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Assessment of Intravascular Volume in Intensive Care Patients by Using Bedside Ultrasound

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Original Article

Summary

The use of bedside ultrasound in the intensive care unit has been expanding over the last two to three decades. The application of Point of care ultrasound has become the standard of care in many Intensive care units for diagnostic and therapeutic purposes. This study aimed to assess the intravascular volume in intensive care patients by using bedside ultrasound. A prospective observational study was performed in the Intensive Care Units (ICU) of The Medical City /Baghdad Teaching Hospital. A convenient sample of 50 patients was enrolled in the study and all the patients were on mechanical ventilation with sedation. Results revealed a mean age of the patients of (48.8±16.8) years, with a male to female ratio of 1.38:1. 10 (58.8%) of hypovolemic patients with score -4, 5 (29.4%) with score -3 and 2(11.8%) with score 0. For euvolemic patients 10(71.1%) of them were resented with score 0, 2(14.3%) with score 1, and 2 (14.3) in score 3. 11 (57.9%) of those in hypervolemic group was found with score 3, 6(31.5%) with score 4 and 1 (5.3%) in score 1, 1 (5.3%) in score 2. In conclusion, the inferior vena cava (IVC) score by using bedside ultrasound can help create a more standard method when discussing the IVV status of a patient.

Keywords: *Bedside ultrasound, Intensive care units, Point of care ultrasound, mechanical ventilation*

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1. INTRODUCTION

The use of bedside ultrasound in the intensive care unit (ICU) has been expanding over the last two to three decades. The application of Point of care ultrasound (POCUS) has become the standard of care in many Intensive care units (ICUs) for diagnostic and therapeutic purposes. The evolution of Point of care Ultrasound started in Emergency Departments (ED) and been expanding to other areas especially in acute care setting where recent trails and studies have expanded its use in the Intensive Care Units (ICUs) across the globe. In 1990, the American College of Emergency physician (ACEP) published a statement in support of the use of bedside Ultrasound by Emergency Departments (ED physicians that were appropriately trained. This was followed by guidelines and policies by the American College of Emergency physician (ACEP) that are frequently updated. In 2015 (1), the society of Critical Care Medicine (SCCM) published guidelines for the use of general and cardiac ultrasound (2, 3). Throughout the years, most studies have focused on individual organs and systems to evaluate the Intravascular volume(IVV) status, such as examining the right and left heart chambers and contractility(2-4), evaluation of Inferior vena cava (IVC) (5-11) and/or its collapsibility, and the Internal jugular vein (IJV)(12-15) and its respiratory variation, as well as lung waters volumes and pulmonary edema (16-19) Through literature review, we failed to identify a scoring system or a numerical value to help standardize different exams . By applying such a system and combining different organs exams, we are hoping to create a more standardized method of ultrasound evaluation of the volume status. During the past 50 years, ultrasound examination of the heart has been crucial in diagnosis of functional heart status, and echocardiography has become the most used and cost-effective imaging method for the heart (2-4). Studying the inferior vena cava (IVC) is a very common practice in the intensive care unit (ICU) to assess the volume status. Evaluating the inferior vena cava (IVC) alone to determine intravascular volume (IVV) status does not incorporate other factors affecting hemodynamic status of the patient (20). Studying the inferior vena cava (IVC) in mechanically ventilated patients as well as spontaneously breathing has led to its use in the Intensive care unit (ICU) as a common modality for intravascular volume (IVV) status (21,22).

Depending on the Inferior vena cava (IVC) only can have limitation (23) and by adding others variable to assess the hemodynamics, the value of the Inferior vena cava (IVC) interpretation in hemodynamic assessment can be enhanced. Inferior vena cava (IVC) has become one of the standard modalities in assessment of fluid status and responsiveness and its use as guide for fluid therapy. Many protocols have been developed in Emergency department (ED) and Intensive care unit (ICU) regarding the use of point of care ultrasound (POCUS) to standardize the application and have an organized manner to evaluate the intravascular volume (IVV) status (24). Examples of such protocols are rapid ultrasound for shock and hypotension (RUSH) (25), focused assessment of transthoracic echocardiography, focused assessment with sonography in trauma (FAST) and the addition to detect pneumothorax in extended FAST(E-FAST), and others. None of these protocols use a numerical value to describe the fluid status of the patient (26). In the current study, we are trying to quantify the findings of different organs examined specifically inferior vena cava (IVC). We are performing point of care ultrasound (POCUS) exams to different organs as done by many protocols, with adding a numerical value which will give us a value and a target that can be used for initial and subsequent assessments and comparisons. The selection was based on the need of the primary treating Intensive Care Units (ICU) physician to assess the hemodynamic and the volume status of the patient. Recruitment was based on the presenting symptoms leading the treating Intensive Care Unit (ICU) physician to decide if the patient needed volume status assessment and whether the volume status was hypervolemia, euvolemia, or hypovolemia (27,28).

