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ORIGINAL ARTICLE

Does Point-of-Care Ultrasonography Improve Outcomes for Patients with Undifferentiated Hypotension in Emergency Intensive Care Unit?

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Abstract:

Background: Early recognition and management of hypotension reduce mortality, with point-of-care ultrasonography (POCUS) and the Rapid Ultrasound in Shock and Hypotension (RUSH) protocol aiding rapid and accurate shock diagnosis, though patient outcome benefits remain uncertain. This study aimed to assess the effect of point-of-care ultrasonography protocol in patients with undifferentiated hypotension on survival and outcomes in the emergency intensive care unit (ICU).

Methods: This is a prospective randomized controlled clinical trial that was conducted on 100 adult patients who presented to the Emergency ICU with undifferentiated, non-traumatic hypotension or shock. The cases were randomly allocated into 2 groups (50 cases with POCUS and 50 matched control group). The study's primary outcomes included mortality incidence, 30-day survival, and hospital discharge rates. Secondary outcomes assess ICU/hospital stay duration, need for mechanical ventilation (MV), use of Vaso inotropes and fluids, CT scan rates, and dialysis requirements.

Results: The use of POCUS significantly improved early diagnosis time (1.52±0.50 vs. 9.46±2.24 hours, $p<0.001$), reduced ICU stay (6.02±1.25 vs. 7.56±1.80 days, $p<0.001$), and decreased total IV fluid administration (9300 vs. 11000 mL, $p=0.004$) compared to the control group. The POCUS group had higher systolic (114.10±3.45 vs. 112.30±4.42 mmHg, $p=0.014$), diastolic (65.40±4.27 vs. 61.70±2.39 mmHg, $p<0.001$), and mean arterial pressures (81.54±3.38 vs. 78.39±2.33 mmHg, $p<0.001$) after 60 minutes. Mechanical ventilation duration was shorter in the POCUS group ($p<0.001$). The CT scan use was lower in the POCUS group (20% vs. 48%, $p=0.003$). Higher albumin ($p<0.001$) and platelet counts ($p<0.001$) were observed in the POCUS group, while WBC count ($p=0.014$) and procalcitonin ($p=0.004$) were higher in the control group.

Conclusion: Implementing the POCUS protocol in the emergency ICU for adult patients with undifferentiated, non-traumatic hypotension or shock significantly improved patient outcomes. Compared to the control group, POCUS reduced mean hospital discharge time, ICU length of stay, and median IV fluid administration.

Keywords: Point-of-Care Ultrasonography; Outcomes; Undifferentiated Hypotension; Emergency Intensive Care Unit.

INTRODUCTION

The early recognition and treatment of hypotension lower morbidity and mortality in patients with undifferentiated hypotension and septic shock [1]. Point-of-care ultrasonography can assist the clinician in rapidly diagnosing and managing patients with undifferentiated hypotension in the emergency department [2,3].

The Rapid Ultrasound in Shock and Hypotension (RUSH) protocol was introduced by Weingart et al. [4] in 2006 and published in 2009. This protocol was designed to be a rapid, easily performed ultrasound examination, which usually does not take longer than 2 minutes and can consequently be performed efficiently by most emergency physicians. Over the years, the RUSH protocol has shown excellent diagnostic utility in evaluating and differentiating various shock causes with considerable accuracy. In addition, it has successfully advocated further integration of protocol-driven assessment methods into clinical practice [5].

There is significant evidence that each point-of-care ultrasonography (POCUS) component contributes to improved clinical outcomes for certain patients. One example is the benefit of reduced POCU patient management after early resuscitation on survival, fluid infusion in hypotensive intensive care unit (ICU) patients, and increasing inotropic therapy [6]. The benefits of all these POCUS components have been clinically significant. Still, present evidence is limited concerning patient-centered outcome benefits when using integrated ultrasound protocols, such as Abdominal and Cardiothoracic Evaluation with Sonography in Shock (ACES) and Rapid Ultrasound for Shock and Hypotension (RUSH), for patients with undifferentiated non-traumatic shock in the ICU [7].

In trauma, POCUS has been shown to minimize the time to surgical intervention and computed tomography (CT) imaging of these patients [8]. Moreover, POCUS allows rapid screening of standard shock states such as cardiac dysfunction, ruptured aortic aneurysm, pulmonary embolism, and cardiac tamponade, thereby facilitating timely and directed management of severely affected patients.[9].

It has been found that the institution of a structured POCUS protocol significantly increases diagnostic accuracy in undifferentiated shock patients from 60.6% with conventional diagnostic techniques to 85.0%. This increase in precision affects initial management by significantly affecting treatment decisions in 24%- 50% of patients within clinical settings [10]. So, we aimed in this research to assess the effect of using a point-of-care ultrasonography protocol among patients with undifferentiated hypotension on survival and outcomes in emergency ICU.

METHODS

This prospective randomized controlled clinical trial was conducted at the Emergency Intensive Care Unit (EICU) of Zagazig University Hospitals, which serves the Delta governorates and receives many complicated cases daily. The study was conducted over six months, from May 2024 to December 2024.

The sample size was calculated based on data from a previous study by Shokoohi et al. [9], which reported that the mean diagnostic certainty in all diagnoses improved from 1.852 ± 1.0 before ultrasound to 1.339 ± 0.8 after ultrasound. Using these values, with a confidence level of 95% and a power of 80%, the estimated required sample size was determined to be 100 cases, as calculated using OpenEpi.

All participants were asked to sign an informed consent after institutional review board (IRB) approval (ZU-IRB#6523/20-12-2020). Human subjects research adhered to the guidelines set in the Declaration of Helsinki, which is part of the World Medical Association's Code of Ethics.

One hundred twenty patients were assessed for eligibility, with twenty excluded due to not meeting the inclusion criteria, while none declined to participate or had other reasons for exclusion. The remaining 100 patients were randomized into two groups: 50 were allocated to the POCUS group and received the assigned

intervention. At the same time, the other 50 were assigned to the control group and received the allocated intervention. No patients were lost during follow-up, and no interventions were discontinued in either group. Finally, all fifty patients from each group were included, with none excluded from the study (Figure 1).

