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Role of Point of Care Ultra Sound (POCUS) in Assessment of Fluid Resuscitation in Septic Patients

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Background: Initial fluid resuscitation in sepsis must be guided by clinical judgment based on ongoing reevaluation of the hemodynamic status (heart rate, blood pressure, arterial oxygen saturation, respiratory rate, temperature, urine output) and ultrasound measurements (stroke volume, cardiac output, lung ultrasound and inferior vena cava diameter) as positive fluid balance is harmful.
Methods: Adults Patients (≥ 18 years old) with symptoms or signs of tissue hypoperfusion (Sequential organ failure assessment score SOFA≥ 2) are included. Patients with elevated intra-abdominal pressure (as, ascites, pregnancy), Recent abdominal operation, cannot lie flat, Patient on mechanical ventilation and patients with valvular heart disease were excluded. IVC CI, SV, COP and B mean score were measured on patient arrival and after every 10 ml/kg isotonic saline over the first hour of patient arrival. Thereafter, patients were divided into two groups high caval index and low caval index according to inferior vena cava collapsibility index.
Results: Among our 50 patients,38% of patients were with high caval index and 62% have low caval index.
Conclusion: POCUS has additive value in guiding of fluid resuscitation in sepsis in order to avoid fluid overload and to identify proper timing of vasopressor use.

Keywords: Point of care ultra sound; fluid resuscitation; sepsis; vasopressor.

1. INTRODUCTION

Sepsis is a global healthcare problem and consider the leading cause of death from infection so that, early recognition and diagnosis of sepsis is required to prevent the transition into septic shock, which is associated with higher mortality rate [1]. Sepsis is "life-threatening organ dysfunction caused by a dysregulated host response to infection" with a SOFA score ≥2[2]. Septic shock is "a subset of sepsis in which particularly profound circulatory, cellular, and metabolic abnormalities are associated with a greater risk of mortality than with sepsis alone", identified clinically by a vasopressor requirement to maintain a MAP ≥ 65 and serum lactate ≥ 2 mmol/L in the absence of hypovolemia [3].

Diagnosis of sepsis relies on assessing a variety of nonspecific signs, symptoms, examination findings, and laboratory values [4]. Transition of sepsis to multiple organ dysfunction could be prevented with rapid and appropriate resuscitation of shock [5]. The most important change in the revision of the SSC bundles is that the 3-h and 6-h bundles have been combined into a single "hour-1 bundle" with the explicit intention of beginning resuscitation and management immediately [6].

Early aggressive fluid resuscitation forms the basis for stabilization of patients in severe sepsis/septic shock. Initial fluid resuscitation with crystalloids should be started to achieve minimum of 30 mL kg−1 of fluids in patients with sepsis-induced tissue hypo perfusion [7].

Point of care (PoC) ultrasound presently serves as a tool assisting clinicians in solving problems at a patient's bedside and assessment of intravascular volume status That allow clinicians to assess the degree of hydration non-invasively [8].

The inferior vena cava (IVC) is a very compliant vessel whose size varies with changes in intravascular pressure making it possible for sonographic evaluation of the IVC to provide a non-invasive measure of volume status [9]. Lung ultrasound (LUS) facilitates the assessment of extravascular lung water (EVLW). It has been proved that the degree of lung aeration, dependent on the fluid volume in the interstitial and inter alveolar spaces, directly correlates with the ultrasound image [10].

The LVOT VTI is a good predictor of a potential fluid responsiveness. An increase in LVSV >12% is considered a positive response. An increase < 10% is seen as a weak response to fluid therapy. The increase of the LVOT VTI >12.5% after a passive leg raise (PLR) maneuver is diagnostic of fluid-responsive state [11].

Corrected carotid flow time (cCFT) refers to the time length of blood flow through the common carotid arteries (CCA) during systole corrected for heart rate, it increases in dehydrated patients who received fluid intravenously [12].

2. PATIENTS AND METHODS

This is a prospective observational study carried on 50 in sepsis with clinical signs of tissue hypo perfusion requiring ongoing fluid resuscitation, admitted to Emergency Medicine Department critical care unit requiring further resuscitation during the period from March 2019 to March 2020. Adults Patients (≥ 18 years old) with SOFA score≥ 2 are included in this study. Patients with valvular lesions, elevated intra-abdominal pressure, recent abdominal surgery or mechanically ventilated were excluded. All patients included in this study were screened for demographic data (including age, sex, and co-morbidities), provisional cause of sepsis (e.g., pneumonia, UTI, skin infection), noninvasive static parameters of volume state including heart rate, blood pressure (mean arterial blood pressures).

