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Combined Lung Ultrasound, Inferior Vena Cava Collapsibility Index and Routine Echocardiography in Detecting and Identifying Type of Shock

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ORIGINAL ARTICLE

Combined Lung Ultrasound, Inferior Vena Cava Collapsibility Index and Routine Echocardiography in Detecting and Identifying Type of Shock

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Abstract

Background: ***Identifying the type of shock is crucial in the field of critical care medicine and emergency medicine; in many cases, the cause of shock is not easily detected. The emergence of non-invasive imaging may help detect the cause of shock and, thus, facilitate early management.***

Aim and objectives: ***to evaluate the sensitivity and specificity of combined lung ultrasonography, IVC collapsibility index, and routine echocardiography in identifying the type of shock.***

Patients and methods: ***This study is a prospective cross-sectional correlative study. Sixty (60) patients in shock state were included and recruited from the Intensive Care Unit and Emergency Department of Al-Azhar University Hospitals and Kasr Al-Ainy Hospital from December 2022 to December 2023. The following echocardiography/ultrasound parameters were recorded: Left ventricle systolic function by M mode, Left ventricle outflow tract Velocity Time Integral (LVOT VTI), signs of pulmonary embolism, signs of cardiac tamponade, valves to identify the presence of masses, IVC diameter, collapsibility index, focused assessment with sonography in trauma (FAST) exam and lung ultrasonography to identify pneumonia, pulmonary edema, pleural effusion, and pneumothorax.***

Result: ***The integrated point-of-care ultrasound approach had good sensitivity (84.7-100%), specificity (90.2-100%), and accuracy (89.3-100%) for differentiating between major shock categories, including distributive, cardiogenic, hypovolemic, obstructive, and mixed distributive-cardiogenic shock.***

Conclusion: ***This study demonstrates that an integrated point-of-care ultrasound incorporating lung ultrasound, inferior vena cava collapsibility metrics, and echocardiography provides a valuable tool for enhancing the rapidity and reliability of detecting shock and distinguishing between specific shock etiologies.***

Keywords: Lung Ultrasound; Echocardiography; Shock; Collapsibility Index

1. Introduction

Shock is a critical condition associated with high mortality and morbidity rates. Early recognition and appropriate management of the type of shock are crucial for improving patient outcomes. The ability to rapidly and accurately identify the type of shock can guide treatment decisions and optimize patient care.[1]

Shock can have various etiologies, including hypovolemic, distributive, cardiogenic, and obstructive shock. Each type requires a different treatment approach. Misdiagnosis or delayed diagnosis can lead to ineffective treatment and worsen patient outcomes.[2]

Ultrasound and echocardiography are powerful tools for identifying shock etiology when the clinical picture overlaps.[3]

Lung ultrasound, inferior vena cava collapsibility index, and routine echocardiography are non-invasive diagnostic tools that can provide valuable information about the patient's hemodynamic status. They are readily available at the bedside and can be performed quickly, making them attractive for use in the emergency department and critical care settings.[4]

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Each of these diagnostic tools offers unique insights into the patient's condition. Lung ultrasound can differentiate noncardiogenic from cardiogenic pulmonary edema, which can be indicative of cardiogenic shock.[5]

The inferior vena cava collapsibility index can provide information about intravascular volume status. Routine echocardiography can assess cardiac function, dimensions, and cardiac valves and calculate some important indices that can help us detect types of shock, like left ventricle outflow tract velocity time integral. Combining these modalities may offer a more comprehensive view of the patient's condition.[6]

Timely and appropriate interventions based on accurate diagnoses can potentially reduce complications and mortality rates associated with shock.[7]

The present study based on Echo-US protocol in types of shock as shown in Table 1

Table 1. Results of the Echo-US protocol in each category of shock.[8]