Shock or hypotension, as defined by Volpicelli et al. [11], they were diagnosed with an SBP <100 mmHg confirmed after three measurements, along with at least one sign of hypoperfusion, such as unresponsiveness, altered mental status, syncope, respiratory distress, profound asthenia, or severe chest/abdominal pain.

The inclusion criteria required patients to be 18 years or older and to have provided consent, either personally or through a relative. Both sexes were included. Patients had to present with a systolic blood pressure (SBP) of less than 100 mmHg or a shock index (heart rate/SBP) greater than 1.0 when SBP was below 120 mmHg.

Exclusion criteria involved patients showing clear and identifiable etiology for hypotension or shock and those transferred from another health facility with a prior diagnosis. Patients requiring immediate cardiopulmonary resuscitation (CPR) or advanced cardiac life support (ACLS) interventions like defibrillation, emergency pacing, or insertion of a ventricular assistance device (VAD) before the screening were also excluded. Also excluded were patients with a 12-lead ECG diagnostic of AMI, hypotensive due to a vagal episode, or arrhythmias, including drug-induced tachycardia, tachyarrhythmia, and atrial fibrillation. Patients on beta-blocker therapy or known heart block were also excluded.

Patients were randomly allocated into two groups using the closed envelope technique. The POCUS Group (Group 1) (n=50) underwent assessment using the RUSH protocol, with management tailored accordingly. In contrast, the Control Group (Group 2) (n=50) received standard investigations and treatment without delay.

All participants underwent a comprehensive initial clinical assessment, beginning with detailed history-taking, including demographic data (age, sex, occupation), special medical habits, and comorbidities. Previous hospital or ICU admissions and the reason for ICU admission were also documented. A thorough clinical examination followed, assessing vital signs (pulse, blood pressure, respiratory rate, and respiratory pattern), Glasgow Coma Scale (GCS), and a complete systemic evaluation. Attending physicians recorded their initial assessment, noting the perceived shock category—cardiogenic or non-cardiogenic—along with the suspected diagnosis.

Laboratory investigations included a complete blood count, liver function tests (AST, ALT, INR, and albumin), kidney function tests (urea, serum creatinine, sodium, and potassium), and random blood glucose levels. Additionally, arterial blood gases were analyzed, including the calculation of the base deficit, to assess the patient's metabolic status.

Ultrasound Protocol

The ultrasound protocol involved a portable machine with a linear probe (10–5 MHz) and a phased-array or curved-array probe (5–1 MHz). In the POCUS group, the RUSH (Rapid Ultrasound in Shock and Hypotension) protocol was completed within the first 60 minutes of the presentation. The principal investigator performed the ultrasound, with assistance from a POCUS-trained physician if necessary. Standard imaging views were obtained, with alternative opinions utilized if primary imaging was not feasible. Physicians reassessed patients at 60 minutes, documenting the updated category of shock and suspected diagnosis. Meanwhile, the control group received standard care without POCUS assessment.

RUSH Protocol Components

The RUSH protocol is comprised of three main components: Pump (cardiac evaluation), tank (volume status evaluation), and pipes (vascular system evaluation). The Pump component assessed pericardial effusion, identified as an anechoic collection around the heart, which could indicate cardiac tamponade if

accompanied by right ventricular diastolic collapse. Left ventricular (LV) contractility was evaluated visually based on end-systolic and end-diastolic volume changes, with poor LV contraction suggesting cardiogenic shock. Right ventricular (RV) strain was assessed through RV enlargement (RV/LV ratio >0.9) or the presence of a D-sign (flattened interventricular septum), indicative of acute pulmonary embolism.

The Tank component focused on evaluating volume status. Inferior vena cava (IVC) collapsibility greater than 40% suggested volume responsiveness, while a dilated, non-collapsible IVC indicated fluid overload or obstructive shock. The FAST (Focused Assessment with Sonography in Trauma) exam was used to detect free fluid in Morison's pouch, the splenorenal space, or the pouch of Douglas, suggesting hemorrhagic shock. Pleural effusion and pulmonary edema were identified by anechoic fluid collections or B-lines (comet-tail artifacts) on lung ultrasound, indicative of cardiogenic shock.

The Pipes component assessed the vascular system. Abdominal aortic aneurysm (AAA) was diagnosed when the aortic diameter exceeded 3 cm, with rupture risk increasing at diameters greater than 5 cm. Deep vein thrombosis (DVT) was identified by incomplete vein compressibility or echogenic clot material within the lumen, indicating a potential pulmonary embolism. Pneumothorax was confirmed by the absence of lung sliding and the presence of a barcode sign on M-mode imaging.

The type of shock was determined based on ultrasound findings using the THIRD protocol, as described by Geng et al. [12]. This protocol guided shock classification, allowing for a more precise and timely diagnosis.

Data Collection

Data collection was conducted for each patient, including demographic details such as age, sex, and physical status. Clinical data encompassed vital signs, including blood pressure, respiratory rate, heart rate, and temperature, along with the initial assessment. The study results were the ultrasonographic findings and clinical impressions that were prospectively recorded. The primary and secondary diagnoses took place at 0 and 60 minutes, respectively, while the POCUS was conducted before the secondary assessment in the POCUS group itself. CT scan, further lab tests, and consultation with specialists did the secondary evaluation. The prognosis for the patient was based on outcomes of either survival in 30 days, discharge from the hospital, or mortality.

Additionally, the cost of saved resources was analyzed, considering expenses related to initial therapy, including fluids, inotropes, and vasopressors, CT scan utilization rates, and ICU length of stay.

Study Outcomes

The primary outcomes included the incidence of mortality. Secondary outcomes focused on ICU and hospital admission duration, the need for mechanical ventilation, the administration of vasopressors and fluids, survival at 30 days, and the hospital discharge rate.

Statistical analysis

Qualitative and quantitative data was analyzed using IBM SPSS Statistics Version 22.0. The Kolmogorov-Smirnov test was used to check for normality, and all results were assessed for significance at the 0.05 level. Qualitative data relationships were evaluated using the Chi-Square test, a non-parametric method for analysis. Quantitative data comparisons between groups utilized the Kruskal-Wallis test with the Mann-Whitney U test for non-parametric data. The significance of the results was expressed in terms of p-values, categorized as non-significant ($p > 0.05$), significant ($p \leq 0.05$), and highly significant ($p < 0.001$), with all results reported as two-tailed probabilities.