Patients received intravenous normal saline fluids according to surviving sepsis campaign in form of 10 ml / kg increments up to 30 ml/kg in the first hour of zero time (i.e., patient arrival to hospital), then we measured Vital data, Serum lactate level, Mean B score and calculated SV and COP on admission and after each 10 ml/kg fluid up to 30 ml/kg. We stopped fluid resuscitation when mean B score>2.

2.1 Measurements

2.1.1 Inferior Vena Cava diameters and collapsibility index

- low frequency curvilinear probe is used.
- Patients lie supine with the head slightly elevated.
- The IVC was imaged in a longitudinal plane with the transducer in the subxiphoid

position using the liver as the acoustic window.

- The IVC diameter (IVCD) was then measured at a point 2 cm from its entry into the right atrium, where its walls are parallel.
- Maximum and minimum diameters were measured.
- M-mode was used to capture of the IVC over two or three respiratory cycles.
- IVC Collapsibility index (CI) calculated by measuring IVC maximum (IVCe) and minimum (IVCi) diameter according to equation below.

CI=(IVCe–IVCi)/(IVCe)×100% [13].

2.1.2 Calculation of cardiac output

- Cardiac output (CO) = stroke volume (SV) × heart rate (HR).
- Stroke volume (SV) determined by left ventricle outflow tract (LVOT) area multiplied by the LVOT velocity time integral (VTI).

SV= LVOT area × LVOTVTI [14].

LVOT area = π×LVOT2 radius

(π = 0.785)

- LVOT diameter evaluation should be at the point of entry of aortic valve cusps in a zoomed parasternal long-axis view at mid-systole by phased array probe.
- LVOT VTI Measurement in apical 5 chamber view.
- Pulsed wave Doppler Flow is traced in Left Ventricular Outflow Tract (LVOT), and Velocity Time Integral (VTI) is traced in 3-5 cardiac cycles.

2.1.3 Lung ultrasound

- Patients lie supine in a semi-recumbent position using a curvilinear curved probe.
- Standardized points are used (the BLUE-points).
- By using mean B score; each region was classified as ‘B0’ if less than three B-lines were identified in all the intercostal space; ‘B1’ if at least three B-lines were present in at least one intercostal space, ‘B2’ in case of presence of the “white lung pattern” (multiple and coalescent B-lines).
  - ✓ According to inferior vena cava collapsibility index, patients divided in to 2 groups.

Group 1: high caval index (≥ 40) [15].

Group 2: low caval index (< 40).

3. RESULTS

Our study included 50 patients including (28) male patients representing (56%) and (22) female patients (44%). The age of our patients ranged between 39 years and 86 years with a mean age of 59 years old ± 9 years. pneumonia was the main cause of sepsis in our patient sample followed by UTI (fig.1). 28% of our patients needed mechanical ventilation while 68% required vasopressor support.

Among our 50 patients, only 19 (38%) patients have high caval index (Table1). Our data showed no statistically significant difference between both groups regarding age, sex, baseline hemodynamic parameters or etiology of sepsis. Also, there is no significant difference between both groups regarding the need for mechanical ventilation as supportive treatment, but there is significant increase in need to vasopressor support in low caval index group (83.87%) compared to high caval index group group (42.11%) (Table 5).

Furthermore, data showed statistically significant difference between both groups regarding hemodynamic parameters as HR, MAP, SV, COP as there was statistically significant increase in MAP, SV, COP and decrease in HR after fluid resuscitation in the high caval index group in comparison with low caval index group (Tables 2,3).

Among all studied 50 patients; the majority of patients (39 of 50) received 30ml/kg bolus fluid but there were 11 patients received only 20ml/kg fluid bolus and did not complete 30ml/kg. Those 11 patients distributed as 9 patients (81.82%) from low caval index group and 2 patients (18.18%) from high caval index group (Table 6). Patients who did not complete 30ml/kg were with chronic diseases as HTN is the most common risk factor associated by 63.64%, CKD represented 54.55% then cardiac and diabetic patients represented 36.36% (Table 7).

4. DISCUSSION

Point of care ultrasound presently serves as a tool assisting clinicians in solving problems at a patient’s bedside and assessment of intravascular volume status That allow clinicians to assess the degree of hydration non-invasively.

