ORIGINAL ARTICLE

Effect of use of Integrated Cardiac and Lung Ultrasound on the Clinical outcome of the Patients Admitted to ICU Suffering from Shock

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Abstract

Background: ***Ultrasound technology has become a cornerstone in medical imaging, employing high-frequency sound waves to visualize internal structures in real time. This non-invasive technique finds applications across various fields, most notably in emergency medicine through point-of-care ultrasound(POCUS).***

Aim and objectives: ***To assess the severity of cardiac and pulmonary problems in shock patients in order to direct their treatment and determine the likelihood of a positive result.***

Subjects and methods: ***From March 2022 through March 2024, 108 patients suffering from shock were enrolled in this randomized prospective case-control research at the intensive care units (ICUs) of the Cairo University Hospitals affiliated with the Faculty of Medicine, Al-Azhar. Patients who were shocked enough to participate in this trial were split evenly among two categories.***

Results: ***There were no discernible variations in APACHE II scores or cardiopulmonary ultrasonography measures between the categories. IVC diameter ranged from 0.65-2.71cm (mean 1.62±0.642cm), LUSS from 0-22cm (mean 11.94±7.183cm), MAPSE from 0.80-2.90cm (mean 1.34±0.655cm), and TAPSE from 1.10-2.60cm (mean 2.35±0.832cm). Group (A) had an APACHE II score of 21.80±6.725 and Group (B) had a score of 20.78±8.284, with a p-value of only 0.485. Nevertheless, with a p-value of just 0.035, Group-(A) required mechanical ventilation for a considerably longer period of time (81.82±38.827 hours) than Group-(B) (68.31±25.332 hours).***

Conclusion: ***A significant decline in the overall mortality rate among the ultrasound treated Group, contrasted with the control group. Integrated cardiopulmonary ultrasound resulted in shorter ICU stay and mechanical ventilation. Pearson's correlation coefficients between patient mortality and the diameter of IVC, LUSS, EPSS, and APACHE II showed a strong positive correlation between these variables and mortality.***

Keywords: Cardiopulmonary ultrasound; Clinical outcome; Shock

1. Introduction

Ultrasound technology has become a cornerstone in medical imaging, employing high-frequency sound waves to visualize internal structures in real time. This non-invasive technique finds applications across various fields, most notably in emergency medicine through point-of-care ultrasound(POCUS). POCUS allows healthcare providers to conduct immediate assessments at the patient's bedside, which is crucial for rapid diagnosis and clinical decision-making in acute care situations. The technology has evolved significantly since its initial development, with portable devices making ultrasound accessible in diverse settings, enhancing its utility in clinical practice.[1]

Image formation in ultrasound relies on the principles of reflection and refraction. When ultrasound waves encounter tissue boundaries, some are reflected back while others penetrate deeper, forming images based on the differential acoustic impedance of the tissues. This principle is vital in POCUS, where clinicians need to quickly identify conditions like fluid collections or organ abnormalities.[2]

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For contemporary intensivists, POCUS has become a vital tool. One of the most well-known uses of POCUS is in the evaluation of cardiorespiratory failure. Critical care echocardiography, a subdomain of POCUS, has been endorsed as a primary tool for assessing shock by the European Society of Intensive Care Medicine because of its ability to quickly and accurately inform management of the anatomical, hemodynamic, and non-cardiac causes of shock.[3]

Pulmonary artery dissection (PAD), pulmonary embolism (PE), and edema are only a few examples of the cardiopulmonary disorders that have benefited greatly from combined pulmonary and cardiac perfusion ultrasonography (POCUS).[4]

This study set out to assess the impact of targeted cardio-pulmonary ultrasound on the heart and lungs of shocked individuals, as well as how these circumstances affected the patients' prognoses.

2. Patients and methods

From March 2022 through March 2024, 108 patients at the intensive care units (ICUs) of the University Hospitals affiliated with the Faculty of Medicine Al-Azhar were the subjects of this randomized, prospective case-control study. Patients who were shocked enough to participate in this study were divided evenly among two categories: Group A: Standard treatment procedures (n=54) were used in this study; point-of-care cardio-pulmonary ultrasound scans were not used in this Group. Group B: Cardio-pulmonary ultrasound-guided management (n=54) was used in this Group.

