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Efficacy of Fluid Administration Followed by Lung Sonography in Hemodynamic Assessment in Acute Circulatory Failure in Critically Ill Patients

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Authors' contributions

This work was carried out in collaboration among all authors. Author Ahmed M. Elkashef designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MGE and Ahmed M. Hamed managed the analyses of the study. Authors AEE and MAEmanaged the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Background: Early recognition and appropriate treatment of shock have been shown to decrease mortality. Incorporation of bedside ultrasound in patients with undifferentiated shock allows for rapid evaluation of reversible causes of shock and improves accurate diagnosis in undifferentiated hypotension. The aim of the present study was to evaluate efficacy of fluid administration followed by lung sonography in hemodynamic assessment in acute circulatory failure in critically ill patients.
Materials and Methods: This prospective cohort controlled randomized study was carried out on 50 Critically ill Patients who had acute circulatory failure in intensive care unit Tanta university hospital Critically ill patients of either sex aged 21-60 years when mean blood pressure was below 65 mmHg were included. Patients have been uniformly distributed in 2 categories, The patients assigned either to the Control Group (group I) or to the FALLS (fluid administration limited by lung sonography) protocol group (group II).

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Results: Comparison between two groups revealed that, the heart rate showed that heart rate is lower in group II in comparison to group I .Comparison between two groups revealed that, the mean arterial blood pressure changes showed that it is higher in group II in comparison to group I .Comparison between two groups revealed that, the Central venous pressure showed that no significant difference in the base line .Intensive care unit stay in group I ranged between 5 – 11 days while in group II ranged between 3 – 8 days .Survival analysis (Kaplan Mier curve), Mortality at 28 days found in group I mean 21.28 days with SE 1.898 and in group II mean 24 days with SE 1.64 with no significant difference in time but there was significant difference in number of mortalities as discussed before.

Conclusion: We conclude from this study that bedside Lung Ultrasound has a good accuracy and superiority in assessment over other traditionally used methods for detecting early signs of pulmonary congestion and thus guides the fluid administration in shock management to decrease complications, mortality and intensive care stay.

Keywords: Fluid administration; lung sonography; hemodynamic assessment; acute circulatory failure; critically ill.

1. INTRODUCTION

Early recognition and appropriate treatment of shock have been shown to decrease mortality [1]. Incorporation of bedside ultrasound in patients with undifferentiated shock allows for rapid evaluation of reversible causes of shock and improves accurate diagnosis in undifferentiated hypotension [2]. Reflecting a trend to integrate ultrasound early into the care of the critically ill patient, multiple resuscitation protocols have been recently developed [3]. Each of these protocols combines many of the same core ultrasound elements, differing mainly in the priority of the exam sequence [4].

Ultrasound technology has been rapidly integrated into general medicine and specifically, Emergency Department care, in the last decade. More practicing emergency physicians (EP's) and critical care physicians are now trained in bedside point of care, or goal directed ultrasound [5], and this training is now both supported by the American Medical Association and included in the formal curriculum of all United States Emergency [6].

The FALLS-protocol (Fluid Administration Limited by Lung Sonography) is a tool proposed for the management of unexplained shock, mainly using lung ultrasound. Acute circulatory failure is one of the most familiar concerns of the intensivist, and echocardiography or transpulmonary thermodilution device are among the most widely used tools at present [7]. They accurately measure changes in cardiac output, however, giving only an indirect idea of the mechanism of shock, they are not fully designed to provide a diagnosis [8].

The aim of the present study was to evaluate efficacy of fluid administration followed by lung sonography in hemodynamic assessment in acute circulatory failure in critically ill patients.

2. SUBJECTS AND METHODS

This prospective cohort controlled randomized study was carried out on 50 Critically ill Patients who had acute circulatory failure in intensive care unit Tanta university hospital Critically ill patients of either sex aged 21-60 years when mean blood pressure was below 65 mmHg were included. A code number for each patient was used, names and addresses symbols stored in a separate register, we mask the identities of patients when we use the study and only used the findings for scientific purposes.

Exclusion conditions included: Patient or their legal relatives who refused to participate in this study, those on inotropic or vasopressor drugs and also patients with obstructive shock and with organ failure were excluded from this study.