RESULTS

The study found no statistically significant differences between the groups in age, sex, or clinical scores. Group 1 had a mean age of 53.02 years versus 54.54 years in group 2, with males comprising 50% and 64%, respectively. GCS, APACHE, and SOFA scores did not show significant differences. Shock and hypoxia were the most common ICU admission

causes (40% vs. 38%). Comorbidities, including hypertension, diabetes, smoking, dyslipidemia, chronic kidney disease, and hepatic and thyroid disorders, showed no significant differences. BMI was also comparable (25.17±2.22 kg/m² vs. 25.15±2.53 kg/m²) (Table 1).

After 60 minutes, group 1 showed significantly higher systolic, diastolic, and mean arterial blood pressure ($p<0.05$) and central venous pressure ($p=0.001$) compared to group 2. Conversely, heart and respiratory rates were significantly higher in group 2 ($p=0.012$ and $p=0.036$, respectively), while temperature showed no significant difference (Table 2).

Laboratory findings showed significantly higher white blood cell (WBC) count and aspartate aminotransferase (AST) levels in group 2 ($p=0.014$, $p=0.023$). In contrast, group 1 had significantly higher platelet count, albumin, and blood urea nitrogen (BUN) ($p<0.001$, $p<0.001$, $p=0.04$, respectively). Arterial blood gases revealed significantly higher bicarbonate (HCO_3) levels in group 2 ($p=0.029$). Among cardiac markers, procalcitonin was considerably higher in group 2 ($p=0.004$) (Table 3).

The echocardiographic findings in group 1 showed a mean ejection fraction of 45.88±10.04%, mean end-systolic volume (ESV) of 3.48±0.46, and mean end-diastolic volume (EDV) of 4.64±0.34. The mean inferior vena cava (IVC) expiratory diameter was 2.098±0.36, inspiratory diameter was 1.58±0.25, collapsibility index was 48.0±5.88, and distensibility index was 18.60±2.64. A comparison of the associated echocardiographic findings showed no statistically significant differences between the two groups (Table 4).

Group 1 (POCUS) had significantly shorter hospital discharge time ($p<0.001$), ICU stay ($p<0.001$), mechanical ventilation duration ($p<0.001$), and lower IV fluid use ($p=0.004$) than group 2. CT utilization was also lower in group 1 (20% vs. 48%, $p=0.003$). Mortality and readmission rates showed no significant difference. Significantly, group 1 had a much faster diagnosis time (1.52±0.50 vs. 9.46±2.24 hours, $p<0.001$), highlighting POCUS's efficiency (Table 5).

Table (6) and Supplementary Figure (1) show that the area under the curve (AUC) for the inferior vena cava (IVC) collapsibility index in differentiating alive from deceased cases is 0.610, indicating fair but not statistically significant diagnostic value ($p=0.328$). The best cutoff point identified was 46.8, with a sensitivity of 87.5% and a specificity of 35.7%.

In the POCUS group, cases with non-mixed shock had a significantly higher mean international normalized ratio (INR) than those with mixed shock ($p=0.02$). In the Control group, patients with non-mixed shock had a considerably higher mean albumin level than those with mixed shock ($p=0.014$). No statistically significant differences were observed in other parameters, including age, sex, vital signs, or other laboratory markers (Supplementary Table 1).

Table (1): Comparison of demographic characteristics, ICU admission causes, and Comorbidities between studied groups

Variables	Group 1 (POCUS group) N=50	Group 2 (Control group) N=50	Test of significance	*P value*
Age/ years Mean±SD (range)	53.02±7.10 30-64	54.54±5.06 46-65	t=1.23	0.221
Sex n(%) Female Male	25(50) 25(50)	18(36.0) 32(64.0)	X^2=2.72	0.257
APACHE II score	25.26±4.20	24.96±4.16	t=0.359	0.721

Variables	Group 1 (POCUS group) N=50	Group 2 (Control group) N=50	Test of significance	*P value*
	20-30	25-34		
SOFA SCORE	13.02±1.93 10-15	12.82±1.79 12-15	t=0.537	0.593
GCS	10.46±1.11 10-14	10.88±1.30 9-12	t=1.73	0.086
Causes of ICU admission Shock Shock & hypoxia Shock& DCL Shock, hypoxia &DCL Shock & fits Shock, DCL& fits Shock &AKI Shock, hypoxia & rapid AF	 13(26.0) 20(40.0) 6(12.0) 4(8.0) 2(4.0) 2(4.0) 2(4.0) 1(2.0)	 12(24) 19(38) 7(14) 2(4) 3(6) 3(6) 2(4) 2(4)	χ^2=1.54	0.981
Comorbidities				
Hypertension	14(28.0)	16(32.0)	X2=0.190	0.663
DM	27(54.0)	22(44.0)	X2=1.0	0.317
Smoking	10(20.0)	12(24.0)	X2=0.233	0.629
Dyslipidemia	10(20.0)	8(16.0)	X2=0.271	0.602
Chronic kidney disease	26(52.0)	24(48.0)	X2=0.160	0.689
Hepatic disorders	7(14.0)	4(8.0)	X2=0.919	0.338
Thyroid disorders	3 (6.0)	2(4.0)	X2=0.211	0.646
BMI(Kg/m2)	25.17±2.22	25.15±2.53	t=0.029	0.977

t: Student t test, X^2= Chi-Square test, APACHE II =Acute physiology and Chronic health evaluation, SOFA score = Sequential organ failure assessment, GCS =Glasgow coma score. DCL= Disturbed conscious level, AKI = Acute kidney injury. DM= Diabetes mellitus, BMI = Body mass index.

