ORIGINAL ARTICLE

DETERMINATION OF INTRAVASCULAR VOLUME STATUS BY MEASURING IVC DIAMETER ON ULTRASONOGRAPHY IN HEMODIALYSIS PATIENTS KEEPING CVP AS GOLD STANDARD

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ABSTRACT

BACKGROUND: Among the indices able to replace invasive central venous pressure (CVP) measurement in patients undergoing hemodialysis the diameters of the inferior vena cava (IVC) and their respiratory fluctuations, so-called IVC collapsibility index (IVCCI), measured by echocardiography, have recently gained ground as a quite reliable proxy of CVP. **OBJECTIVE:** The aim of our study was to determine the accuracy of intravascular volume status by measuring inferior vena cava (IVC) diameter on ultrasound, keeping central venous pressure (CVP) as a gold standard in patients undergoing hemodialysis. **STUDY DESIGN:** Prospective Cross sectional descriptive Study. **DURATION OF STUDY:** Study was carried out over a period of six months from 16-09-2015 to 15-03-2016 at radiology department combined military hospital Quetta. **MATERIAL AND METHOD:** A total of 174 patients (107 males (61.5%) and 67 females (38.5%)were included in this study. Patient's age, sex, CVP and IVC diameter measurement values at inspiration and expiration, arterial blood pressure & heart rate was recorded. Serial longitudinal and transverse images were taken in sub-xiphoid region and maximum anteroposterior (AP) diameter of inferior vena cava from outer to inner was taken just caudal to the confluence of hepatic veins in its longitudinal plane. **RESULTS:** In this study on ultrasound IVC diameter within normal limit was seen in 51 cases and not within normal limits was seen in 123 cases. CVP not within normal limits was found in 118 cases and within normal limit was observed in 56 cases. Sensitivity, specificity, diagnostic accuracy of IVC (ultrasound) was 91.2%, 73.2% and 85.6%, respectively. Positive predictive value was 87.8% and negative predictive value was 80.3%. **CONCLUSION:** Ultrasound assessment of IVC dimensions can be performed easily. Use of ultrasound to determine intravascular volume status may help to reduce intradialytic post dialytic adverse events and prevent long-term cardiovascular complications.

Key Words: IVC, CVPs, Intravascular Volume Status, Ultrasonography

Introduction

Volume regulation is among the most critical yet challenging aspects of dialysis therapy. Chronic hypervolumia leads to hypertension, structural heart disease and pulmonary edema.[1] A correct estimation of volume status and so called dry weight in dialysis patient remains a clinical problem.[2] There are various

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techniques for assessing the fluid status such as clinical examination like breathlessness revealing increased blood pressure and edema, central venous pressure (CVP) measurements, biochemical markers, bioimpedence, continuous blood volume measurements, or Sonographic inferior vena cava diameter assessment.[3] Parameters like clinical evaluation is not sensitive enough while invasive methods like central venous pressures (CVPs) are not always readily available.[2] An invasive method, such as central venous catheter placement, is required in order to measure the CVP. Complications such as arrhythmias, cardiac chamber injury, vascular - nerve injury, pneumothorax, hemothorax, local bleeding, hematoma, infection, SVC thrombosis, occlusion, pulmonary embolism and post phlebitis syndrome may occur with catheter placement.[4] Ultrasound imaging has several advantages; it is simple, noninvasive and can be used for repeated assessments.[5]

The inferior vena cava (IVC) is a highly compliant vessel that can distend and collapse. Inferior vena cava diameter at inspiration ranges from 0-14 mm at rest and at expiration it ranges from 15-20 mm.[6] Thus in volume depletion, it is easily collapsible and has smaller diameter. In fluid overload, the vein elasticity reaches threshold after which is minimally distensible and cannot collapse, thus maintain a relative constant diameter.[3] Measurements of the inferior vena cava (IVC) diameter have been shown to trend with renal failure as well as heart failure. Absolute diameter decreases with progressive diuresis in chronic heart failure and with dialysis in renal failure.[7]

Estimation of fluid status is needed for guiding fluid therapy for dialysis patients.[3] Sonography of the inferior vena cava is a valuable tool for estimating the dry weight in dialysis patients.[2]