All patients at first follow ICU protocol for shocked patients admitted and it Was précised and rapid as it's an emergency so management initially was as ABCD approach as follow, Special care to air way to remove any bleeding and suctioning maintain air way after sedation with midazolam 70 mcg/kg and muscle relaxant rocuronium with dose 1 mg/kg and intubation with mechanical ventilation with lung protective strategy Tidal volume 6 ml/kg, Respiratory rate 16 breaths\min, I:E ratio 1:2, volume controlled mode, Peep 5 cm H2O, FiO2 100% and decrease gradually till achieve SpO2 95, FiO2 40% or above to maintain effective oxygenation

and parameters adjusted by assess arterial blood gases also with patient survey and exclude any source of bleeding .History taking from their legal relatives, Clinical examination, Routine laboratory investigation (Complete blood count, liver function, renal function, bleeding & coagulation profile, lactate level) assessment and Urinary catheterization for monitoring urinary output. Special care of lactate level serum (normal level 0.5-1 mmol/L) to assess sepsis and shock with acidosis and prognosis of treatment, Elevated serum lactate is < 2 mmol/L.

All procedures were carried out in intensive care unit following the standard monitorization including continuous electrocardiogram, invasive automated arterial blood pressure, central venous line was inserted guided by ultrasound, and pulse oximetry was applied. Cardiac and lung sonography was done to exclude obstructive shock e.g. Cardiac tamponade or pneumothorax.

The patients assigned either to the Control Group (group I) or to the FALLS (fluid administration limited by lung sonography) protocol group (group II).

The sample size was calculated at N < 23 for each study group based on the following criteria: 95% confidence limit, 80% power of the study, the ratio between the two studied groups is 1:1, expected outcome ranging between 55-85% of ideal required, so we will include 25 patients in each group. 1- Group I (Control group): (25 patients)

Patients of group I were treated with traditional method for management of shock by fluid therapy and assessment of hemodynamic parameters by measuring mean arterial blood pressure with heart rate and central venous pressure. 250 ml Normal saline were infused over 15 minutes, infusion repeated until an end point is reached as central venous pressure more than 12 cmH2o or mean blood pressure more than 65 mmHg or amount of infused fluids more than 30 ml/kg. When mean arterial blood pressure below the target level < 65 mmHg despite reaching CVP > 12 cm H2o, or infusing a total amount of normal saline > 30 ml/kg norepinephrine was used as a vasopressor at dose (0.05-0.3 mcg/kg/min).

Patients in group II were examined in supine position and chest wall was individualized into 11 areas (3 anterior and 3 lateral on right side and 2 anterior and 3 lateral on lift side), for each one 1 scan was obtained. The sonographic signs of B lines pattern have 5 mandatory features: it arises from the pleural line, it is well defined like laser beam, it spread to the edge of the screen without fading, it erases A lines, and it move with lung sliding lines were counted from zero to ten zero reflects complete absence of B lines in the investigated area, the full white screen in a single scan site was considered as 10 B lines for each zone. Using fluid administration limited by lung sonography protocol were done as follow: Lung ultrasound was done if A profile means no B lines in lung it means that's there is no pulmonary congestion or edema treated by fluid therapy as,250 ml Normal saline were infused over 15 minute and infusion repeated until end point is mean blood pressure is more than 65 mmHg or appear of B lines in lung ultrasound which mean pulmonary congestion or edema. When mean arterial blood pressure below the target level < 65 mmHg despite reaching infusing a total amount of normal saline > 30 ml/kg or the appearance of B lines norepinephrine was used as a vasopressor at dose (0.05-0.3 mcg/kg/min).

Measurements: Hemodynamic measurements (mean blood pressure, Heart rate, Central venous pressure) 5 minute- 10 minutes – 30 minutes- 1 hour – 2 hours – 3 hours from admission to ICU. Total amount of fluid. (Normal saline): The total amount used to resuscitate patient till hemodynamic stability achieved or complication start to present. Time needed to reach goal (hemodynamic stability). Number of patients need vasopressor and their total dose. Intensive care unit stay. Complication: End organ failure as renal failure and pulmonary edema. ICU mortality.

2.1 Statistical Analysis

SPSS v20 (IBM ©, Chicago, IL, USA) conducted statistical analysis. Quantitative results have been provided as a mean and standard deviation (SD) and have been measured, if appropriate, by the ANOVA(F) method. Qualitative results is provided as numbers and percentages and contrasted, if possible, with the Chi-square (X2) method. Statistically significant was a P value <0.05.

3. RESULTS

There was no significance difference in demographic data (age, weight and height) among the three groups [Table 1].