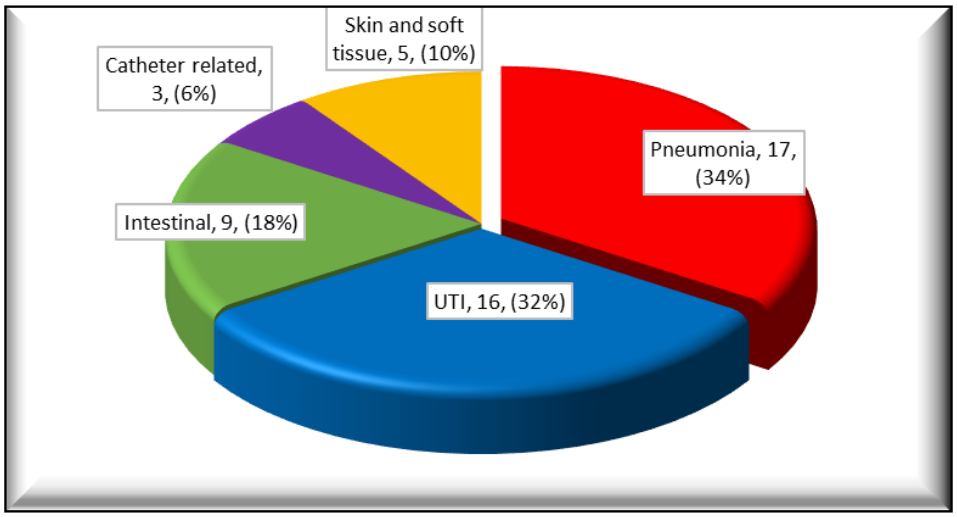

Fig. 1. Distribution of studied cases according to source of infection

Table 1. Distribution of studied cases into groups

Groups		
	N	**%**
Low caval index (Low CI)	31	62.00
High caval index (High CI)	19	38.00
Total	50	100.00

Table 2. Mean arterial blood pressure (MAP) changes in both studied groups

MAP (mmhg)		**Groups**						**T-Test**	
		Low CI			**High CI**			**t**	**P-value**
Baseline	Range	40	-	60	40	-	60	-0.025	0.980
	Mean ±SD	50.484	±	5.531	50.526	±	6.432		
After 10 ml	Range	50	-	60	45	-	60	1.940	0.058
	Mean ±SD	55.000	±	3.162	52.895	±	4.508		
After 20 ml	Range	45	-	65	50	-	65	-2.108	0.040*
	Mean ±SD	55.000	±	4.655	57.895	±	4.806		
After 30 ml	Range	55	-	65	55	-	65	-0.916	0.366
	Mean ±SD	58.864	±	3.758	60.000	±	3.953		
B-A10ml	Differences	-4.516	±	15.680	-2.368	±	6.743		
	P-value	0.119			0.143				
B-A20ml	Differences	-4.516	±	17.113	-7.368	±	7.335		
	P-value	0.152			<0.001*				
B-A30ml	Differences	-8.409	±	22.053	-10.000	±	6.847		
	P-value	0.088			<0.001*				

Oord et al [16] evaluated the role of Ultrasound in the assessment of fluid responsiveness in patients with mild sepsis in the emergency department, they enrolled 37 patients with mild and severe sepsis, they divided patients in high collapsibility index and low collapsibility index groups. The majority of patients received a second fluid bolus of 500 mL and patients who did not receive a second fluid bolus; had a low CI, history of reduced left ventricular function and hypertensive at baseline. In agreement with our study, there was no significant difference between the low and high CI group in hemodynamic parameters after first fluid bolus of 500 mL 0.9% NaCl. There was a significant change in stroke volume and/or cardiac output in studied patients after second fluid bolus. Stroke volume significantly increased in the high CI group than low CI group. In contrast to our results, there were no significant changes in

heart rate and blood pressure after the fluid bolus of 500 and 1000 mL which explained by low sample size of patients and small amount of fluid administrated.