A research article "point-of-care ultrasound to estimate central venous pressure: a comparison of three techniques" showed that an inferior vena cava diameter < 2 cm predicted a central venous pressure < 10mmHg with sensitivity of 85% (95% confidence interval 69% to 94%), specificity of 81% (95% confidence interval 60% to 93%) and a positive predictive value of 87% (95% confidence interval 71% to /95%).[8]

The rationale of the study is to assess the accuracy of volume status in hemodialysis patients by measuring inferior vena cava diameter employing ultrasound which is cost effective, reproducible, quantifiable, portable and noninvasive method of intravascular volume status.

Material and Method

This prospective cross sectional descriptive study was conducted at radiology department Combined Military Hospital Quetta for a period of six months from 16-09-2015 to 15-03-2016. Prior approval by institutional ethical review committee was obtained. A prospective review of 174 Patients (Total sample size calculated by positive predictive value of 87% (95% confidence interval 71% to 95% (Non probability consecutive sampling technique) using WHO formula using reference of Point of care ultrasound to estimate central venous pressure(a comparison of three techniques) were studied. Patient both males & females (20 to 75 years)with sign and symptoms of fluid hypervolumia/hypovolumia on blood pressure and central venous pressure undergoing acute/ emergency hemodialysis and undergoing hemodialysis by uncuffed (nonmetallic temporary) dialysis catheter were included in this study. Patient with documented tricuspid regurgitation, right heart failure or pulmonary disease confirmed from the medical record, clinical/radiological evidence of mediastinal mass, pneumo/hemothorax, portal hypertension which could produce false positive results of inferior vena cava by raising intra-abdominal pressure were not included because above conditions could act as confounders and if included in the study would create bias in results.

DATA COLLECTION PROCEDURE

Inclusion Criteria:

1. Sex: - Both males & females.
2. Age: - 18 to 76 years.
3. Patient with sign and symptoms of fluid hypervolumia/hypovolumia on blood pressure and central venous pressure undergoing acute/ emergency hemodialysis.
4. Patients undergoing hemodialysis by uncuffed (nonmetallic temporary) dialysis catheter.

Exclusion criteria:

1. No documented tricuspid regurgitation, right heart failure or pulmonary disease confirmed from the medical record.

2. Patients with clinical/radiological evidence of mediastinal mass, pneumo/hemothorax, portal hypertension which will produce false positive results of inferior vena cava by raising intra abdominal pressure.
3. Above conditions will act as confounders and if included in the study will create bias in results.

All those patient fulfilling inclusion criteria were included from hemodialysis center and emergency department of Combined Military Hospital Quetta. Informed consent was taken from patient or attendant. Explanation was given regarding the nature of procedure, time consumed, involved risk, data review and publication. A data collection form was created to gather the standard data. Patient's age, sex, CVP and IVC diameter measurement values at inspiration and expiration, arterial blood pressure, heart rate was recorded in the data collection form. Patient was screened in the presence of an attendant by ultrasound machine having curved array transducer with frequency ranging between 3.5-5 MHz, Serial longitudinal and transverse images will be taken in subxiphoid region and maximum anteroposterior (AP) diameter of inferior vena cava from outer to inner wall was taken just caudal to the confluence of hepatic veins in its longitudinal plane. Bias and confounders were controlled by strictly following the exclusion criteria and thoroughly reviewing charts of patients for present and past history of the disease. CVP of patients with fluid overload was measured by connecting the patient's central venous catheter to a small diameter water column. The height of the column indicates the central venous pressure. All the information was collected through a specially designed Performa.

DATA ANALYSIS PROCEDURE

Data was analyzed on SPSS version 20. Frequency and percentages were calculated for gender. Mean and standard deviation was calculated for age and duration of symptoms. 2 x 2 table was used to calculate the diagnostic accuracy of IVC. Stratification was done with respect to age, gender and duration of symptoms. Post stratification chi square test was applied. P value greater than or equal to 0.05 was taken significant.