Inclusion criteria:

All male and female patients admitted to the intensive care unit (ICU) within six hours after experiencing shock met one of the following shock inclusion criteria: hypotension (systolic blood pressure (BP)<90 mm Hg or mean arterial pressure (MAP)<60 mm Hg), a serum lactate level of 2 mmol/L or higher, and the presence of at least one of the following conditions: People who met the following criteria were included in the study: lactate level greater than 2 mmol/L, capillary refill time greater than 4.5 seconds, urine output per hour less than 0.5 ml/kg, clammy skin, cold limbs, unconsciousness, or the start of intravenous vasopressors.

Exclusion Criteria:

Those who have a history of trauma, those who are pregnant, those who have a mediastinal mass, those who are experiencing intracerebral hemorrhage, those who have an elevated intracranial pressure, those who have valvular heart disease, those who have atrial fibrillation, and those who either refused to participate or whose families did not want them to participate.

Procedures:

Dedicated investigators tracked individuals from the time they registered until they died or ended their intensive care unit stay. Emergency management, including vascular access, fluid resuscitation, and oxygen support, was administered to all patients in both groups. The intervention group utilized both clinical indicators and Doppler ultrasonography to guide each stage of fluid and vasoactive management, while the control group relied solely on clinical symptoms. The study included patients who fulfilled the prior requirements. The patient underwent an initial clinical evaluation and was promptly administered resuscitative measures (hydration, intravenous (IV)) in accordance with established medical guidelines. Every patient underwent a comprehensive evaluation that included a thorough history taking, all standard laboratory tests and investigations, and any necessary radiographic examinations.

Simultaneously, bedside sonographic examination equipment was arranged so that patients' first care was not interrupted. When necessary, the standard ventilatory settings were used.

Cardiopulmonary Ultrasound(CPUS):

The examination machine was a GE Versana Balance V2 ultrasound machine (Figure 1).

Figure 1. GE Versana Balance V2 ultrasound machine.

Within six hours after admission, patients were scheduled for echocardiogram (Echo) and lung ultrasonography (LUS) exams. Echocardiography offers five distinct views—the subcostal long axis view (SLAX), the subcostal inferior vena cava view (SIVC), the parasternal short axis view (PSAX), and the apical four chamber view (A4CH)—from which hemodynamic data can be explored and acquired. The dimensions of the inferior cava vein (IVC) and its distensibility index (dIVC) were measured during the echocardiography procedure.[5]

Following the worldwide evidence-based guidelines for point-of-care lung ultrasonography, an eight-zone LUS examination technique was employed to assess the pathophysiological alterations in the lungs of shock patients. The top and lower parts of the right and left lungs were identified inside the anterior lateral zones, which were delimited by the anterior axillary lines.

Finding consolidation/atelectasis, pleural effusion, A lines, B lines, lung sliding, and lung point all needed a LUS exam. The following criteria were used to score LUS patterns in each exam region: 0 points for the presence of lung sliding with A lines or fewer than two isolated B lines; 1-point for multiple, well-defined B lines (B1 lines); 2-points for multiple coalescent B lines (B2 lines); and 3-points for the presence of lung consolidation. The highest-scoring ultrasound patterns were recorded in each zone, and the total was computed using a maximum score of 24 (Figure 2).

Figure 2. Lung point, B lines.

Measuring TAPSE:

A correct apical four-chamber picture of the heart could only be achieved by positioning all patients in the left lateral decubitus posture. In order to create live B-mode and M-mode active tracings at the same time, an M-mode sampling spike was inserted at the right lateral border of the heart, specifically at the tricuspid valve annulus. The apex-to-base shortening, which is the TAPSE value, was determined by measuring the vertical height between the peak and trough in one cardiac cycle. Next, the patients were divided into three categories. Categories for TAPSE include those with a value of 16 mm or less, 16 mm to 20 mm, and 20 mm or more (Figure 3).

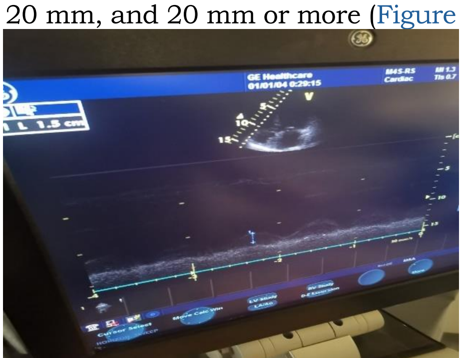

Figure 3. Measuring TAPSE.