2. PATIENTS and METHODS

This prospective, observational study was performed in the Intensive Care Units (ICU) of The Medical City /Baghdad Teaching Hospital. A convenient sample of 50 patients was enrolled in the study and all the patients were on mechanical ventilation with sedation.

Inclusion criteria:

The inclusion criteria are age more than 40 years, admission to the ICU preoperative (in need of ventilation) or postoperative, and sedation on controlled mechanical ventilation with central venous catheters. The included patients were in need of intravascular fluid challenge for resuscitation based on clinical characteristics (systolic blood pressure < 90 mmHg, with signs of hypoperfusion as oliguria less than 0.5 ml/kg/h and arterial lactate >2.5 mmol/h).

Exclusion criteria

The exclusion criteria are spontaneous breathing, poor cardiac echogenicity cardiac arrythmia, severe valvular heart disease or intracardiac shunt, impaired left ventricular function (ejection fraction <40%), ascites, pregnancy and any contraindication to fluid resuscitation, such as congestive heart failure, evidence of fluid overload and renal dysfunction.

Study protocol:

The Point of care ultrasound (POCUS) was performed by operators who were experienced in ultrasound and use this technology on daily basis to assess their patients. The ultrasound exam and images were obtained and stored using Versana Essential for GE healthcare ultrasound system is a color Doppler ultrasound machine easy to use, own and learn.

The prescribed examination and measurement techniques was shown in (Figure 1) as follow:

(1) Place the patient in a supine position or 35 degrees.

(2) Place a phased array or curvilinear transducer midline in epigastric area to locate the inferior vena cava (IVC).

(3) Measure the IVC diameter by M-mode, just distal to right hepatic vein, with the maximal and minimal diameter.

(4) Calculate the collapsibility index: (maximal diameter –minimal diameter)/maximal diameter) x100

(5) During mechanical ventilation the maximal diameter will be during inspiration and the minimal diameter during expiration, and the opposite is true during spontaneous breathing.

(6) Store the image for review.

Figure 1. Inferior vena cava(IVC) exam (a)transducer placement, midline upper abdomen below the xyphoid (b) B-mode IVC (c)M-mode IVC measurement during respiratory cycle.

The assessment of the Inferior Vena Cava (IVC) was done to correlate with the volume status where measurement of the Inferior Vena Cava (IVC) diameter was done as well as respiratory variation, assign a score as follow:

(a) <2.5 cm in widest diameter and > 50% respiratory variation in diameter =-1

(b)1.5 -2.5 cm in widest diameter and <50% respiratory variation in diameter =0

(c) >2.5cm in widest diameter and < 50% respiratory variation in diameter =+1

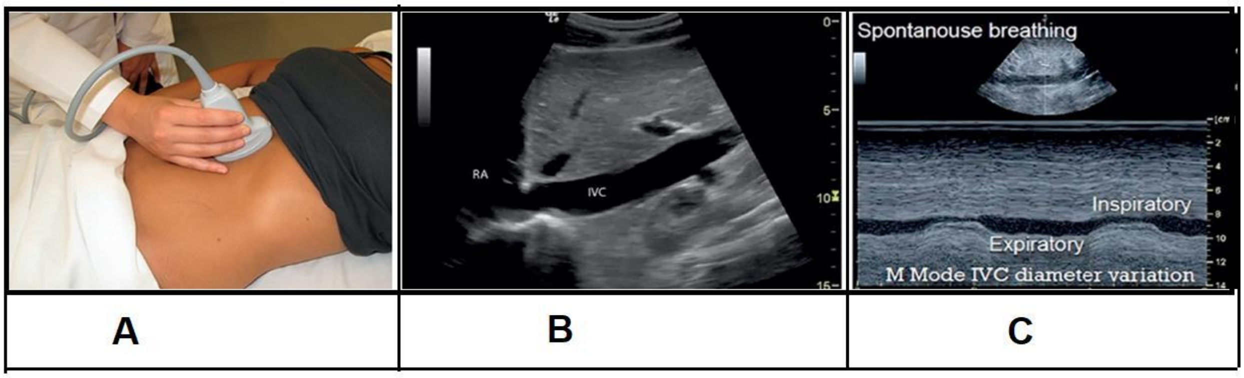

Figure 1. Inferior vena cava (IVC) exam: (A): Transducer placement, midline upper abdomen below the xyphoid , (B): B-mode IVC , (C): M-mode IVC measurement during respiratory cycle.