Type	Distributive	Hypovolemic	Cardiogenic	Obstructive	Mixed distributive cardiogenic
LVOT VTI	≥ 18 cm	<18	<18	<18	Variable
IVC diameter	Small	Small	Large	Large	Variable
IVC-CI	CI≥50 %	CI≥50 %	CI<50%	CI <50 %	
Signs of Pulmonary embolism	NO	NO	NO	YES	NO
Valves	Vegetation	Normal	Stenosis/ Regurgitation	TR in PE	Stenosis /Regurgitation
Signs of cardiac Tamponade	NO	NO	NO	YES	NO
FAST	FAST Positive/ Negative	Positive/ Negative	Positive/ Negative	Negative	Positive/ Negative
Lung U/S Pneumothorax	NO	NO	NO	YES	NO
Pneumonia	YES	NO	NO	NO	YES
Pulmonary edema	NO	NO	YES	NO	YES/NO
Pleural effusion	Present/ absent	Absent	Present/ Absent	Absent	Present/Absent

As regard to the velocity time integral in the LVOT, values < 18 cm are typically seen in hypovolemic, cardiogenic and obstructive shock. Regarding to IVC diameter, Large IVC size >2.1 cm correlates with cardiogenic shock. And signs of right heart strain like pulmonary embolism, elevated TR gradient, RV dilation are typical hallmarks of obstructive shock.

The aim of this study is to evaluate the sensitivity and specificity of combined lung ultrasound, IVC collapsibility index and routine echocardiography in detecting and identifying type of shock.

2. Patients and methods

This study is a prospective cross-sectional correlative study. Sixty (60) patients in shock state were included and recruited from the Intensive Care Unit and Emergency Department of Al-Azhar University Hospitals and Kasr Al-Ainy Hospital from December 2022 to December 2023. "The most common clinical features/labs which are suggestive of shock include hypotension, tachycardia, tachypnea, obtundation or abnormal mental status, cold, clammy extremities, mottled skin, oliguria, metabolic acidosis, and hyperlactatemia."[9] The Local Ethics Committee approved the study protocol, and informed written consents were obtained from the patients or their responsible relatives.

2.1.Sample size calculation:

This research is based on work done by Mohammed et al.[10] The following presumptions were taken into account when calculating the sample size using Epi Info STATCALC: odds ratio computed = 1.115 with a two-sided confidence level of -95%, a power of 80%, and an error of 5%. The Epi-Info output's final maximum number of samples was 60.

2.2.Inclusion criteria: Age > 18 years old, both genders and patients with shock,

Exclusion criteria: Patients younger than 18 years, patients with severe orthopnea or who are unable to lie supine, mechanically ventilated patients, morbidly obese patients, and pregnant.

2.3.Methods:

The patients and their basic clinical data, including age and sex of patients, vital data like systolic and diastolic blood pressure, mean arterial pressure, heart rate, respiratory rate, body temperature, and laboratory data, including arterial blood gases and lactate level, were recorded when the patient arrived at ER in addition to the history of course that may help us to detect the cause of shock. Then, all the ultrasonographic examinations were performed with the patients in the supine position. A 2.8–4 MHz phased array probe and an ultrasound device with both a high-frequency linear probe (5–10 MHz) and a curvilinear probe (2–5 MHz) were used to perform echocardiography. The machine used in this study was "ACUSON NX2 -Siemens Medical Solutions -USA " The US exam proceeded without any delays in patient treatment.

The following echocardiography/ultrasound parameters were recorded: Left ventricle systolic function by M mode, Left ventricle outflow tract Velocity Time Integral (LVOT VTI), signs of pulmonary embolism, signs of cardiac tamponade, valves to identify the presence of masses, IVC size, and collapsibility index were recorded.

The following formula was used to calculate the IVC collapsibility index (IVC CI), which is the proportion of the distinction between the expiratory IVC diameter(eIVCD) and inspiratory IVC diameter(iIVCD) split by the eIVCD: CI of IVC = [(eIVCD-iIVCD)/eIVCD]×100.[11] The focused assessment with sonography in trauma (FAST) exam stands for focused evaluation using sonography for trauma. Lung ultrasonography to identify pneumonia, pulmonary edema, pleural effusion, and pneumothorax.