Measuring MAPSE:

Typical perspectives were utilized in a 2D echocardiography assessment. The MAPSE measurement was conducted using the apical four-chamber mode. A straight line of systolic excursion was located and studied from the mitral valve's lateral annulus to the left ventricle's apex, with the M-mode cursor positioned parallel to the left ventricle's lateral wall. The waveform was examined on the M-mode picture, and the millimeter-scale vertical distance between the peak and nadir was measured.

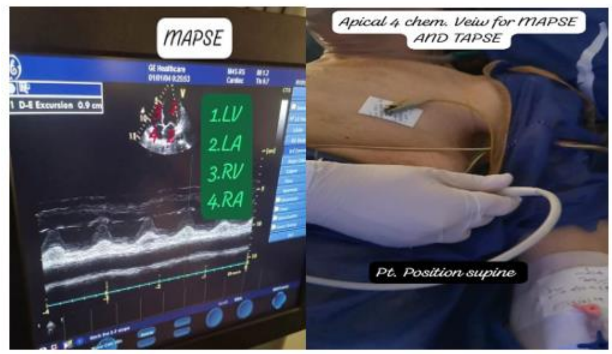

Figure 4. Measuring MAPSE.

Measuring EPSS:

The researchers took M-mode EPSS measurements using a distinct parasternal long-axis perspective. The shortest distance (in millimeters) between the interventricular septum and the tip of the anterior mitral valve leaflet was measured in early diastole.

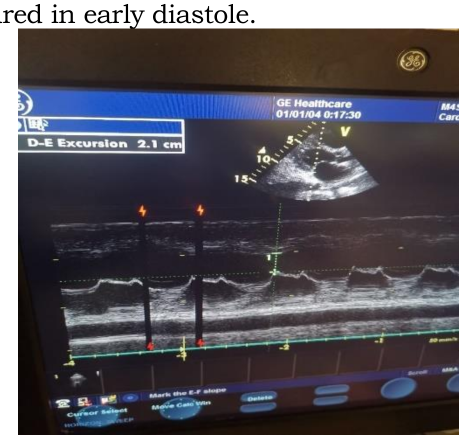

Figure 5. Measuring EPSS.

Measuring IVC:

When determining volume status or responsiveness, the dIVC, or diameter and distensibility index, of the inferior vena cava was used. A 2-5 Hz ultrasonic curvilinear low-frequency probe was used to measure the inferior vena cava distensibility index (IVC-DI). A measure of the IVC's pliability, the IVC distensibility index is defined as the ratio of its inner diameter to its outer diameter divided by its minimum diameter during expiration.

In this long-axis subcostal four-chamber image, the inside diameter of the right ventricle was measured at the end of expiration, 2 cm from the right atrial junction. Hypovolemia was indicated if the dIVC was greater than 18% or if the IVC diameter was smaller than 1 cm. When the dIVC is less than 18% and the IVC diameter is between 1 and 2 cm, it signifies hypervolume.

Figure 6. Measuring IVC.

Primary Outcome:

Mortality rate (estimated as the total number of deaths that occurred during initial fluid resuscitation), time of death relative to randomization, number of deaths overall, number of subjects who did not survive, and group comparison.

Secondary Outcome:

Total fluid intake, total inotropic support, shock time, length of ICU stay, and the incidence of acute kidney injury(AKI).

Administrative and Ethical Design:

The Al-Azhar University Faculty of Medicine officially gave its consent. The intensive care units at the university hospitals of Al-Azhar gave their formal approval. The Institutional Review Board (IRB) has given its clearance to the study. Before any patient or eligible relative could be included in this study, they were asked to provide written informed consent.

Statistical analysis:

We used the IBM SPSS software package version 20.0 to analyze the data that was fed into the computer. (New York, USA: IBM Corporation) Numbers and percentages were used to describe the qualitative data. To ensure distribution normality, the Kolmogorov-Smirnov test was employed. Standard deviation, mean, and range (minimum and maximum) were used to characterize quantitative data. We used a 5% level of significance to evaluate the results.

For categorical data, the chi-square test or Fisher's exact test can be used to compare distinct groups. When comparing two groups, the Student's t-test is useful for typically quantitative variables. The Mann-Whitney test is used to compare two groups when dealing with non-quantitative variables. To analyze the link between two continuous variables, we computed the Pearson or Spearman correlation coefficients and used p-values to test for significance. The log-rank test was performed to evaluate the survival distributions between groups, and the Kaplan-Meier method was utilized to estimate the odds of surviving over time.