Table (2): blood pressure and vital signs changes between studied groups

Variables		Group 1 (POCUS group) N=50	Group 2 (Control group) N=50	Test of significance	*P value*
Systolic blood pressure (mm/Hg)	Baseline	83.50±3.07	84.0±3.83	t=0.720	0.473
	After 60 minutes	114.10±3.45	112.30±4.42	t=2.51	0.014*
Diastolic blood pressure (mm/Hg)	Baseline	44.90±5.19	45.62±6.57	t=0.608	0.545
	After 60 minutes	65.40±4.27	61.70±2.39	t=5.95	<0.001*
MAP (mm/Hg)	Baseline	56.58±3.46	57.22±4.07	t=0.846	0.399
	After 60 minutes	81.54±3.38	78.39±2.33	t=5.41	<0.001*

Variables (after 60 minutes)	**Group 1 (POCUS group) N=50**	**Group 2 (Control group) N=50**	**Test of significance**	***P value***
Central venous pressure (CVP)	5.90±1.54	4.88±1.30	t=3.57	0.001*
Heart rate (beat/min)	112.88±7.68	117.14±8.95	t=2.55	0.012*
Respiratory rate (breath per minute)	20.80±3.12	22.22±3.54	t=2.13	0.036*
Temperature	37.63±0.55	37.66±0.52	t=0.282	0.778

t: Student t test, *statistically significant, CVP: Central Venous Pressure, BP: Blood Pressure, MAP: Mean Arterial Pressure, mmHg: Millimeters of Mercury (unit of pressure), HR: Heart Rate, and POCUS: Point-of-Care Ultrasound.

Table (3): comparison of laboratory findings between studied groups at admission

Variables	Group 1 (POCUS group) N=50	Group 2 (Control group) N=50	Test of significance	*P value*
HB (gm/dl)	11.89±3.06	12.54±2.93	t=1.08	0.284
WBCS count (10^3/mm^3)	11.96±6.70	15.50±7.45	t=2.51	0.014*
Platelet count(10^3/mm^3)	285.78±54.39	242.24±53.98	t=4.02	<0.001*
ALT	46.26±4.78	46.5±8.39	t=0.146	0.884
AST	43.38±5.33	46.24±6.93	t=2.31	0.023*
INR	1.22±0.25	1.26±0.32	t=0.664	0.508
Albumin (gm/dl)	3.71±0.47	3.20±0.14	t=7.38	<0.001*
BUN	57.26±16.17	51.10±13.43	t=2.07	0.04*
Serum creatinine	1.07±0.19	1.07±0.19	t=0.201	0.841
Serum Na	135.78±2.82	136.86±3.17	t=1.79	0.08
Serum K	3.93±0.27	3.91±0.35	t=0.417	0.677
RBS (mg/dl)	101.88±13.98	100.24±14.32	t=0.579	0.564
PH	7.24±0.07	7.24±0.05	t=0.569	0.571
Pao2	72.92±2.64	72.32±3.05	t=1.05	0.296
Paco2	26.96±2.93	27.54±3.31	t=0.927	0.356
HCO3	10.70±2.98	12.0±2.86	t=2.22	0.029*
SAO2	92.80±1.26	92.92±1.45	t=0.441	0.660
Troponin (ng/ml)	0.20(0.01-3.0)	0.10(0.08-7.0)	Z=0.777	0.439
CK (units/l)	128.5(62-500)	123.5(58-430)	Z=0.838	0.402
Myoglobin (ng/ml)	76(24-432)	79(24-542)	Z=0.603	0.546
Pro calcitonin (ng/ml)	7.0(5.0-23.0)	19.0(5.0-26.0)	Z=2.84	0.004*
CRP (mg/dl)	151.71±20.06	150.93±22.51	t=0.183	0.855
D-dimer (ng/ml)	945.30±124.93	932.04±122.64	t=0.536	0.593

t:Student t test , z:Mann Whiteny U test *statistically significant, HB: Hemoglobin, WBCS: White Blood Cells, ALT: Alanine Aminotransferase, AST: Aspartate Aminotransferase, INR: International Normalized Ratio, BUN: Blood Urea Nitrogen, Na: Sodium, K: Potassium, RBS: Random Blood Sugar, pH: Potential Hydrogen (acidity/alkalinity level), PaO_2: Partial Pressure of Oxygen, $PaCO_2$: Partial Pressure of Carbon Dioxide, HCO_3: Bicarbonate, SaO_2: Oxygen Saturation, CK: Creatine Kinase, CRP: C-Reactive Protein.

Table (4): comparison of associated echocardiographic findings between studied groups

	Group 1 (POCUS group) N=50	Group 2 (Control group) N=50	Test of significance	*P- value*
	N(%)	N(%)		
Pleural effusion	5(10.0)	4(8.0)	χ^2=0.122	0.727
Pulmonary edema	4(8.0)	3(6.0)	χ^2=0.154	0.695
Pneumothorax	3(6.0)	1(2.0)	χ^{2FET}=0.104	0.307
Abdominal Aortic Aneurysm	1(2.0)	1(2.0)	χ^{2FET}=0.0	1.0
DVT	4(8.0)	0	χ^{2FET}=4.17	0.117
Pericardial effusion	2(4.0)	0	χ^{2FET}=2.04	0.495
RV strain	3(6.0)	0	χ^{2FET}=3.09	0.242

POCUS: Point-of-Care Ultrasound, DVT: Deep Vein Thrombosis, RV: Right Ventricular, χ^2: Chi-Square Test, FET: Fisher's Exact Test.