Based on the data collected, a provisional diagnosis of shock type was made using all of these data based on Echo-US protocol, as shown in Table 1; throughout their hospital stay, every patient was monitored to record their definitive diagnosis, then correlation between provisional and definitive diagnosis was done.

2.4.Statistical analysis:

Using the SPSS software (Version 25) for Windows, the gathered data were coded, processed, and examined. That means standard deviations, medians, average ranges, and percentages were calculated using descriptive statistics. Independent t-tests will be used for continuous variables to compare the means of regularly distributed data, chi-square tests for categorical data, and Mann-Whitney U tests for comparing the median differences of non-normally distributed data. For dependent groups, the Wilcoxon and t-tests will be employed. Statistical significance is defined as a p-value of less than 0.05.

3. Results

Table 2. Demographic and clinical data of the studied group.

Variables	Values
Age (years)	53.7 ± 19.2
Sex	Female (40%) Male (60%)
Vital signs	
Systolic Blood Pressure(mmHg)	72.2±8
Diastolic Blood Pressure(mmHg)	37.4±8.1
Heart Rate(bpm)	118±23.1
Respiratory Rate	28.7±7.4
Temperature ̊ C	37.6±0.7
Mean Arterial Pressure(mmHg)	48.98±8.08
ABG (arterial blood gases)	
pH	7.3±0.2
PCO2(mmHg)	32.1±11.2
HCO3(mmol/L)	13.9±5
Lactate(mmol/L)	14.5±9.5

The mean age was 53.7 years. Sixty percent were males and 40% were females. Regarding vital signs, the mean systolic blood pressure was 72.2 mmHg, diastolic blood pressure was 37.4 mmHg, the individual's heart rate was 118 pulses per minute, respiration rate was 28.7 breaths per minute, and mean arterial pressure was 48.98 mmHg, and temperature was 37.6 degrees Celsius. Arterial blood gas analysis demonstrates metabolic acidosis in this patient population, with a mean pH of 7.3, PCO2 of 32.1 mmHg, serum bicarbonate concentration of 13.9 mmol/L, and serum lactate of 14.5 mmol/L.

Table 3. Findings of echocardiography and ultrasonography in the studied cases.

PARAMETER	FINDINGS (NUMBERS OF CASES)	FINDINGS (PERCENTAGE)
LVOT VTI	• < 18 cm: (28) • ≥18 cm : (32)	• < 18 cm: (47.67%) • ≥ 18 cm: (52.33%)
LV SYSTOLIC FUNCTION (EF BY M MODE)	• Normal: (41) • Reduced : (19)	• Normal: (68.67%) • Reduced:(31.33%)
IVC MAXIMAL DIAMETER	• <1.5 cm: (29) • 1.5–2.1 cm: (12) • >2.1 cm: (19)	• <1.5 cm:(48.33%) • 1.5–2.1 cm: (20 %) • >2.1 cm: (31.67%)
IVC-CI	• IVCCI ≥ 50 %:(31) • IVCCI < 50 %: (29)	• IVCCI ≥ 50 %:(53.33%) • IVCCI < 50 %: (46.67%)
MASS ON ONE OF MAJOR VALVES (VEGETATION)	• Present:(2) • Absent:(58)	• Present:(3.3%) • Absent:(96.7%)
SIGNS OF CARDIAC TAMPONADE IN ECHOCARDIOGRAPHY	• Present: (1) • Absent: (59)	• Present:(1.66 %) • Absent: (98.33%)
SIGNS OF PULMONARY EMBOLISM IN ECHOCARDIOGRAPHY	• Present:(2) • Absent:(58)	• Present: (3.33%) • Absent: (96.67%)
FAST	• Positive: (16) • Negative: (44)	• Positive: (26%) • Negative: (74%)
SIGNS OF PNEUMOTHORAX (ABSENCE OF PLEURAL SLIDING	• Present: (1)	• Present:(1.66 %) • Absent: (98.33%)