3. Results

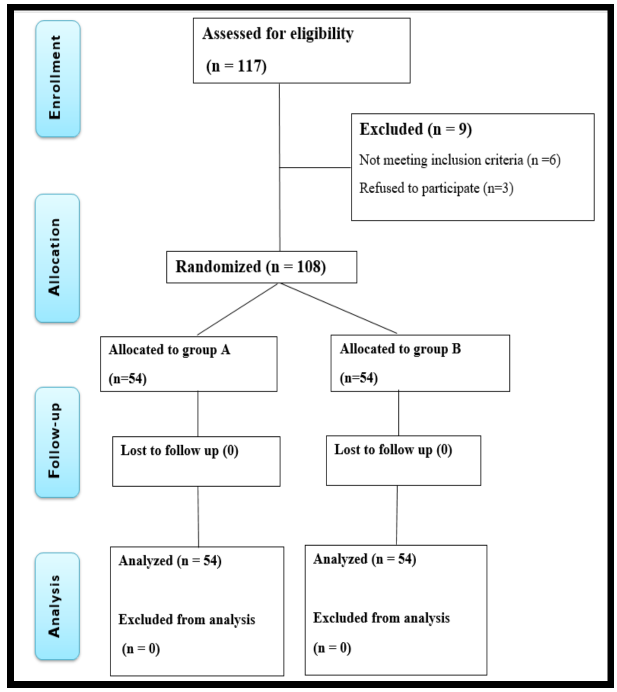

Figure 6. Flow diagram of studied patient.

When comparing the groups according to age, no statistically significant variations were found (P=0.861),(Table 1;Figure 7).

Table 1. Considering the age of the patients, we compare two groups.

AGE	GROUP-(A) (N=54)	GROUP-(B) (N=54)	T VALUE	P-VALUE
MIN-MAX.	31-82	32-80	0.481	0.632
MEAN±SD	56.72±11.153	55.57±13.552		

t:Student t-test

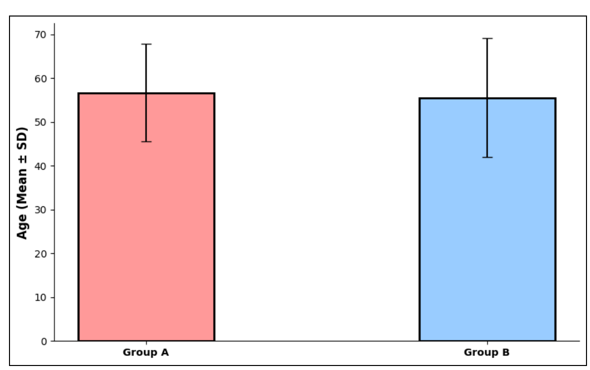

Figure 7. Evaluation of two groups based on the average age of their patients.

There were no statistically significant variations among Group-(A) and Group-(B) with respect to the initial PaCO2 and PaO2/FiO2,(Table 2).

Table 2. Evaluation of two groups with respect to the PaCO2 and PaO2/FiO2 levels of patients.

	GROUP-(A) (N=54)	GROUP-(B) (N=54)	T-VALUE	P-VALUE
$PACO_2$				
MIN-MAX	31.60-47.20	28.1-42.4	0.63	0.086
MEAN±SD	38.76±4.429	35.63±3.984		
PAO_2/FIO_2				
MIN-MAX	115.9-222.2	129.9-240.40	1.650	0.102
MEAN±SD	173.94±31.636	184.61±35.482		

t:Student t-test

On the basis of the first modified APACHE II score, no statistically significant variations were found between Group-(A) and Group-(B), (Table 3;Figure 8).

Table 3. Two groups are compared based on the patients' initial adjusted APACHE II scores.

MODIFIED APACHE II SCORE	GROUP-(A) (N=54)	GROUP-(B) (N=54)	T-VALUE	P-VALUE
MIN-MAX	9-38	4-38	0.701	0.485
MEAN±SD	21.80±6.725	20.78±8.284		

t:T-Student test; *:Statistically significant at P <0.05

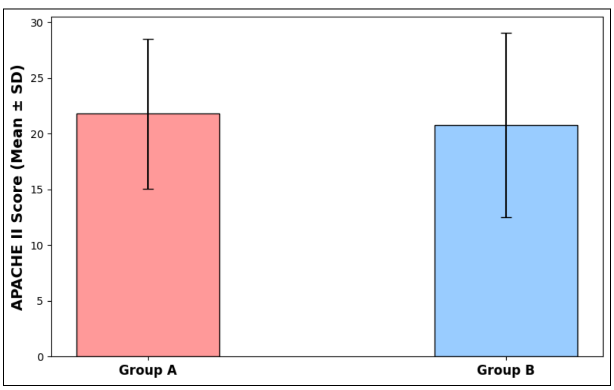

Figure 8. Patients' APACHE II scores were used to compare the two groups.