3. RESULTS

We evaluated 50 patients admitted to the intensive care unit. As shown in (Tables 1&2) and (Figure 2); the patients were enrolled in the current study and the mean age was (48.8±16.8) years, the male was 29(58%) and the female was 21(42%) with male to female ratio 1.38:1, the mean BMI was (33.1± 3.2) Kg/m². Mean pulse rate was (98.7±22.0), Systolic blood pressure mean (136.09±33.3), while diastolic blood pressure (79.9±16.56) mmHg, urine output during the day (1950±290)/24 hours, IVC mean (1.71±0.42), CVP (9.93±7.25) and serum lactate was (1.195±0.84). Figure 3 shows the distribution of the patients according to volume status, 17 (34%) were hypovolemic patients, 14 (28%) was euvolemic and 19(38%) was hypervolemic patients. Mean AP in hypovolemia was (82.2±13.7), euvolemia (84.01±14.2) and hypervolemia was (83.9±13.9) mmHg. Mean IVC (diameter) in hypovolemia was (1.38±0.12), euvolemia (1.47±0.10) and hypervolemia was (1.51±0.15). Significant difference was found in mean AP between the volume status groups (P=0.005), significant differences found in Mean IVC (P=0.007), while highly significant differences between groups regarding Mean PR, SBP and DBP (P<0.001), (Tables 3)

As shown in (Table 4), 10 (58.8%) of hypovolemic patients with score -4, 5 (29.4%) with score -3 and 2(11.8%) with score 0. For euvolemic patients 10(71.1%) of them were resented with score 0, 2(14.3%) with score 1, and 2 (14.3) in score 3. 11 (57.9%) of those in hypervolemic group was found with score 3, 6(31.5%) with score 4 and 1 (5.3%) in score 1, 1 (5.3%) in score 2.

Table 1: Patient's characteristics

Patient's criteria	Mean ± SD
Age (years) mean ± SD	48.8±16.8
BMI (kg/m) mean ± SD	33.1±3.2
Male (no;%)	29(58%)
Female (no;%)	21(42%)
SD: standard deviation	

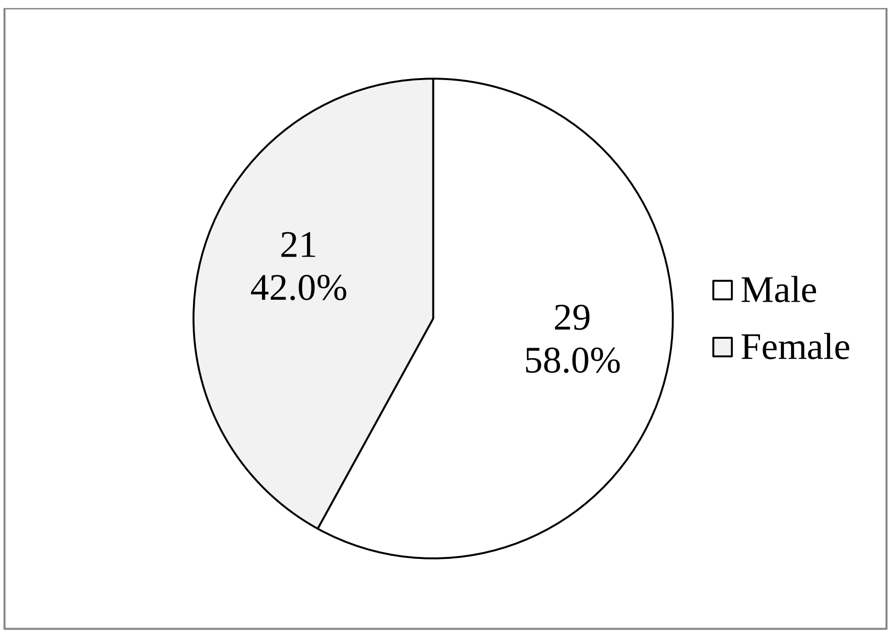

***Figure 2: Gender distribution of the patients*.**

Table 2: Patient's parameters

Patient's parameters	Mean ± SD
CVP (cmH2O)	9.93 ± 7.25
Pulse rate (per minute)	98.7 ± 22.0
SBP (mmHg)	136.09 ± 33.3
DBP (mmHg)	79.9 ± 16.56
UOP (/24 hours) ml	1950 ± 290
IVC (cm)	1.71 ± 0.42
S. lactate (mg/dl)	1.195 ± 0.84
SD: standard deviation	

