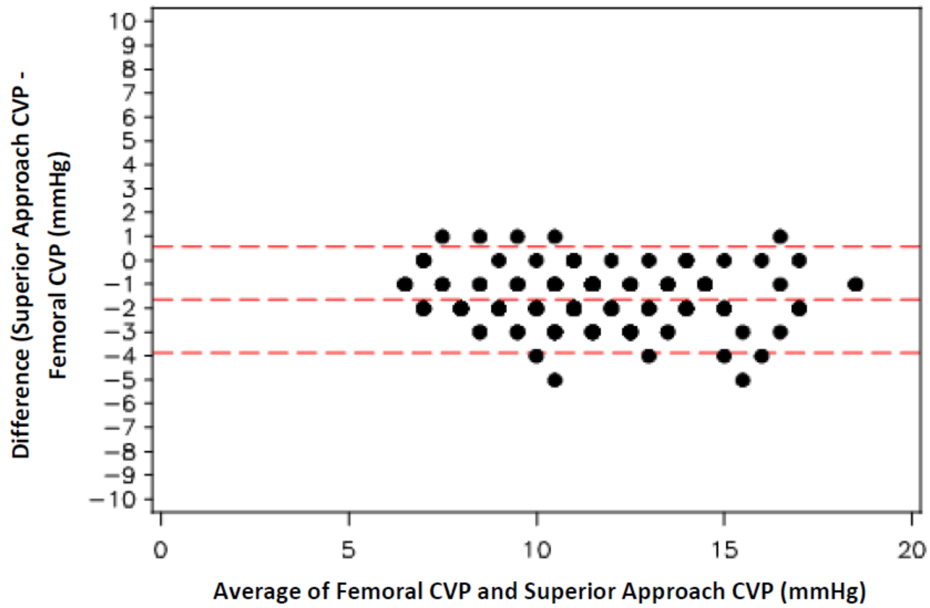


Figure 2.3: Bland-Altman Plot comparing Femoral CVP and Superior Approach CVP

3. FACTORS INFLUENCING THE DIFFERECE BETWEEN SUPPEROR APPROACH CVP AND FEMORAL CVP

3.1 Effect of positive end-expiratory pressure (PEEP) on the difference between Superior Approach CVP and Femoral CVP

Table 3.1: Summary of Positive End Expiratory Pressure (PEEP)

	Mean ± SD	Min. – Max.
PEEP	7.30 ± 2.25	5 - 12

Table 3.1 showed that, there was a weak negative significant correlation (correlation coefficient = -0.17, p-value =0.02) existed between the PEEP and difference in superior approach CVP and femoral CVP measurements.

3.2 Effect of Mean Airway Pressure (MAP) on the Difference between Superior Approach CVP and Femoral CVP

Table 3.2: Summary of MAP

	Mean ± SD	Min. – Max.
MAP	12.10 ± 2.53	7 - 18

Table 3.2 showed that there was a weak negative significant correlation (correlation coefficient = -0.32, p-value <0.001) existed between the MAP and difference in superior approach CVP and femoral CVP measurements.

3.3 Effect of Intra-Abdominal Pressure (IAP) on the Difference between Superior Approach CVP and Femoral CVP

Table 3.3: Summary of Intraabdominal Pressure (IAP)

IAP	Mean ± SD	Min. – Max.
	8.2 ± 1.75	5 - 12

Table 3.3 showed that there was a very weak negative correlation (correlation coefficient = -0.08, p-value =0.27) between the MAP and difference in superior approach CVP and femoral CVP measurements.

Discussion

Patient safety remains a national concern, as evidenced by frequent consumer and professional reports highlighting the impact of medical errors, hospital infection rates, and other examples of suboptimal outcomes. American Association of Critical Care Nursing (AACN) identified 6 essential standards including communication, true collaboration, effective decision making regarding the safe practices, meaningful recognition, appropriate staffing, and authentic leadership (American Association of Critical-Care Nurses 2010). One of the decisions making regarding the safe practice was determination of the best approach used to insert the central venous catheter which has fewer patient's complications. The choice of the central venous access for a particular patient is based on the rate and severity of failures and complications. Francois (2003). Cannulation of the internal jugular and subclavian veins are associated with number of major and serious complications in comparing with the femoral route. Dillon (2001). This study aimed to compare the CVP measurements obtained from superior approach and femoral approach and to what extent femoral approach can be used safely as an alternative to superior approach.