The heart rate decreased progressively in both groups, but Group-B showed a significantly lower heart rate from day-2 onward, with statistically significant differences on multiple days. Group-A consistently maintained higher heart rates, particularly on day-14, where Group-A had significantly higher heart rates than Group-B(p<0.001),(Table 4;Figure 9).

Table 4. Heart rate follow-up in study groups.

TIME INTERVAL	GROUP-A (N=54)	GROUP-B (N=54)	T-VALUE	P-VALUE
DAY-1	123.65±5.20	123.72±2.52	0.832	0.274
DAY-2	120.30±5.23	122.20±3.97	2.127	0.036*
DAY-3	117.16±5.12	117.33±5.01	0.169	0.866
DAY-4	113.93±5.28	112.44±5.78	1.399	0.165
DAY-5	110.47±5.50	107.82±5.96	2.402	0.018*
DAY-6	107.63±5.95	103.11±6.75	3.686	0.001*
DAY-7	105.42±6.55	99.14±7.19	4.746	0.001*
DAY-8	102.97±6.51	95.33±7.09	5.833	0.001*
DAY-9	100.64±6.80	90.73±6.97	7.480	0.001*
DAY-10	97.91±6.68	87.49±7.28	7.756	0.001*
DAY-11	95.43±6.83	83.65±7.42	6.581	0.001*
DAY-12	92.81±6.73	80.32±8.21	6.550	0.001*
DAY-13	90.57±6.43	76.75±7.37	7.410	0.001*
DAY-14	87.80±6.44	74.09±7.31	10.340	0.001*

t:Student t-test, *:for significant p-value(<0.05)

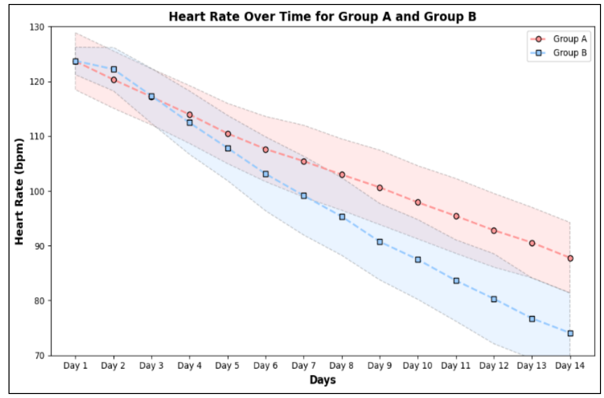

Figure 9. Heart rate follow-up in study groups.

APACHE II scores, were initially similar between Group-A and Group-B, with a slightly higher but non-significant difference in Group-A on day-1(p=0.057). However, from day-2 onward, Group-B showed significantly lower APACHE II scores(p<0.001), reflecting better clinical outcomes and less severe illness progression compared to Group-A. By day-14, Group-B had notably lower APACHE II scores, indicating a faster and more pronounced improvement in their condition, (Table 5;Figure 10).

Table 5. APACHE II Score follow-up in study groups.

TIME INTERVAL	GROUP-A (N=54)	GROUP-B (N=54)	U-VALUE	P-VALUE
DAY-1	21.57±3.05	20.41±3.66	1.905	0.057
DAY-2	19.72±2.70	18.36±3.52	2.255	0.026*
DAY-3	18.29±2.69	16.34±3.19	3.440	0.001*
DAY-4	16.75±2.76	14.44±2.97	4.187	0.001*
DAY-5	15.18±2.67	13.11±2.90	3.576	0.001*
DAY-6	14.00±2.78	11.83±2.88	3.730	0.001*
DAY-7	12.90±2.74	10.67±2.58	4.342	0.001*
DAY-8	11.87±2.50	9.52±2.29	5.078	0.001*
DAY-9	10.82±2.29	8.65±2.08	5.159	0.001*
DAY-10	9.97±2.05	7.71±1.94	5.211	0.001*
DAY-11	9.13±2.01	7.07±1.81	5.167	0.001*
DAY-12	8.25±1.86	6.38±1.63	5.112	0.001*
DAY-13	7.66±1.76	5.67±1.51	5.641	0.001*
DAY-14	7.05±1.66	5.13±1.38	5.936	0.001*

U:Mann whitney test, *:for significant p-value(<0.05).