Table 1. Show comparison between the age in years, weight in kg, height in cm and sex in both groups

Number of patients	Age years		Weight kg		Height cm		Sex	
	Group I	Group II	Group I	Group II	Group I	Group II	Group I	Group II
1	21	48	74	76	165	158	M	F
2	34	57	75	78	160	162	F	M
3	60	60	82	85	162	163	F	F
4	50	46	85	83	164	159	M	F
5	59	49	78	78	163	162	F	M
6	45	58	79	79	164	164	M	F
7	36	25	84	83	159	158	F	F
8	54	36	79	81	158	157	F	F
9	56	55	83	84	163	162	M	F
10	59	41	85	79	164	164	F	M
11	44	57	76	80	163	159	M	F
12	39	60	83	81	158	157	F	F
13	28	46	81	83	159	160	M	F
14	48	52	80	79	156	161	F	M
15	53	59	77	78	157	163	F	F
16	57	22	79	76	163	159	F	M
17	60	35	78	79	165	158	M	M
18	21	44	82	82	158	157	F	F
19	49	57	81	84	157	162	F	F
20	29	33	84	79	162	165	F	M
21	60	58	82	77	157	157	M	M
22	53	43	77	84	164	159	F	F
23	52	38	79	79	165	163	M	M
24	38	60	84	82	158	165	M	M
25	47	20	82	77	162	158	F	M
Range	21-60	22-60	74-85	76-85	156-165	157-165	M=15	M=14
Mean + SD	46+12.2	46.2+12.5	80.4+3.1	80.2+2.7	161+3	160.5+2.7	F=10	F=11
P value	0.955		0.886		0.496		0.774	

As regards HR, Comparison between two groups revealed that, the heart rate showed that heart rate is lower in group II in comparison to group I but with no significant difference in the base line and (5-10-30) minutes and (1-2-3) hours after starting procedure when compared to each other .(p value > 0.05). [Table 2]

As regards MAP, Comparison between two groups revealed that, the mean arterial blood pressure changes showed that it is higher in group II in comparison to group I but with no significant difference in the base line and (5-10-30) minutes and (2-3) hours after starting procedure when compared to each other. (p value > 0.05)But mean arterial blood pressure show significant difference at (1) Hour after starting procedure in group II when compared to group I which indicate better hemodynamic stability in group II. (p value = 0.027*) [Table 3].

Table 2. Show comparison between heart rate changes in both groups

		Base line	5 min	10 min	15 min	30 min	1 h	2 h	3 h
Group I	Mean	122.0	117.2	114.4	110.9	107.8	105.2	102.6	99.0
	SD	8.0	8.3	7.1	7.6	7.7	9.3	11.8	14.9
Group II	Mean	121.9	117.0	112.3	109.8	106.5	103.5	99.0	96.1
	SD	10.0	9.2	8.1	7.3	7.3	10.6	13.9	14.0
P value		0.988	0.925	0.340	0.633	0.571	0.543	0.333	0.492

Table 3. Show comparison of mean arterial blood pressure (mmhg) changes in both groups

		Base line	5 min	10 min	15 min	30 min	1 h	2 h	3 h
Group I	Mean	46.3	49.9	53.8	55.5	58.6	58.8	62.4	68.0
	SD	5.6	6.1	6.2	5.7	6.9	7.6	10.2	14.1
Group II	Mean	46.1	50.0	53.2	57.1	59.4	63.9	67.4	72.1
	SD	5.5	5.4	4.4	3.7	5.1	7.8	8.7	11.6
P value		0.901	0.981	0.718	0.252	0.620	0.027*	0.077	0.278

Comparison between two groups revealed that, the Central venous pressure showed that no significant difference in the base line and (5-10-30) minutes and (1-2-3) hours after starting procedure when compared to each other. (p value > 0.05). [Fig. 1]

Total amount of fluid in group I ranged between 5 – 30 ml\kg with Mean ± SD 24 ± 8.71 while in group II ranged between 5 – 30 ml\kg with Mean ± SD 18.6 ± 9.22. which show significant difference with P value (0.042*) as fluids is lower in group II when compared to group I. [Fig. 2]