The result of the current study has demonstrated that, CVP measured by catheter placed in the femoral vein can adequately reflect the CVP obtained from either subclavian or internal jugular in critically ill mechanically ventilated adult patients. 180 Paired measurements of superior approach CVP and femoral CVP were compared by the method of Bland and Altman. The mean difference between superior approach CVP and abdominal CVP was 1.64 mm Hg (95% CI -3.86 - 0.57). The difference was normally distributed around the mean with a standard deviation of 1.11 mmHg. i.e., on an average, the femoral CVP measurements were higher than superior approach CVP of 1.64 mm Hg. The limit of agreement was therefore -3.90 – 0.80 mmHg. These differences are considered clinically insignificant. The close correlation between the CVP in the right atrium and the femoral vein may be explained by the absence of venous valves above the femoral vein, which establishes an uninterrupted column of blood from the common iliac vein to the right atrium. In addition, the current study revealed that, mean airway pressure, intra-abdominal pressure, and positive end-expiratory pressure had weak negative significant correlations & no measurable effect on the difference between superior approach CVP and femoral CVP was observed.

Multiple studies' results were congruent with the result of the current study and they have looked to the CVP measurements obtained from femoral vein are as reliable and accurate as CVP measurements obtained from superior approach (internal jugular or subclavian veins). The same result was claimed by Silva et al in (2008), Gavin et al in 2008 and Caramelo (2006). In prospectively and openly Silva allocated 60 patients, who underwent heart surgery, three measures were obtained from each patient at each site (admission, 6 and 12 hours after surgery). Based on the Silva's result, she concluded that, the CVP can be measured with accuracy in the femoral venous approach in the immediate postoperative period of heart surgery. On the same vein, Gavin et al concluded that, Vascular catheters inserted via the femoral route can be routinely used to measure CVP in most critically ill patients with normal or moderately raised intra-abdominal pressure (<15 mmHg), but should not be used to measure CVP in patients with abdominal compartment syndrome.

Moreover, Caramelo et al (2006) aimed to compare central venous pressure (CVP) measurements obtained in two different locations (jugular or subclavian veins and femoral veins). The IAP was previously evaluated in all patients using the method described by Sugrue and Hillman. A good correlation between measurements was found with a correlation coefficient and P > 0.001. The researchers concluded that, CVP can be accurately measured in femoral accesses, using standard CVC in patients with normal intraabdominal pressure.

Furthermore, Six studies were identified that assessed the CVP measured in adults via the femoral route and compared it with simultaneous measurement of the pressure in the superior vena cava. Three of the studies **(Dillon** (2001), Alzeer (1998) and Ho (1998) confined themselves to the critically ill adult population. In these studies a total of 328 paired readings were made in 68 mechanically ventilated patients. The mean difference between the CVP measured via the femoral route and the superior vena cava route was less than 1 mmHg in all three papers. The three other studies also showed good correlation between the relevant measurements however there were important differences in the patient population or the catheters used. Walsh et al (2000) studied patients undergoing cardiac catheterization and found good correlation between the pressures in the right atrium, inferior vena cava and femoral vein. The study by Sheridan (1999) included adult and pediatric patients, again finding good correlation. Joynt et al (1996) examined ventilated adult intensive care patients however they used 40-70 cm lines positioned in the inferior vena cava, above the diaphragm, close to the right atrium.

The same result has been demonstrated by Joel. He carried out a short cut review to establish whether femoral central venous lines were as reliable as subclavian or jugular lines at assessing right atrial filling pressure**.** Altogether 141 papers were found using the reported search, of which seven presented the best evidence to answer the clinical question. He found that, there is extensive and consistent evidence that right atrial pressure can be reliably measured using both inferior vena cava and common iliac venous pressure measurements in supine patients. This has been proved in ventilated and spontaneously breathing adults and children. This may not apply to patients with raised intra-abdominal pressure but applies to patients with high PEEP or raised mean airway pressures. Joel Desmond (2010).