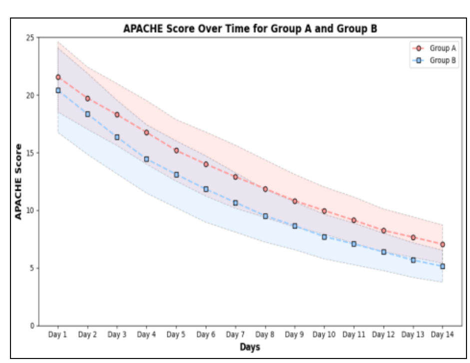

Figure 10. APACHE II Score follow-up in study groups.

The time of mechanical ventilation was significantly shorter in Group (B) compared to Group (A), with a p-value of only 0.035 indicating statistical significance,(Table 6;Figure 11).

Table 6. Comparison between two groups as regard to patient's duration of mechanical ventilation.

DURATION OF MECHANICAL VENTILATION	GROUP-(A) (N=54)	GROUP-(B) (N=54)	T-VALUE	P-VALUE
MIN-MAX	19-150	26-117	2.140	0.035*
MEAN±SD	81.8±38.8	68.31±25.332		

t:T-Student test; *:Statistically significant at P <0.05

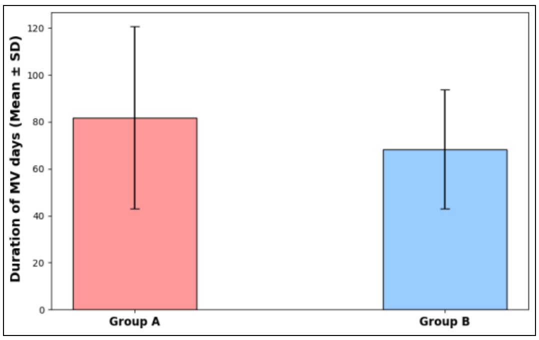

Figure 11. Examining the two groups in relation to the amount of time that patients required mechanical ventilation.

There were statistical significant differences between Group-(A) and Group-(B) with a p-value of only 0.027 when it came to the total mortality rate of patients. Group-(A) had a substantially lower rate. Group-B had a lower total mortality rate during the intensive care unit stay (55.4% vs. 35.6%, respectively), which is in line with these results; the difference between the two groups was statistically significant (P=0.015), (Table 7; Figure 12).

Table 7. The overall death rate of patients in two groups compared.

OVERALL MORTALITY RATE	GROUP-(A) (N=54)		GROUP-(B) (N=54)		X2 VALUE	P-VALUE
	No.	%	No.	%		
SURVIVOR	29	35.6	40	55.4	4.856	0.027*
NON-SURVIVOR	25	46.3	14	25.9		

X2:Chi-square test; *:Statistically significant at P

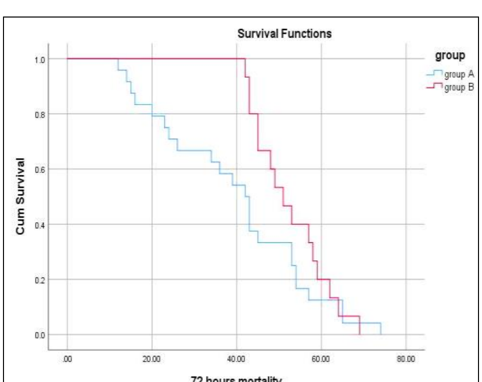

Figure 12. Kaplan Meier estimate of overall of mortality among 2-groups.

4. Discussion

Group A had a much higher overall mortality rate than group B (P=0.027), according to this study. According to these numbers, there were statistically significant variations between Group A and Group B in terms of total mortality throughout the intensive care unit stay (55.4% vs. 35.6%, respectively; P=0.015).

According to the results of this study, there is a strong positive correlation between patient mortality and the following ultrasound variables: APACHE II score, LUSS, EPSS, HR, and MAP. Additionally, there is a correlation between APACHE II score, serum lactate, APACHE II score, and EPSS.