Table (5): comparison of outcome and time of final diagnosis between studied groups

	Group 1 (POCUS group) N=50	Group 2 (Control group) N=50	Test of significance	*P value*
Time of hospital discharge/Death (days)	12.06±2.39	16.96±2.39	t=10.22	<0.001*
Length of ICU stay(days)	6.02±1.25	7.56±1.80	t=4.95	<0.001*
amount of IV fluids used/Days (total liters)	9300(1000-16000)	11000(2000-19800)	Z=2.85	0.004*
Vasoinotropes used dosage (Nor adrenaline µg/min)	1.5(1-2.5)	3(2-3.3)	Z=1.564	0.08
Number of ventilated patients	5(10.0)	4(8.0)	χ^2=0.122	0.726
Mechanical Ventilation duration/Days	3(1-4)	4(2-5)	Z=4.02	<0.001*

	Group 1 (POCUS group) N=50	Group 2 (Control group) N=50	Test of significance	*P value*
	N(%)	N(%)		
Mortality rate	8(16.0)	11(22.0)	χ^2=0.585	0.444
Readmission rate	5(10.0)	7(14.0)	χ^2=0.379	0.760
Type of shock Cardiogenic Hypovolemic Obstructive septic	 15(30.0) 10(20.0) 4(8.0) 21(42.0)	 10(20.0) 7(14.0) 2(4.0) 31(62.0)	χ^{2MC}=4.12	0.249
CT used	10(20.0)	24(48.0)	χ^2=8.73	0.003*
Types of shock Non mixed Mixed	 18(36.0) 32(64.0)	 14(28.0) 36(72.0)	χ^2=0.735	0.521
Variables				
Time of final diagnosis (hours)	1.52±0.50 (1-2)	9.46±2.24 (6-12)	T=24.42	<0.001*

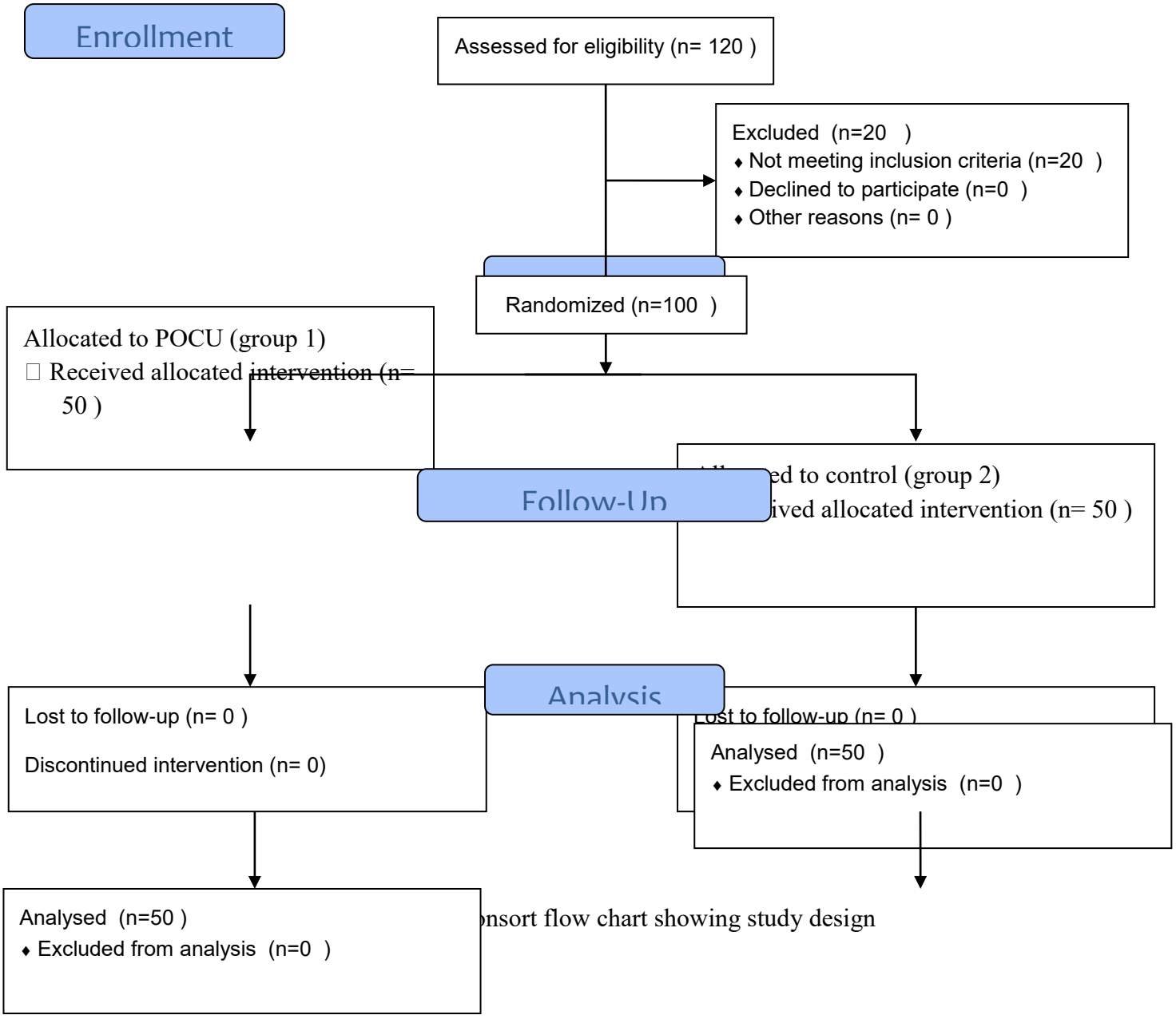
POCUS: Point-of-Care Ultrasound, ICU: Intensive Care Unit, IV: Intravenous, µg/min: Micrograms per Minute, CT: Computed Tomography, χ^2: Chi-Square Test, MC: Monte Carlo Test.

Table (6) validity of IVC Collapsibility index in differentiating alive from died cases

	AUC	Std. Error[a]	P value	Asymptotic 95% Confidence Interval		Cut off point	Sensitivity	Specificity
				Lower Bound	Upper Bound			
IVC Collapsibility index	.610	.083	.328	.447	.773	46.80	87.5%	35.7%

IVC: Inferior Vena Cava, AUC: Area under curve

Figure (1): Consort flow chart showing study design



nsort flow chart showing study design

DISCUSSION

The diagnostic precision in patients with undifferentiated shock strikingly raised from 60.6% to 85.0% following the application of structured point-of-care ultrasonography (POCUS) protocol; this directly impacted initial management in a case of 24% to 50% of cases. Accordingly, POCUS is also valuable for the prompt diagnosis of shock-inducing conditions, such as cardiac dysfunction and ruptured aortic aneurysm, and assessment of fluid status in shocked patients, as stated by Leroux et al. [13]. All these findings complement our findings and give more weight to structured POCUS protocols in improving shock management.