Results

A total of 174 patients were included in this study during the study period of six months from 16-09-2015 to 15-03-2016. Patients age ranged between 20-75 years. Mean age of the patients was 49.95 ± 10.86. There were 107 males (61.5%) and 67 females (38.5%). Mean heart rate was 81.3 ± 3.10 bpm, mean atrial blood pressure was 13.60 ± 1.08 mmHg and mean duration of symptoms was 12.39 ± 4.69 months (Tab. 1). On ultrasound IVC diameter within normal limit was seen in 51 cases and not within normal limits was seen in 123 cases. CVP not within normal limits was found in 118 cases and within normal limit was observed in 56 cases. (Tab. 2).
Sensitivity, specificity, diagnostic accuracy of inferior vena cava (ultrasound) was 91.2%, 73.2% and 85.6%, respectively. Positive predictive value was 87.8% and negative predictive value was 80.3%. Stratification with regard to duration of symptoms was carried out and presented in (Tab. 3).

Variables	Mean	S.D
Heart rate (bpm)	81.3	3.10
Atrial blood pressure (mmHg)	13.60	1.08
Duration of symptoms (months)	12.39	4.69

Table 1: Mean values of heart rate (bpm), atrial blood pressure (mmHg) and duration of symptoms (months)

IVC diameter on ultrasound	Central Venous Pressure (CVP) (Gold Standard		Total
	Not within normal limits	Within normal limits	
Not within normal limits	108 (TP)	15 (FP)	123
Within normal limits	10 (FN)	41 (TN)	51
Total	118	56	174

Table 2: Comparison of overload volume on inferior vena cava (ultrasound) vs central venous pressure (CVP) n = 174

Duration (month)	IVC diameter on ultrasound	Central Venous Pressure (CVP) (Gold Standard		P value
		Not within normal limits	Within normal limits	
≤ 12	Not within normal limits	65	12	P<0.001 51
	Within normal limits	7	24	
> 12	Not within normal limits	43	3	P<0.001
	Within normal limits	3	17	

Table 3: Stratification with regard to duration of symptoms

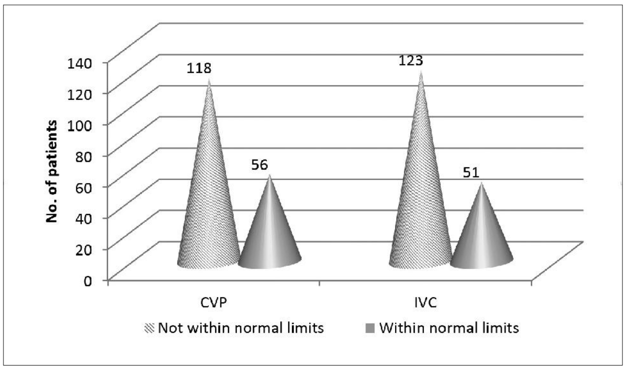

Figure 1: Comparison of overload volume on inferior vena cava (ultrasound) vs central venous pressure (CVP)

Discussion

Ultrasound has rapidly gained popularity in the emergency medicine setting because it is safe, rapid, non-invasive and can be brought to the bedside. Bedside ultrasound is not a complete radiological investigation but, rather, a focused evaluation to answer a clinical question. The inferior vena cava is a large vein that carries deoxygenated blood into the right atrium of the heart.[9] Since the size and shape of the IVC is correlated to the central venous pressure and circulating blood volume, sonographic evaluation of the IVC is an instantaneous non-invasive measure of volume status.[10]

The IVC is a very compliant vessel whose size varies with changes with intravascular pressure and respiration. Consequently, the IVC collapses with inspiration as the blood is pumped out of the IVC due to the negative pressure created by chest expansion. In healthy subjects breathing spontaneously, cyclic changes in thoracic pressure, result in collapse of the IVC diameter of approximately 50%.[11] Although there is a lack of universally accepted cutoffs, in healthy individuals, IVC diameter at inspiration ranges from 0 to 14 mm at rest, and expiratory diameter of 15 to 20 mm at rest. An IVC collapsible index is defined as (IVCd exp - IVCd insp)/ IVCd exp. The closer the collapsibility index is to 0% or 100% the higher the likelihood that patient is volume overloaded or depleted, respectively.[9]