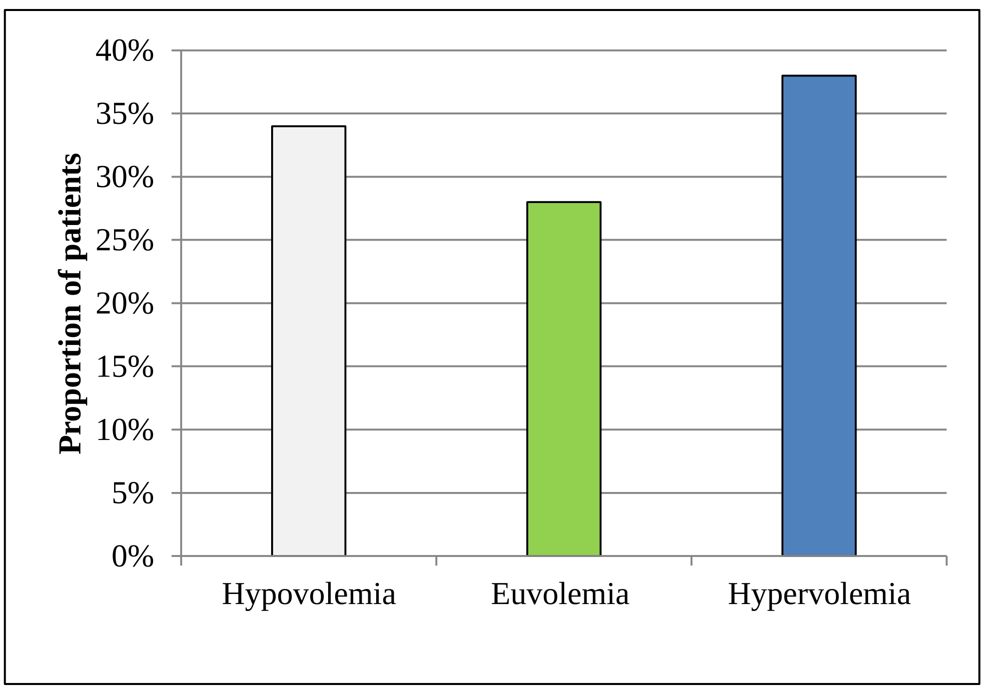

Figure 3: Proportional distribution of the patients according to volume status

Table 3: Parameters of the patients with volume status.

Parameter	**Hypovolemia n=17**	**Euvolemia n=14**	**Hypervolemia n=19**	**P. value**
Mean AP(mmHg)	80.2 ± 1.7	83.01 ± 14.2	83.9 ± 4.9	0.005
Mean IVC	1.38 ± 0.12	1.47 ± 0.10	1.51 ± 0.15	0.007
Mean PR /min	96.5 ± 9.8	93 ± 19.8	81.7 ± 8.2	<0.001
SBP(mmHg)	116.1 ± 21.2	132.2 ± 19.8	146.19 ± 41.3	<0.001
DBP(mmHg)	59.9 ± 10.71	80.9 ± 12.18	91.2 ± 21.41	<0.001

Table 4: Distribution of the patients according to IVV status and total ultrasound score.

	Impression by standard measures						Total	
	Hypovolemia		Euvolemia		Hypervolemia			
Score	No.	%	No.	%	No.	%	No.	%
-4	10	58.8	0	0.0	0	0.0	10	20.0
-3	5	29.4	0	0.0	0	0.0	5	10.0
-2	0	0.0	0	0.0	0	0.0	0	0.0
-1	0	0.0	0	0.0	0	0.0	0	0.0
0	2	11.8	10	71.4	0	0.0	12	24.0
1	0	0.0	2	14.3	1	5.3	3	6.0
2	0	0.0	0	0.0	1	5.3	1	2.0
3	0	0.0	2	14.3	11	57.9	13	26.0
4	0	0.0	0	0.0	6	31.6	6	12.0
Total	17	34.0	14	28.0	19	38.0	50	100.0

4. DISCUSSION

Fluid therapy has been a key part in the management of critically ill patients. Excess fluid administration as well as dehydration has been found to have negative effects on patient outcome and have an established correlation with increased morbidity and mortality. Judging the amount of fluid therapy has been a challenging task for the Intensive care unit (ICU) physician.