Despite its diagnostic benefits, no prospective studies have examined patient-centered outcomes, such as survival, for POCUS protocols in hypotensive emergency patients. However, Javali et al. [14] reported improved clinical outcomes with individual POCUS components, supporting our findings, though protocol-based approaches remain less studied.

The present study found no statistically significant differences between the groups' mean age, sex, BMI, GCS, APACHE score, and mean SOFA score. Similarly, A prospective and controlled study was conducted by Pontet et al. [15] on the effect of POCUS on resource use, diagnostic accuracy, and clinical management in medical-surgical intensive care units. Eighty patients were included: 40 in the POCUS group and 40 in the control group, randomized. Neither found any significant differences in baseline demographic characteristics in agreement with our findings, such as age, sex, APACHE II score, and admission diagnosis.

No significant difference was found between the POCUS Group and the control group regarding primary ICU admission causes, with shock and hypoxia being the most common (40% vs. 38%). However, group 1 showed significantly higher systolic, diastolic, and mean arterial blood pressure after 60 minutes and higher mean platelet count, albumin, and blood urea nitrogen levels. Atkinson et al. [16] similarly reported a higher mean pulse rate in group 1 but found no significant differences in systolic blood pressure, respiratory rate, or temperature, partially aligning with our findings. Likewise, Peach et al. [17] observed a higher pulse rate in group 1 with no significant differences in other hemodynamic parameters, supporting our results.

In our study, the mean time from hospital discharge to death was significantly longer in group 2 than in the POCUS group (16.96 vs. 12.06, $p<0.001$), and ICU length of stay was also longer in group 2 (7.56±1.80 vs. 6.02±1.25). Atkinson et al. [16] found no significant difference in ICU or hospital length of stay between groups, contrasting with our findings that POCUS intervention shortened ICU stay. Zieleskiewicz et al. [18] partially agreed, reporting a significantly shorter ICU stay in the POCUS group (3 days [IQR 2–7] vs. 5 days [IQR 3–10], $p=0.01$), supporting our results. However, they found no significant difference in hospital length of stay (16 days [IQR 9–25] vs. 16 days [IQR 9–28], $p=0.44$), which differs from our findings.

In our study, median IV fluid administration was significantly higher in group 2 than in group 1. Similarly, Zieleskiewicz et al. [19] conducted a multicentric, prospective, observational study. They found that a fluid bolus was given to only 31% of patients, aligning with our findings that POCUS-guided resuscitation may reduce fluid administration compared to standard approaches. Mechanical ventilation duration was also significantly longer in group 2. Pontet et al. [15] reported a comparable finding, showing a shorter duration of mechanical ventilation in the POCUS group (5.1±5.7 vs. 8.8±9.4 days, $p=0.03$), further supporting our results.

Among group 2, CT use was more frequent than in group 1 (48% vs. 20%). Likewise, as Pontet et al. [15] reported, the POCUS group used fewer resources in the first five days after hospitalization. These include fewer chest radiographies (2.6 ± 2.0 vs. 4.1 ± 3.5, $p = 0.01$), fewer extra ultrasound evaluations by Radiology specialists (0.6 ± 0.7 vs. 1.1 ± 0.7, p

= 0.002), and fewer CT investigations (0.5 ± 0.6 vs. 0.9 ± 0.7, p = 0.007), all of which are pretty much in good accord with those of the current study. It was contrary to our findings, as Atkinson et al. [16] found no significant difference in CT scan use between groups, as 36 of 137 patients in the POCUS group received CT compared with 32 of 134 in the control group.

Our study found no statistically significant relationship between mortality and shock type within each group. Similarly, Peach et al. [17] reported no significant association between shock type and mortality, supporting our findings. Additionally, Atkinson et al. [16] found no meaningful difference in survival rates between groups, with 76.5% (104 of 136) of POCUS group patients surviving compared to 76.1% (102 of 134) in the control group (difference 0.35%; 95% CI –10.2% to 11.0%), further aligning with our results.

In our study, the area under the curve (AUC) for the IVC collapsibility index was fair but not statistically significant in differentiating between alive and deceased cases. The best cutoff point detected was 46.8%, with a sensitivity of 87.5% and specificity of 35.7%. Additionally, mean INR was significantly higher in non-mixed shock cases than mixed shock cases in the POCUS group, while mean albumin levels were higher in non-mixed shock cases in the control group. Stickles et al. [20] reviewed the evidence that diagnostic accuracy improved from 45-60% to 80-89% when POCUS was combined with clinical information, corroborating our findings. The meta-analysis on the RUSH exam in undifferentiated shock revealed positive likelihood ratios (LR+) ranging from 8.2 to 40.5, the highest for obstructive shock and the lowest for mixed-etiology shock, thus providing further evidence in our findings.

Beyond the diagnosis, there was a reduced viable number of diagnostic etiologies as found by Jones et al. [21] through POCUS with a median of 4 in the POCUS arm versus 9 in the control arm ($p<0.001$), thus corroborating our findings of increased diagnostic efficiency with POCUS. As further demonstrated by Brunet and Chaplin [22], Ahn et al. [23], and Haydar et al. [24], POCUS has also augmented physicians' certainty in diagnosing such conditions as sepsis, chest pain, dyspnea, and symptomatic hypotension, further corroborating with our findings.

However, despite these diagnostic benefits, Atkinson et al. [16] found no significant difference in IV fluid volume administration or inotrope use between the POCUS and standard care groups. Their post hoc analysis also showed no treatment differences between cardiogenic and non-cardiogenic shock when POCUS was used, which does not align with our findings. Atkinson et al. [16] suggested that this lack of treatment impact might be due to the high prevalence of sepsis in their study population, where POCUS findings can be variable and less conclusive in early shock diagnosis.

The lack of treatment changes in Atkinson et al. [16] may be due to the limited number of POCUS-sensitive cases, as over half had sepsis, a condition with highly variable findings that complicate early diagnosis. Additionally, access to advanced imaging, physician expertise, and an unclear definition of undifferentiated shock may have influenced results. These factors could explain why they found no treatment differences between POCUS and standard care, contrasting our findings.