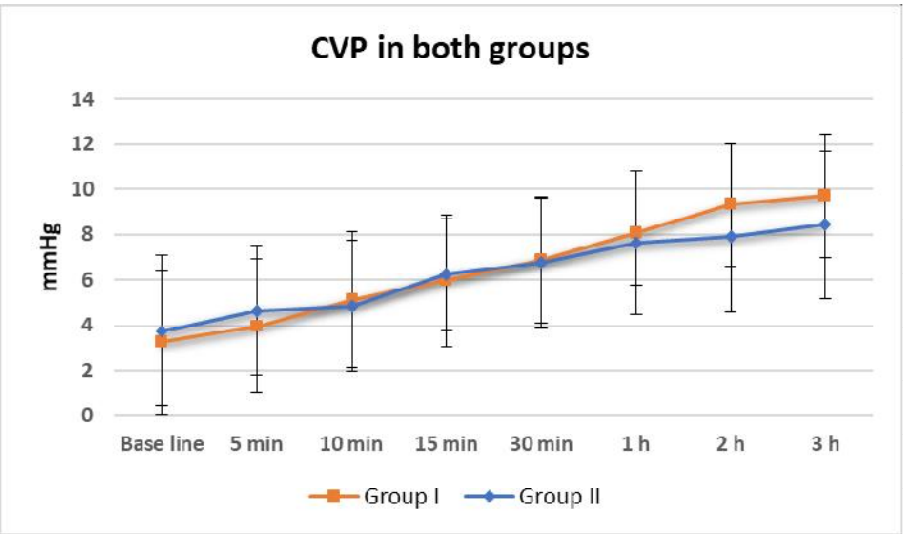

Fig. 1. Show comparison of central venous pressure changes in both groups

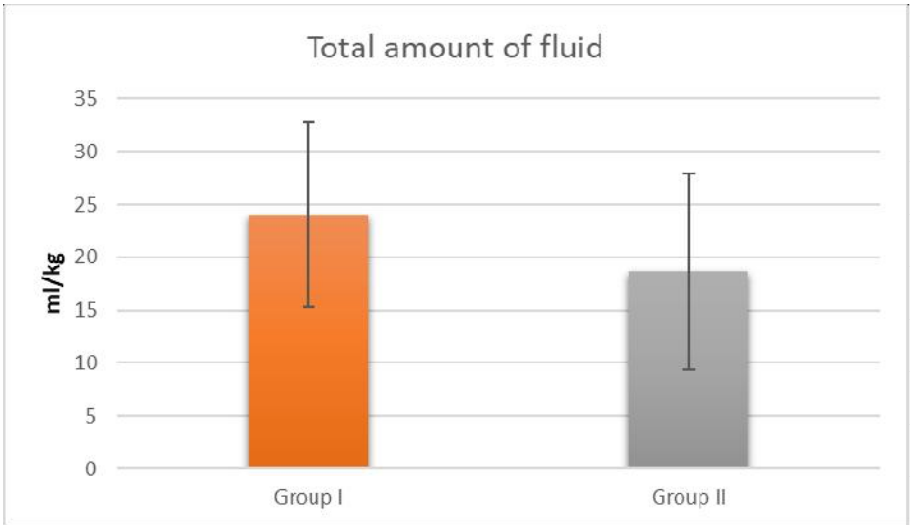

Fig. 2. Total amount of fluids (normal saline) used in both groups

Patients need vasopressor drug (Norepinephrine) and their doses in group I ranged between 0 – 6.75 mg/kg hours with Mean ± SD 4.13 ± 2.69 mg/kg hours while in group II ranged between 0 – 6.75 mg/kg hours with Mean ± SD 3.1±2.56 mg/kg hours which show is lower in group II but with no significant difference between groups. P value (0.189). [Fig. 3]

Intensive care unit stay in group I ranged between 5 – 11 days with median 3.89 and IQR 5-11 while in group II ranged between 3 – 8 days with median 4.14 and IQR 3-8, which show is lower in group II but with significant difference between groups P value (0.032*). [Fig. 4]

Survival analysis (Kaplan Mier curve), Mortality at 28 days found in group I mean 21.28 days with SE 1.898 and in group II mean 24 days with SE 1.64 with no significant difference in time but there was significant difference in number of mortalities as discussed before. [Fig. 5]