Several methods ranging from history, clinical evaluation up to complex invasive measurements have been postulated to help estimating the current volume status of the patient and whether additional Fluid administration is needed or not (1).

In current study, 50 patients were enrolled and the mean age was (48.8±16.8) years, the male to female ratio was 1.38:1, the mean BMI was (33.1±3.2) Kg/m2, we found that the distribution of the patients according to cardinal signs of volume status was as follow; 17(34%) were hypovolemic patients, 14(28%) were euvolemic patients and 19% (38%) were hypervolemic patients. Moreover, significant difference was found in mean AP between volume status groups(p=0.005), significant differences found in Mean IVC (p=0.007), while highly significant differences between groups regarding Mean PR, SBP and DBP according to volume status (p<0.001).

In the current study according to IVV status of total ultrasound score of the assessment of IVC diameter was as follow;

For hypovolemic patients 10(58.8%) of them were with score -4, 5(29.4%) with score -3 and only 2 (11.8%) with score 0 was euvolemic patients.

For euvolemic patients 10(71.1%) of them were resented with score 0, 2(14.3%) with score 1 and 2(14.3%) with score 3 were hypervolemic patients.

For hypervolemic patients 11(57.9%) of those group was found with score 3, 6(31.5%) with score 4 and 1(5.3%) in score 1 and 1(5,3%) in score 2.

Ilyas A et al study assessed intravascular volume status by inferior vena cava ultrasound was focused on comparing the IVC diameter with measured central venous pressure (CVP). The outcomes of these studies suggested a positive correlation of the mean IVC diameter with the CVP but an inverse relation with IVC collapsibility index, these results are comparable to our findings (14). A meta-analysis by Zhang et al, study demonstrated that respiratory variation of ΔIVC diameter measured with point of care ultrasound (POCUS) is of great value in predicting fluid responsiveness, particularly in patients on controlled mechanical ventilation and in patients resuscitated in colloids, however correlates with our study (21).

Ilyas A et al. demonstrated that the IVC-CI strongly correlates with low (<20%) and high (>60%) CVP values and suggested that the closer the CI is to (0% to 100%), the more is the probability that the patient is either volume-overload or volume depleted, respectively. There is no such evidence that support a linear relationship between CI and CVP; however, these results are comparable to our findings (14).

Alistair K et al, study performed paired ultrasound examination of IVC-IJV and IVC-FV, both of them scans took less time to complete than IVC-CI scans(both, $P<0.02$). correlations between IVC-CI/FV-CI ($R2=0.41$) and IVC-CI/IJV-CI ($R2=0.38$) were weak. There was a mean -3.5% measurement bias between IVC-CI and IJV-CI, with trend toward overestimation for IJV-CI with increasing collapsibility. In contrast, FV-CI underestimated collapsibility by approximately 3.8% across measured collapsibility range. So, these results indicate that IJV-CI and FV-CI should not be used as a primary intravascular volume assessment tool for clinical decision support in ICU (15).

The objective of David J et al, study was to quantify both craniocaudal and mediolateral movements of the IVC as well as the vessel's axis of collapse during respirophasic ultrasound imaging in comparison with our results, demonstrated the average diameter of the IVC was 13.8mm (95% CI 8.41 to 19.2mm), with a mean respiratory collapse of 34.8% (95%CI 19.5% to 50.2%) (23).

5. CONCLUSIONS

The inferior vena cava (IVC) score by using bedside ultrasound can help create a more standard method when discussing the IVV status of a patient.

Therefore, is recommended to use the bedside ultrasound in assessment of IVV status has been shown to decrease medical errors, provide more efficient real time diagnosis and allow for more urgent and aggressive mode of resuscitation and management in the ICU patients.

Ethical Clearance: Ethical clearance and approval of the study are ascertained by the authors. All ethical issues and data collection were in accordance with the World Medical Association Declaration of Helsinki 2013 of ethical principles for medical research involving human subjects. Data and privacy of patients were kept confidentially.

Conflict of interest: Authors declared none

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