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ORIGINAL ARTICLE

ASSESSMENT OF FLUID STATUS: COMPARING VASCULAR PEDICLE WIDTH AND INFERIOR VENA CAVA MEASUREMENTS WITH CENTRAL VENOUS PRESSURE - A CROSS-SECTIONAL STUDY

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ABSTRACT

Background: Fluid measurement is one of the critical and vital interventions in the treatment of postoperative patients and a slight delay in it may increase the complication of fluid overload or under-load that may have a worse outcome. The objective of this study was to estimate the fluid balance status in postoperative patients by central venous pressure and correlate it with vascular pedicle width and inferior vena cava

Materials and Methods*:* This was a single blinded cross-sectional comparison study done in surgical Critical care unit, Combined Military Hospital Rawalpindi from 3rd Oct 2021 to 3rd Jan 2022. Total 180 adult patients admitted to the surgical ICU were included in the study by purposive random sampling. Variables included in the study were age, gender, Central venous pressure, Vascular pedicle girth, and Inferior vena cava measurement. The correlations between the CVP, IVC diameter, and VPWs were determined by Pearson's correlation. The p-value >0.05 was calculated as statistically significant. The SPSS version 20 was exercised for statistical analysis

Results: Total 180 participants were included in the study, 80% were male and 20% were female. The mean age of participants was 51.7 ± 9.5 years and BMI was 26 ± 3.5Kg/m2. CVP mean was 9.9 ± 6.4 cm (P<0.005) of water (-2 to 24 cmH2O). *We* also noted that 40% had low CVP (>6),44% had normal (7-14) while 16% had high CVP value (15-24). VPW value mean was 68mm±4.8 (P<0.005) while the IVC mean was 16.4±4.4. (P<0.005). The association of IVC-d and CVP values was 0.92 (*p* <0.005) which displayed a strong positive relationship while the association among CVP and VPW was 0.802 (*p* <0.005) which was also significant.

Conclusion: Bedside ultrasound measurements of IVC width are highly correlated with CVP and VPW, making them a useful tool for assessing intra-vessel fluid balance.

KEY WORDS: Central venous pressure, Fluid measurement, fluid overload, vascular pedicle width, Ultrasonography.

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INTRODUCTION

Fluid management in patients admitted to the intensive care unit (ICU) is one of the most challenging and vital jobs for critical care physicians since determining hydration status in critically ill patients is still difficult and various techniques have been employed for the assessment of preload.[1,2,3] Fluid overload (FO) was found in 62%-64.8% of ICU patients; it is well-established that FO is related to poorer outcomes and higher mortality in this population.[4] Even though noninvasive approaches like physical examination, fluid balance monitoring, and chest radiography are commonly employed, their use might result in misleading data and conclusions, particularly when used alone.[1] Combining numerous noninvasive approaches to improve fluid status is the best solution.[4] A study in the USA found that recent dynamic measurements like IVC-d and CVP have great potential for assessing fluid state.[5] Salahuddin et al.[6], conducted a cross-sectional study in Saudia Arabia to look at the link between VPW and IVC

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in mechanically ventilated patients and come up with result that VPW of 64 mm accurately predicted fluid repletion, with 88.5% positive predictive value. There were also minor associations between VPW, beta natriuretic peptide, and lung comet scores that indicate fluid balance. This groundbreaking study is the first of its kind to investigate the most precise method for evaluating the fluid status, as well as the correlation between Vascular Pedicle Width (VPW) measurements on X-rays, Central Venous Pressure (CVP) readings, and Inferior Vena Cava (IVC) diameter obtained through bedside ultrasonography. The rationale of this study will be a guide for intensive care physians to manage fluid balance admitted in ICU. The objective of this study was to estimate the fluid balance status in postoperative patients by central venous pressure and correlate it with vascular pedicle width and inferior vena cava

MATERIALS AND METHODS

The cross-sectional comparison study on 180 patients was performed via purposive sampling in the Surgical critical care unit, Combined Military Hospital Rawalpindi from 3rd Oct 2021 to 3rd Jan 2022. All assessments were done by a team of 3 that is 2 × critical care physicians, and 1x critical care nurse. On each step 3 readings were taken and the mean of the reading was considered. The study was permitted by the Ethical Board of the Combined Military Hospital Rawalpindi. Postoperative patients of both genders between 20-80 years of age who had central venous lines (neck region) were involved. Patients with heart disease, shunts, pericardial effusion, pregnancy, pneumothorax, pulmonary hypertension, hypertrophic cardiomyopathy, aortic aneurysm, valvular heart disease, stroke, COPD, and morbid obesity (BMI > 35) were not involved in the study.