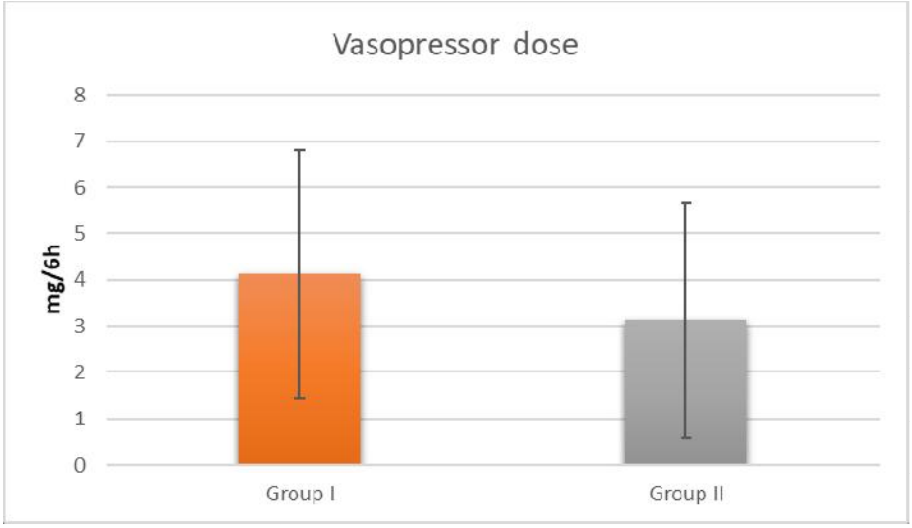

Fig. 3. Patients need vasopressor drug (Norepinephrine) and their doses in both groups