A randomized study by Pontet et al. [15] supports our findings, concluding that systematically applying a POCUS protocol upon ICU admission improves diagnostic and therapeutic decisions in critically ill patients. Their study suggests that POCUS enhances resource efficiency and reduces mechanical ventilation duration, aligning with our results. However, they emphasized the need for more extensive multicenter studies to confirm associations between ultrasound-driven fluid resuscitation and improved outcomes. Additionally, they highlighted diastolic function assessment as a key factor in fluid management for septic shock patients, which

was not directly evaluated in our study but could enhance POCUS-based strategies.

Similarly, Zieleskiewicz et al. [19] found that POCUS was used for diagnosis in 87% and procedural guidance in 13% of critically ill patients, with a diagnostic impact of 84% and a therapeutic impact of 69%. It confirmed or altered diagnoses in 63% and 21% of cases, respectively, and was applied across the heart (51%), lungs (17%), and brain (16%). POCUS also led to 373 therapeutic interventions, 73 discontinued treatments, and 108 avoided examinations. These findings align with ours, reinforcing POCUS as a valuable tool for improving clinical decision-making and patient management.

This study's single-center design and small sample size may limit generalizability and statistical power. The absence of long-term follow-up prevents assessing outcomes beyond ICU discharge, and the study did not fully evaluate fluid responsiveness or compare POCUS to advanced imaging modalities. Lastly, variability in the standard of care among clinicians may have influenced patient outcomes.

Conclusion

Implementing the POCUS protocol in the emergency ICU for adult patients with undifferentiated, non-traumatic hypotension or shock significantly improved patient outcomes. POCUS reduced mean hospital discharge time, ICU length of stay, and median IV fluid administration compared to the control group. In addition, POCUS decreased the costs of resources as it decreased rates of CT scans and amounts of IV fluids. However, it doesn't affect the mortality rate, ICU readmission rate, need for mechanical ventilation, and Vaso inotropes dosage used.

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Conflict of interest:

The authors declare that they have no conflicts of interest with respect to authorship or publication ofthis article .

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Supplementary Table (1): relationship between types of shock &demographic, vital signs and laboratory findings among POCUS group and Control group

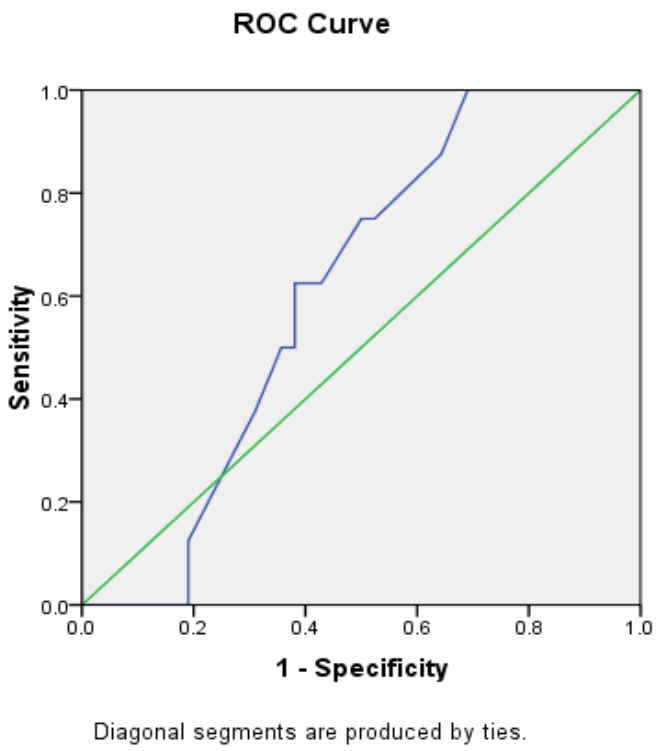
	Type of shock among POCUS group		Test of significance	P value
	Non mixed N=18(%)	Mixed N=32(%)		
Age/ years Mean±SD	51.61±7.47	53.81±6.88	t=1.05	p=0.298
Sex n(%) Female Male	 7(38.9) 11(61.1)	 17(53.2) 14(43.8)	χ^2=1.74	0.418
BMI(Kg/m^2)	25.57±2.34	24.94±2.16	t=0.951	p=0.346
GCS	10.56±1.09	10.41±1.13	t=0.453	p=0.653
Hypertension	5(27.8)	9(28.1)	χ^2=0.001	0.979
DM	9(50.0)	18(56.2)	χ^2=0.181	0.670
Smoking	3(16.7)	7(21.9)	χ^2=0.195	0.659
Dyslipidemia	10(55.6)	15(46.9)	χ^2=0.347	0.556
Chronic kidney disease	12(66.7)	14(43.8)	χ^2=2.42	0.119
Hepatic disorders	2(11.1)	5(15.6)	χ^2=0.195	0.659
Thyroid disorders	0 (0.0)	3(9.4)	χ^2=1.79	0.18
MAP (mm/Hg)	56.72±3.89	56.50±3.26	t=0.216	p=0.830
CVP	5.44±1.50	6.16±1.53	t=1.59	p=0.118