The CVP was recorded using the manometer method and the CXR was performed within 1 hour of arrival in the ICU and interpreted by the Ist investigator i.e. critical care physician, while the IVC was assessed afterward. To reduce the interobserver variability 2nd investigator (Critical care physician) measures the IVC by placing the transducer on the same landmarks. CVP is measured by 3rd investigator (Critical care Nurse) by calibrating the device to minimize any error and measuring it at the end of expiration. This technique was done to minimize the measurement error i.e., random and systematic measurement errors. Using manometric CVP measuring scale, CVP was measured from the midaxillary line in cm of H2O it was pondered the golden rule in the study CVP <7 cm of water was measured as hypovolemia, between 8 and 15 cm as normovolemia, and ≥16 cm of water as hypervolemia. Patients on ventilatory support that have higher positive end-expiratory pressure (PEEP) would have greater CVP due to greater pulmonary artery resistance. So, the PEEP was deducted from the final CVP value. CVP was assessed at the end of exhalation to prevent any bias.

IVC width was assessed in peak inspiration and expiration to avoid bias of the Valsalva-like maneuver. IVC is a great vessel that can expand and collapse in response to intravascular volume. In hypovolemia, its diameter becomes smaller, and with fluid replacement, its diameter becomes greater. Fluid status can easily be assessed in ICU by bedside ultrasound (Toshiba Ultrasound (UICW-660A, Japan)SUP. SYMBOL SN99C10112232 machine with 17mm curved probe and 21 mm phase array. Ultrasonographic findings were measured consistently with standard practice, containing B-mode imaginings of the IVC in the extended and small axes from the subcostal region. Caval index was determined by recording a 10-sec video during spontaneous breathing and then calculating by using the formula

Caval index %= IVC diameter at end of expiation – IVC diameter at the end of Inspiration/IVC diameter at the end of expiration.

Chest radiographs were obtained in supine, anteroposterior diameter by the trained radiographer. The X-ray radiographic modus operandi was a 40-inch distance from the source to the patient's chest wall, 60–70 kV peaks, and a classic 3- to 6-mA exposure. Imageries were taken on 14-inch × 17-inch films. VPW was determined by calculating the distance from where the subclavian artery leaves the aorta to the point where it bypasses the superior vena cava and left bronchus.

The patients' demographic variables, hemodynamic factors, biochemical markers, CVP, Inferior vena cava diameter (IVC_d) and inferior vena cava collapsibility index (IVC-CI), and CXR findings were described as mean ± standard deviation (SD) and percentage. For quantitative variables mean and standard deviation and frequencies were calculated. The correlations between the CVP, IVC diameter, and VPWs were determined by Pearson's correlation. This model is used to assess each parameter in the approximation of CVP. The p-value >0.05 was calculated as statistically significant. The SPSS version 20 was exercised for statistical analysis

RESULTS

Total 180 participants were included in the study, 80% were male and 20% were female. The demographic details are shown in Table-1.

It has been found that a considerable constructive correlation between CVP and VPW by using Pearson correlation as depicted in Table 2. The association for IVC-d and CVP values was 0.92 which displayed a significant relationship while the correlation between CVP and VPW was 0.802 which was also significant. Pearson correlation, which analyses the strength and direction of the linear relationship between CVP, VPW AND ICV-d, was calculated using Correlate and Bivariate Analysis in

SPSS 24. The numbers are all close to +1, indicating that there is a perfect positive connection.

Table-1: Demographic Details of participants

S no.	Demographics	Mean±SD	%ages
1.	Age	51.7± 9.5	
2.	Gender Male Female	 144 36	 80% 20%
	BMI	26±3.5	
3.	CVP (cmH_2O) >6 7-14 15-24	9.9±6.4	 40% 44% 16%
	MAP(mmHg)	70±10.3	
4.	VPW(mm)	68±4.8	
	IVC_CI	34.5±2.9	
5.	IVC(mm)	16.4±4.4	
6.	On inotropic Support	36	20%
6.	Comorbid Diabetes Mellitus CKD HTN IHD Malignancy		64% 30% 10% 25% 16% 5%
9.	Hrly urine Output (ml/kg/hr)	0.7±0.2	

DISCUSSION

Donahue, et al. found similar findings that IVC can be used to monitor the functionality of the right heart and the diameter of the IVC.[2] The IVC diameter of < 2.1 cm and collapses > 50% with a sniff represent hypovolemia. While an IVC diameter greater than 2.2 cm without a sniff represent hypervolemia. He determined that internal jugular vein width in patients with CVP < 10 cm H2O was 7.0 mm (0.05) while in patients with CVP > 10 cm H2O was 12.5 mm (0.05). A study led by Weekes et al. concluded that IVC width and caval index can be continuously reassessed after fluid resuscitation to assess fluid responsiveness. Exceptional cases are patients with right heart failure in which even in hypovolemia the IVC status remains elevated. Conversely, Taghizadieh et al. concluded that caval index >35.0% with 89.5% sensitivity and 73.0% specificity, directed low CVP <8 cmH_2O.[1] Hence ultrasonographic findings determined fluid resuscitation enhanced the effectiveness and efficiency of fluid management for seriously ill patients.[7] Another researcher revealed alike judgments that an IVC diameter greater than 2.1 cm anticipated a Central venous pressure of less than 10 mm Hg.[8] Prekker et al. emphasized that the manometric measurement of CVP was 2.4 cmH_2O greater than the CVP measurement with an electronic transducer so the electronic method is more commended. Additional researchers publicized that bedside easily available ultrasonography of IVC width relates to extreme limits of CVP.[9] Analogously, Shalabay et al., also described that significant correlation between CVP and inferior vena cava collapsibility index for expecting fluid responsiveness.[10] IVC Caval index >50% is strongly related to low CVP < 8mmhg. De Valk et al. correlated the Inferior vena cava _Collapsibility index (IVC-CI)with fluid challenge and made judgments that a high (IVC-CI) >36.6% after fluid administration of 500ml crystalloid solutions represents more vigorous fluid restoration whereas a low <36.6%caval index after fluid administration represent no response of fluid therapy.[11] But Corl et