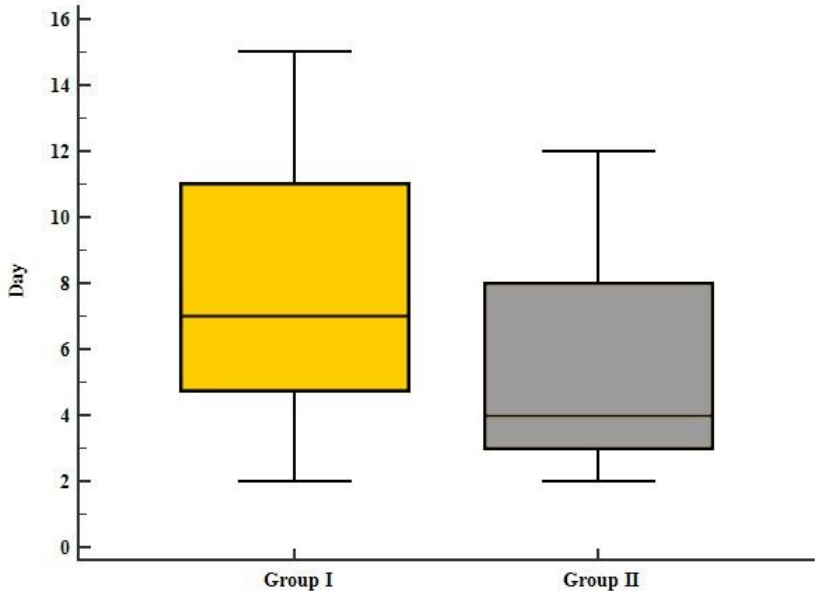

Fig. 4. Intensive care unit stay in both groups

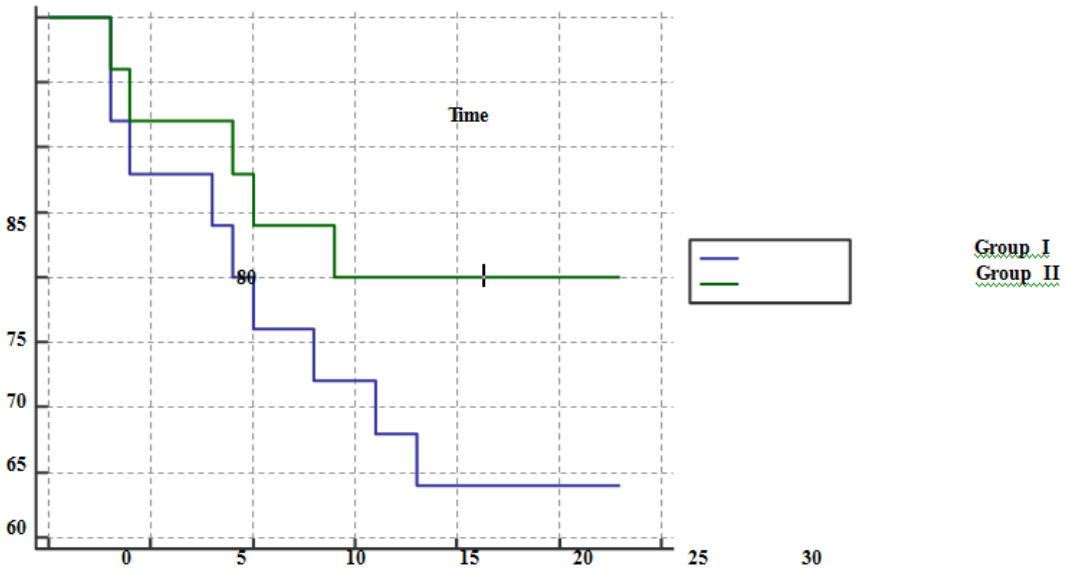

Fig. 5. Survival analysis (Kaplan Mier curve), mortality at 28 day

4. DISCUSSION

Traditional methods of volume assessment such as measurement of central venous pressure, or use of the pulmonary arterial catheter have each been scrutinized for their lack of accuracy in critically ill patients.Lichtenstein et al [9] who studied the comet tail artifact as an ultrasound sign for alveolar- interstitial syndrome conducted at Hospital Ambroise-Paris, showing that from 92 patients with positive CXR signs recommending lung congestion, 86 patients had B profile lung U/S and from 129 patients with free CXR 120 patients had A profile lung U/S and these showed sensitivity 93.4% and specificity 93% compared to lung U/S sensitivity 80% and specificity in our study. This difference is due to the number of patients which is more than this in our study Xirouchaki et al [10] who compared the diagnostic performance of lung U/S and CXR for the detection of various pathologic abnormalities in the ICU in 42 patients at University Hospital of Heraklion, Greece, the CXR had 46% sensitivity and 80% specificity with PPV 81% and NPV 45% compared to the lung U/S which had 94% sensitivity, 93% specificity, PPV 96% and NPV. Volpicelli et al, [11] who studied the lung U/S with multiple and diffuse B lines (at least 2 positive scans on each side) considering it as positive for lung congestion showing a sensitivity 83.7% and a specificity 90.7% for diagnosing alveolar interstitial syndrome with a PPV 93% and NPV 95.1%. These studies show high accuracy and superiority in assessment of lung U/S which support our study also those next studies show low accuracy of central venous pressure when compared to lung U/S which also support our study. T. G. Eskesen et al [12] who studied the reliability of CVP as a guide for fluid resuscitation in the patients with shock in 51 patients at Copenhagen University Hospital, Denmark using 2 cut off values for CVP 8.Boecxstaens et al [13] who studied the prevention of lung congestion by the application of CVP rule (CVP ≤ 5 cmH2O) during the fluid therapy in the 1st group before CVP rule 29 patient showed lung congestion due to volume overload evident by lung U/S with multiple B-lines while in the 2nd group no patient shows lung congestion excluded by lung U/S after the application of CVP rule and was statistically significant ($p<0.001$). comparing these results with our study we can state that high CVP values are more commonly associated with high risk for volume overload and lung congestion.Osman et al, [14] who examined the adequacy of CVP as predictor for fluid resuscitation in 96 patients with shock at Hospital of Paris. When CVP was 10 - 12 cm H2O, the sensitivity was 77% and specificity of 51% and the PPV was only 47%. Even when CVP was much lower reaching 5 – 10 Cm H2O, the sensitivity was 35% and specificity of 71% and the PPV was still only 47% which shows that using CVP as an endpoint for fluid resuscitation should be revised.As regard complication we found significant difference

between groups with lower incidence of pulmonary edema in group II compared to group I with P value 0.049*, also there is lower incidence of mortality in group II compared to group I with P value 0.0.39*, so we found significant difference in intensive care stay in group II compared to group I with P value 0.032*.These results due to high accuracy and superiority in assessment of lung U/S so it accurately detects endpoint of fluid infusion and avoid hypervolemia which lead to complications and increase mortality rate as we found significant higher central venous pressure in group I compared to group II as discussed before, these results can be supported with following studies. Koonrangsesomboon et al, [15] who found The cumulative fluid intake within the 1st 24 h was (3.2 – 5.6 L) with mortality rate 47% (493) patient and the non-survived group had a higher cumulative fluid intake than survived group (4.6 V 3.9 L) respectively and this findings were statistically significant (p<0.001) confirming that positive fluid balance and volume over load in patients with shock is associated with increased mortality rate.

5. CONCLUSION

We conclude from this study that bedside Lung Ultrasound has a good accuracy and superiority in assessment over other traditionally used methods for detecting early signs of pulmonary congestion and thus guides the fluid administration in shock management to decrease complications, mortality and intensive care stay.

CONSENT

As per international standard or university standard, patient's written consent has been collected and preserved by the author(s).

ETHICAL APPROVAL

As per international standard or university standard written ethical approval has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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