In consistent with the current study results, Zou et al.[6] included 122 patients who were shocked out of a total of 181. Univariate correlation analysis was used to assess the status of the ultrasonic variables volume, RV, and LV systolic function, as well as the LUSS score. The results showed that MAPSE, LUSS, aberrant volume status, and LV systolic dysfunction were associated with overall mortality (p=0.032, 0.001, 0.038, and 0.011, respectively). Our results are in line with this study's emphasis on a 44.8% death rate after 28 days.

No statistically significant variations were found between the groups in this investigation with respect to age or sex (P=0.861 and P=0.846, respectively).

Consistent with the found findings, Zou et al.,[6] They set out to examine the features of ultrasonic hemodynamic patterns and their correlation with outcomes in order to further and expand our understanding of these patterns. With an average age of 58.2±18.0 years, they discovered that out of 181 shock patients, 113 were men and 68 were women.

Also, Sekiguchi et al.[7] We sought to study the actual effects of focused cardiac ultrasound (FCU) in the treatment of sepsis and septic shock following early (6-hour) resuscitation. Sixteen (or 60%) of the thirty patients who required CPR due to severe sepsis or septic shock were men, with a median age of sixty-one years and an interquartile range (IQR) of fifty to seventy-one years.

There were not any statistically significant variations among Group-(A) and Group-(B) in terms of PaCO2 and PaO2/FiO2 levels in the present investigation.

Consistent with the findings of the present investigation, Yin et al.[8] they reported that of 175-shocked patients with a completed lung ultrasound exam, PaO2/FiO2 was 185.0(125.0-265.0) with range of 44.0–620.0.

Also, Li et al.,[9] they revealed that in patients in the ICUS group and patients in the CON group, respectively, the PaCO2 was 34.0(28.0–42.5) and 39.0(31.3–47.5), PaO2/FiO2 was 190.0(126.7–

241.3) and 170.0(115.00–225.8). There were no statistically significant differences between the two groups.

As well, Zou et al.,[6] Out of 181 individuals who had shock, the PaO2/FiO2 ratio varied between 44 and 620, with values ranging from 124.9 to 266.2.

Based on the results of the present research, groups A and B had initial APACHE II scores ranging from 9 to 38, with a mean±S.D. of 21.80±6.725 and a range of 4-38, respectively, and a mean±S.D. of 20.78±8.284. At a significance level of P=0.485, no differences were found between the groups.

In supporting our results, Yin et al.,[8] They found that 175 individuals who had undergone a lung ultrasonography and were in shock were included. An average APACHE II score of 23.7±8.8 was detected.

Also, Zou et al.,[6] From a sample of 181 shock patients, the mean APACHE II score ranged from 2 to 50, with a standard deviation of 8.7.

As well, Wang et al.,[10] 128 intensive care unit individuals suffering from acute pulmonary edema were arbitrarily assigned to one of two groups: one Group was given standard treatment in addition to cardiopulmonary sonography, while the other Group received standard treatment alone. The researchers found that the average APACHE II score in the sonography group (n=66) was 14.68±2.23. As compared to the control group (n=62), the APACHE II score was 15.05±2.64. When comparing the two groups, no statistically significant variations were found (P=0.398).

The current study found that Group-(A) had a somewhat greater but non-significant difference in APACHE II scores on day-1 (p=0.057), and that Group-(B) and Group-(A) had similar scores from the beginning. Nevertheless, Group-(B) exhibited noticeably reduced APACHE II scores (p<0.001) beginning on day 2, indicating improved clinical outcomes and less severe illness progression in comparison to Group-(A). Group (B) showed a marked improvement in their condition by day 14, with significantly lower APACHE II scores.

Consistent with the findings of the present investigation, Tian et al.,[11] The results showed that the APACHE II score on day 3 is the best biomarker for predicting the outcomes of intensive care unit patients, and that a score of 17 is the appropriate threshold for identifying patients at high risk of death.

4. Conclusion

A significant decline in overall mortality rate among ultrasound treated Group, contrasted with the control group. Integrated cardiopulmonary ultrasound resulted in shorter ICU stay and mechanical ventilation. Pearson's correlation coefficients between patient mortality and diameter of IVC, LUSS, EPSS, and APACHE II showed a strong positive correlation between these variables and mortality.

Disclosure

The authors have no financial interest to declare in relation to the content of this article.

Authorship

All authors have a substantial contribution to the article

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Conflicts of interest

There are no conflicts of interest.

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