A correct estimation of the fluid status and the determination of dry weight in dialysis patients remains a difficult clinical problem. The clinical status is insensitive, and a volume excess of several liters may escape recognition. Chest X-ray is limited by radiation exposure and cost, and the evaluation of the pulmonary vasculature is still a matter of debate, in part because of a large inter-observer variation.[12]

Invasively measured central venous pressures are not routinely available, and measurements of the concentrations of atrial natriuretic peptide (ANP) or cyclic GMP are controversial.[13] Based on previous observations relating right-sided cardiac function and pressures to changes in the size of the inferior vena cava, the Maastricht group was the first to evaluate and propose sonography of the inferior vena cava as a noninvasive tool to estimate fluid status in patients with end-stage renal failure[14,15] and Rascher et al (1985)[16] were the first to suggest its possible role in determining fluid status in HD patients.

More recent work, however, has demonstrated a more modest correlation of IVC diameter with CVP.[17] Predictably, with the increased emphasis on dynamic markers of intravascular volume, subsequent studies have compared CVP with US assessments of IVC respirophasicity, rather than IVC diameter alone. Overall, the results of these studies suggest that, at extremes, the CI does have an inverse relationship to CVP. In a small group of emergency department patients with suspected sepsis, Nagdev et al.[18] reported that CI >50% was strongly associated with a CVP <8 mmHg. Kircher et al,[19] came to a similar conclusion, reporting that CI >50% was indicative of right atrial (RA) pressures <10 mmHg, whereas CI <50% indicated RA pressures >10 mm Hg. In a study of patients undergoing right heart catheterization, IVC-US measurements within 1 h of the procedure demonstrated that CI <20% during passive respiration and CI <40% during forceful inhalation were both predictive of RA pressures >10 mmHg. Another study of surgical intensive care unit patients demonstrated that CI appeared to correlate best with CVP in the setting of low (<20%) and high (>60%) values and suggested that the closer the CI is to 0% or 100%, the more likely the patient is volume-overloaded or volume-depleted, respectively.[20]

Barbier et al[21] demonstrated that using a threshold CI of 18%, mechanically ventilated septic responders and nonresponders could be discriminated with 90% sensitivity and specificity. Similarly, Feissel et al[22] reported a threshold CI of 12% could discriminate mechanically ventilated septic responders and nonresponders with positive and negative predictive values of 93% and 92%, respectively.

In haemodialysis patients, these authors found a curvilinear relation of the expiratory vena cava diameter and its collapse index during respiration and the mean right atrial pressure, and a linear relation between the vena cava diameter and the total blood volume, as determined by the radioiodinated serum albumin method. In addition, they demonstrated a linear relation between a-hANP concentrations before dialysis and vena cava diameters.

There are a number of technical and pathophysiologic factors that limit the utility and accuracy of IVC-US. First, the subcostal window may not afford adequate visualization of the IVC, particularly in patients with obesity, abdominal pain, gastric insufflation, large amounts of bowel gas, or post-surgical wounds and/or pneumo-peritoneum. As some studies have excluded patients from enrollment[18,23] or failed to report the degree to which IVC visualization was technically limited, the exact percentage of patients in whom adequate views cannot be obtained is unknown, but even in the hands of experienced echocardiographers, the percentage commonly exceeds 10%[21,24] and has been reported as high as 18%.[17] Whereas there has been speculation that excessive transducer pressure during technically challenging IVC-US may compress the IVC and lead to alterations in measurements, no study has specifically investigated the extent to which this phenomenon plays a role.[2]

In present study, sensitivity, specificity, diagnostic accuracy of inferior vena cava (ultrasound) was 91.2%, 73.2% and 85.6%, respectively. Positive predictive value was 87.8% and negative predictive value was 80.3%. Our results are comparable with a study carried out by Prekker et al.[8]

Conclusion

Ultrasound assessment of IVC dimensions can be performed easily. Use of ultrasound to determine intravascular volume status may help to reduce intradialytic adverse events and prevent long-term cardiovascular complications. On the basis of these results, a larger scale outcomes study that longitudinally incorporates this technology into daily practice should be undertaken.

Conflict of Interest: Authors declared no conflict of interest.

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