HR (b/min)	113.78±7.63	112.38±7.79	t=0.616	p=0.541
RR	20.33±3.53	21.06±2.88	t=0.791	p=0.433
Temperature	37.63±0.52	37.63±0.57	t=0.002	p=0.998
HB (gm/dl)	11.79±3.25	11.96±2.99	t=0.184	p=0.855
WBCS count (10^3/mm^3)	12.15±7.0	11.86±6.64	t=0.146	p=0.885
	Type of shock among POCUS group		Test of significance	P value
Platelet count(10^3/mm^3)	283.28±43.54	287.19±60.26	t=0.242	p=0.810
ALT	45.17±5.50	46.88±4.30	t=1.22	p=0.229
AST	43.89±5.81	43.09±5.11	t=0.503	p=0.617
INR	1.33±0.23	1.16±0.24	t=2.36	p=0.02*
Albumin (gm/dl)	3.76±0.48	3.68±0.47	t=0.552	p=0.584
BUN	56.0±14.99	57.97±16.98	t=0.410	p=0.684
Serum creatinine	1.12±0.19	1.05±0.19	t=1.29	p=0.204
Serum Na	136.06±2.98	135.63±2.77	t=0.514	p=0.610
Serum K	3.97±0.26	3.92±0.28	t=0.638	p=0.527
RBS (mg/dl)	100.28±14.16	102.78±14.03	t=0.604	p=0.549
PH	7.26±0.06	7.23±0.068	t=1.31	p=0.196
Pao2	72.56±2.47	73.13±2.74	t=0.728	p=0.470
Paco2	26.39±3.24	27.28±2.75	t=1.03	p=.307
HCO3	10.44±2.94	10.84±3.05	t=0.450	p=0.654
SAO2	92.44±1.15	93.0±1.29	t=1.51	p=0.137
Troponin	0.25 (0.08-3.0)	0.12(0.01-3.0)	Z=1.35	p=0.174
CK	142.5(62-500)	121(62-470)	Z=0.586	p=0.558
Myoglobin	82(24-432)	76(27-430)	Z=0.142	p=0.887
Pro calcitonin	3.0(2.0-17.0)	3.0(1.0-19.0)	Z=0.438	p=0.661
CRP	155.56±22.88	149.55±18.32	Z=1.02	p=.315
D-dimer	941.22±105.18	947.59±136.34	t=0.171	p=0.865
IVC collapsibility index	46.57±6.74	48.80±5.29	t=1.29	p=0.203
IVC distensibility index	17.96±3.03	18.96±2.38	t=1.29	p=0.288
	Type of shock among Control Group		Test of significance	P value
	Non mixed N=14	Mixed N=36		
Age/ years Mean±SD	56.0±5.33	53.97±4.90	t=1.28	p=0.206
Sex n(%) Female Male	5(35.7) 9(64.3)	13(36.1) 23(63.9)	χ^2=0.001	0.979
BMI(Kg/m^2)	24.99±2.77	25.22±2.47	t=0.278	p=0.782
GCS	10.71±1.38	10.94±1.29	t=0.557	p=0.580
Hypertension	2(14.3)	14(38.9)	χ^2=2.80	0.094
DM	5(35.7)	17(47.2)	χ^2=0.542	0.462

Smoking	2(14.3)	10(27.8)	χ^2=1.01	0.316
Dyslipidemia	6(42.9)	16(44.4)	χ^2=0.010	0.919
Chronic kidney disease	8(57.2)	16(44.4)	χ^2=0.651	0.419
Hepatic disorders	1(7.1)	3(8.3)	χ^2=0.019	1.0
Thyroid disorders	1(7.1)	1(2.8)	χ^2=0.500	0.786
	Type of shock among Control Group		**Test of significance**	**P value**
	Non mixed N=14	**Mixed N=36**		
MAP (mm/Hg)	57.71±4.68	57.03±3.87	t=0.531	p=0.598
CVP	4.64±1.22	4.97±1.34	t=0.799	p=0.428
HR (b/min)	116.86±10.08	117.25±8.63	t=0.138	p=0.891
RR	20.71±4.10	22.81±3.17	t=1.93	p=0.06
Temperature	37.63±0.61	37.67±0.48	t=0.249	p=0.8047
HB (gm/dl)	13.49±0.90	12.17±3.35	t=1.44	p=0.155
WBCS count (10^3/mm^3)	16.0±7.24	15.34±7.62	t=0.279	p=0.781
Platelet count(10^3/mm^3)	243.57±58.41	241.72±53.03	t=0.108	p=0.915
ALT	49.57±7.86	45.25±8.39	t=1.66	p=0.103
AST	46.36±6.42	46.19±7.21	t=0.074	p=0.942
INR	1.19±0.26	1.29±0.34	t=1.03	p=0.310
Albumin (gm/dl)	3.12±0.12	3.23±0.14	t=2.56	p=0.014*
BUN	51±14.89	51.14±13.05	t=0.032	p=0.974
Serum creatinine	1.08±0.18	1.06±0.21	t=0.278	p=0.782
Serum Na	136.43±3.01	137.03±3.26	t=0.596	p=0.554
Serum K	3.80±0.29	3.95±0.36	t=1.38	p=0.174
RBS (mg/dl)	101.57±14.67	99.72±14.36	t=0.407	p=0.686
PH	7.22±0.05	7.24±0.05	t=1.05	p=0.299
Pao2	72.21±3.12	72.36±3.07	t=0.151	p=0.881
Paco2	27.43±3.61	27.58±3.24	t=0.147	p=0.884
HCO3	11.14±2.91	12.33±2.82	t=1.33	p=0.190
SAO2	93.14±1.46	92.83±1.46	t=0.672	p=0.505
Troponin	**0.11 (0.08-5.0)**	**0.10 (0.08-7.0)**	**Z=0.723**	**p=0.470**
CK	106(75-430)	124(58-421)	Z=0.14	P=0.888
MYOGLOBIN	76.8(24-542)	80.5(26-432)	Z=0.303	p=0.762
Pro calcitonin	15.5(2-22)	15(1-22)	Z=0.49	p=0.639
CRP	148.95±21.89	151.70±23.0	t=0.385	p=0.702
D-dimer	927.86±123.36	933.67±124.08	t=0.149	p=0.882

BMI: Body Mass Index, GCS: Glasgow Coma Scale, DM: Diabetes Mellitus, MAP: Mean Arterial Pressure, CVP: Central Venous Pressure, HR: Heart Rate, RR: Respiratory Rate, HB: Hemoglobin, WBCS: White Blood Cell Count, ALT: Alanine Aminotransferase, AST: Aspartate Aminotransferase, INR: International Normalized Ratio, BUN: Blood Urea Nitrogen, RBS: Random Blood Sugar, PH: Potential of Hydrogen, PaO_2: Partial Pressure of Oxygen, $PaCO_2$: Partial Pressure of Carbon Dioxide, HCO_3: Bicarbonate, SaO_2: Arterial Oxygen Saturation, CK: Creatine Kinase, CRP: C-Reactive Protein, IVC: Inferior

Vena Cava, DVT: Deep Vein Thrombosis.t:Student t test , Z:Mann Whitney U test , $\chi 2$: Chi-Square test



Supplementary Figure (1): ROC curve of IVC collapsibility index in differentiating alive from died cases

Citation

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