Table-2: Correlation between central venous pressure, Inferior vena cava, and Vascular pedicle width

Pearson's Correlations between CVP, IVC-d, and VPW

		Central Venous pressure	inferior vena cava Diameter	Vascular Pedicle Width
Central Venous Pressure	Pearson Correlation		.921**	.805**
inferior vena cava Diameter	Pearson Correlation			.731**
Vascular Pedicle Width	Pearson Correlation			

**. Correlation is significant at the 0.05 level (2-tailed).

al., have contrary findings to this study that Caval index did not depict fluid responsiveness.[12] Moreover another scholar conducted a study on thirty patients with shock and found significant association between the IVC-CI and CVP the caval index was 30 at CVP value<10 cm H_2O, 20 at CVP levels (10–15 cm H_2O), and 10 at CVP value of >15 cm H_2O.[13] Hence IVC CI is the best substitute for a more precise valuation of volume status.[14]

VPW is the mediastinal line of the major vessels, so the cardiothoracic ratio can provide strong evidence of preload. Ely et al emphasized that the use of information easily accessible on x-ray to its greatest possible can be beneficial for fluid resuscitation of the patient. He conducted a study on 100 admitted patients in intensive care units and proved that a vascular pedicle width limit of 70.3 mm is considered in distinguishing fluid overload vs hypovolemic patients. The normal range of VPW by Rice et al. is 67-70mm, in hypovolemia its value varies between 58-62mm representing PAOP <8 mmHg, while in fluid overload its value is between 72_77mm increases along with PAOP>18mmHg.[3] As VPW is determined by the vascular structures it is not affected by PEEP, cardiac compliance, or intraabdominal and intra-thoracic pressure difference during inhalation and exhalation.[3] VPW can only be determined accurately if the x-ray is taken in the supine position (Anteroposterior view) its accuracy is decreased by 21% if the x-ray is taken in a standing position. Patient lying on the bed to the right side misleadingly increases the Vascular Pedicle width, while turning to the left side falsely decreases the value.[3] Likewise, another scholar found that Vascular Pedicle width is very strongly correlated with inferior vena cava diameter findings.[15] Hence vascular pedicle width was directly and considerably related to Central venous Pressure.

Many studies proved that CVP may predict the static measure of fluid status, but shah et al, discover that it is not an accurate interpreter of fluid responsiveness and cardiac preload.[14] If CVP is raised > 2 mmHg and raised perfusion markers like blood pressure after fluid challenge in hypovolemic patient and return to baseline represent that patient is fluid responsive. However, if CVP persists without improving the perfusion parameter it represents that the patient is not volume responsive. To convert a manometric measurement in mm Hg, divide manometer CVP by 1.36.[14] As Arora et, al. found that CVP pressure varies with respiration, it must be measured at the end of expiration wherever that pressure is zero compared to the atmospheric pressure.[16] It has been observed that the CVP has been used to predict the intravascular volume as low CVP means fluid under load while high CVP means fluid overload. Many studies proved the relationship between CVP and an increase in cardiac output by 10-15% resulting in a fluid trial.[17] Multiple scientific studies on the precision of CVP measurement found that CVP can predict fluid loading only by 56%. It means that resuscitation depending solely on CVP will manage fluid replacement inadequately which may lead to poor tissue perfusion, kidney failure, and worse outcomes.[17]

CONCLUSION

In conclusion, bedside ultrasound measurements of Inferior Vena Cava (IVC) width are highly correlated with Central Venous Pressure (CVP) readings and Vascular Pedicle Width (VPW), making them a valuable tool for accurately assessing intra-vessel fluid balance status in patients. However, it is important to consider VPW on X-ray findings as a predictive factor for fluid status in postoperative patients in the ICU. These findings demonstrate the clinical utility of utilizing bedside ultrasonography in the precise management of fluid therapy for optimal patient outcomes.

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CONFLICT OF INTEREST
Authors declare no conflict of interest.
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None declared.

AUTHORS' CONTRIBUTION

The following authors have made substantial contributions to the manuscript as under:

Conception or Design:	AJ, KY
Acquisition, Analysis or Interpretation of Data:	AJ, KY, MA, MIM
Manuscript Writing & Approval:	AJ, KY, MA, MIM

All the authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.