Table 3. Changes in stroke volume (ml) in both groups before / after fluids

SV (ml)		Groups						T-Test	
		Low			High			t	P-value
Baseline	Range	49	-	70	57	-	70	-1.584	0.120
	Mean ±SD	62.032	±	6.172	64.526	±	3.791		
After 10 ml	Range	50	-	88	69	-	90	-3.582	0.001*
	Mean ±SD	69.355	±	7.956	77.368	±	7.190		
After 20 ml	Range	65	-	90	70	-	90	-4.462	<0.001*
	Mean ±SD	73.645	±	6.243	82.105	±	6.927		
After 30 ml	Range	65	-	90	75	-	100	-4.403	<0.001*
	Mean ±SD	78.273	±	7.881	89.412	±	7.771		
B-A10ml	Differences	-7.323	±	27.068	-12.842	±	28.030		
	P-value	0.142			0.061				
B-A20ml	Differences	-11.613	±	33.309	-17.579	±	7.691		
	P-value	0.062			<0.001*				
B-A30ml	Differences	-16.818	±	49.674	-25.118	±	8.440		
	P-value	0.079			<0.001*				

Table 4. Changes in serum lactate levels (mmol/l)

S. Lactate (mmol/l)		Groups						T-Test	
		Low CI			High CI			t	P-value
Baseline	Range	5	-	10	5	-	10	-1.650	0.105
	Mean ±SD	7.194	±	1.327	7.842	±	1.385		
After 10 ml	Range	4	-	9	5	-	10	-2.508	0.016*
	Mean ±SD	6.903	±	1.248	7.842	±	1.344		
After 20 ml	Range	4	-	7	4	-	9	-2.867	0.006*
	Mean ±SD	5.419	±	0.886	6.368	±	1.461		
After 30 ml	Range	2	-	5	2	-	5	-0.785	0.437
	Mean ±SD	3.455	±	0.671	3.647	±	0.862		
B-A10m	Differences	0.290	±	0.824	0.000	±	0.667		
	P-value	0.059			1.000				
B-A20m	Differences	1.774	±	1.146	1.474	±	1.073		
	P-value	<0.001*			<0.001*				
B-A30m	Differences	3.864	±	1.583	4.471	±	1.328		
	P-value	<0.001*			<0.001*				

Table 5. Distribution of cases according to need for MV

MV	Groups						Chi-Square	
	Low CI		High CI		Total			
	N	%	N	%	N	%	X^2	P-value
No	19	61.29	17	89.47	36	72.00	3.349	0.067
Yes	12	38.71	2	10.53	14	28.00		
Total	31	100.00	19	100.00	50	100.00		

Table 6. Distribution of patients in studied groups according to volume of fluid

	Received< 30ml/kg		Received 30ml/kg fluid	
Groups	N	%	N	%
Low caval index	9	81.82	22	56.41
High caval index	2	18.18	17	43.59
Total	11	100.00	39	100.00

Table 7. Distribution of patients received <30ml/kg fluids according to risk factors

Co morbidity (N=11)		
	N	**%**
DM	4	36.36
HTN	7	63.64
Cardiac	4	36.36
CKD	6	54.55
Auto immune disease	1	9.09
Hepatic	0	0.00

Khan et al [17] assessed the association between 30 mL/kg crystalloids and intubation rate in patients with sepsis or septic shock and heart failure, end-stage renal disease, or cirrhosis. They included 208 patients divided in 2 groups; standard group (received ≥30ml/kg) and restricted group (<30 ml/kg), they detected no differences in the incidence of intubation in patients with sepsis and cirrhosis, end-stage renal disease, or heart failure who received guideline recommended fluid resuscitation with 30 mL/kg compared with patients initially resuscitated with a lower fluid volume, but in our study; we used B mean score to asses extravascular lung water as indicator to stop fluid in patients with sepsis to rule out intubation caused by fluid overload.

Airapetian et al [18] evaluated the value of IVC respiratory variability in spontaneously breathing patients for predicting fluid responsiveness, they studied Fifty-nine patients, 49 % were considered to be responders. There were no significant differences between responders and non-responders in terms of demographic and baseline clinical characteristics. and they found that cIVC > 42 % may predict an increase in CO after fluid infusion in spontaneously breathing patients as in our study, high caval index associated with increase in COP more than low index.

The strength of this current study is its prospective nature. We were able to obtain acceptable images and quantify IVC diameter, collapsibility, stroke volume and cardiac output in those critically ill patients by bed side Ultrasound machine with new POCUS daily skills.

Limitation of the study; studied patients were small sample size, single-center study, and exclusion of certain conditions as mechanically ventilated patients which represent large number of septic patients and patients with high SOFA score.

5. CONCLUSION

POCUS has additive value in guiding of fluid resuscitation in sepsis in order to avoid fluid overload and to identify proper timing of vasopressor use.

CONSENT

Written informed consent was obtained from patients or their relatives.

ETHICAL APPROVAL

As per university standard guideline ethical approval have been collected and preserved by the authors

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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