Although some of the other studies have demonstrated a strong agreement and support for the current study and they confirmed that, central venous pressure measured via the femoral route correlates well with the pressure measured in the superior vena cava and consequently provides all the functions of a subclavian or internal jugular catheter, they did not support the use of femoral approach. They claimed that, the incidence of septic and thrombotic complications associated with femoral catheterization, are higher than those associated with subclavian catheterization. In addition, the femoral route carries a similar incidence of mechanical complications on insertion to the subclavian approach, but the nature of the complications differs. Seven trials were identified that prospectively examined all patients receiving a femoral venous line in order to determine the rates of thrombotic complications. Three were randomized controlled trials and one was an observational study comparing the femoral route with a thoracic route. Three were observational studies assessing thrombosis rates in patients with femoral catheters only. Merrer (2000), Durbec (1997), Trottier – Randomized controlled trial (1995), Wait (1990), Trottier – Prospective observational (1995), Joynt (2000), Durbec (1997).

The best evidence comes from the study by Merrer (2000) described above in relation to septic complications also assessed for thrombotic complications in 223 out of 293 patients randomized to subclavian or femoral lines. Significantly more patients with femoral lines developed catheter-related thromboses than patients with subclavian lines (both occlusive and non-occlusive) (21.5% vs. 1.9%) and complete vessel thromboses (6% vs. 0%). The other two randomized studies assessing thrombosis rates involved much smaller sample sizes. Durbec (1997) randomized 61 medical and surgical ICU patients to undergo femoral or superior vena cava (axillary or internal jugular) catheterization. Venous thrombosis rates were assessed by bilateral lower limb venography performed by blinded radiologists after catheter removal. There was a non-significant trend towards an increased rate of femoral vein thrombosis in the femoral group (6.6% vs. 3%). There was a non-significant trend towards lower rates of popliteal and posterior tibial vein thrombosis in the femoral group. No patient exhibited clinical evidence of deep venous thrombosis (DVT) or pulmonary embolism.

Trottier (1995) randomized 45 medical/surgical ICU patients to either a femoral vein or superior vena cava (subclavian or internal jugular) catheter. Thrombosis rates were assessed in all patients using bilateral ultrasonography of the lower limb veins prior to catheter insertion, within 48 hours of removal and within seven days of removal. Significantly more patients in the femoral group developed occlusive thrombosis (25% vs. 0%) and in addition 29% vs. 0% had non-diagnostic abnormal examinations (i.e. the presence of fibrin sheaths or thrombus occluding <50% of the lumen). All patients with diagnostic and non-diagnostic scans (i.e. any abnormality) received DVT prophylaxis. No patient in either group developed clinical evidence of pulmonary embolism.

Conclusion

Femoral central venous pressure correlates well and can be used as an alternative to superior approach for central venous pressure measurement in critically ill, mechanically ventilated, adult patients in whom intraabdominal pressure is normal and subclavian or jugular venous cannulation is not appropriate.

Recommendations

Femoral site provides a vital route for central venous access in various groups of patients and in each of these, the ratio of risk to benefit should be weighed up in the decision-making process. In order to maintain the patients' safety, femoral route associated complications should be considered and femoral catheterization may be limited for the following situations:

1) **Where mechanical complications are unacceptable:** The mechanical complications of pneumothorax and arterial puncture associated with subclavian and internal jugular catheterization are unacceptable in some patients, for instance those with severe respiratory disease and coagulopathy.
2) **Site availability:** Patients with extensive upper body burns or patients having had surgery to the area may be unsuitable for subclavian or internal jugular lines.
3) **Patients unable to lie flat for insertion:** These would include many patients with respiratory failure in whom you are trying to avoid intubation. Also included are some patients with elevated intracranial pressure and very low intracranial compliance in whom the act of lying head down or even just flat may precipitate inadequate cerebral perfusion or coning.
4) **Simultaneous use of multiple lines:** Many patients in ICU require more than one central line (for instance pulmonary artery catheters, dialysis lines etc) and so require catheterization of multiple veins.
5) **Sequential use of multiple lines:** Long term patients in ICU or patients who have previously had multiple central lines (eg renal dialysis or oncology patients) may require the use of the femoral route either because of infection concerns at other sites or because of vascular stenoses or thromboses.
6) **Emergency use for resuscitation:** Femoral venous catheters provide good access for volume resuscitation in the emergency department and have been shown to be superior to a saphenous vein cut-down. An exception to this would be patients with disrupted pelvic vessels or inferior vena cava.

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