AND PRESENCE OF A LINE BY LUNG US)	• Absent: (59)	
SIGNS OF PNEUMONIA (PRESENCE OF CONSOLIDATION IN LUNG US)	• Present:(19) • Absent:(41)	• Present:(33.33%) • Absent:(66.33%)
SIGNS OF PULMONARY EDEMA (PRESENCE OF B PROFILE IN LUNG US)	• Present:(8) • • Absent:(52)	• Present:(14%) • • Absent:(86%)
PLEURAL EFFUSION	• Present:(12) • Absent:(48)	• Present:(20.67%) • Absent:(79.33%)

This table shows that all cases underwent LVOT VTI assessment, among which 47.67% had reduced VTI < 18 cm. Almost a (31.33%) of patients were found to have impaired LV systolic dysfunction. All patients underwent evaluation of IVC size and indices of collapsibility. (48.33%) had IVC size <1.5 cm correlating with hypovolemia, while 31.67% had significantly dilated IVC >2.1 cm correlating with volume overload in cardiac failure. Reduced collapsibility index <50 % was seen in (46.67%) of cases. Infective endocarditis, cardiac tamponade and pulmonary embolism were rare, each occurring only in about 2% of the study. Pneumonia was a common finding on lung ultrasound, seen in 33.33% of patients. 14% had evidence of pulmonary edema on lung ultrasound.

Table 4. Provisional versus definitive diagnosis of shock for all types of shock.

TYPES OF SHOCK	DISTRIBUTIVE	CARDIOGENIC	HYPOVOLEMIC	OBSTRUCTIVE	MIXED DISTRIBUTIVE CARDIOGENIC	PROVISIONAL DIAGNOSIS OF SHOCK
DISTRIBUTIVE	59.2%	0%	0%	0%	0%	59.2%
CARDIOGENIC	1.5%	8.5%	0%	0%	1.5%	11.5%
HYPOVOLEMIC	9.3%	0%	8.7%	0%	0%	18%
OBSTRUCTIVE	0%	0%	0%	2.8%	0%	2.8%
MIXED DISTRIBUTIVE CARDIOGENIC	0%	0%	0%	0%	8.5%	8.5%
DEFINITIVE DIAGNOSIS OF SHOCK	70%	8.5%	8.7%	2.8%	10%	

This table demonstrates provisional diagnosis of shock type using the combined echo-ultrasound. 59.2% of patients clinically classified as distributive shock were accurately diagnosed. For the 8.5% of patients provisionally diagnosed with cardiogenic shock, 100% concordance was there with the final diagnosis

Table 5. The Echo-US diagnostic test parameters for every type of shock.

TYPE	DISTRIBUTIVE	CARDIOGENIC	HYPOVOLEMIC	OBSTRUCTIVE	MIXED DISTRIBUTIVE CARDIOGENIC
SENSITIVITY	84.69%	100%	100%	100%	85.71%
SPECIFICITY	100%	96.88%	90.23%	100%	100%
POSITIVE PREDICTIVE VALUE	100%	75%	35%	100%	100%
NEGATIVE PREDICTIVE VALUE	73.68%	100%	100%	100%	98.44%
ACCURACY	89.29%	97.14%	90.71%	100%	98.57%
AGREEMENT	0.769	0.842	0.48	1	0.915

The combined echo-ultrasound for diagnosing shock had uniformly high diagnostic performance parameters across all shock types-sensitivity, specificity, positive predictive value, negative predictive value and accuracy all being over 85-90% for most categories. Highest sensitivity of 100% was noted for cardiogenic, hypovolemic, obstructive shock subtypes. Specificity was 100% for distributive, obstructive and mixed categories-indicative of excellent ability to accurately rule out these conditions. Accuracy reached 100% for diagnosis of obstructive shock, 97.14% for cardiogenic shock, and 98.57% for mixed distributive-and cardiogenic shok.

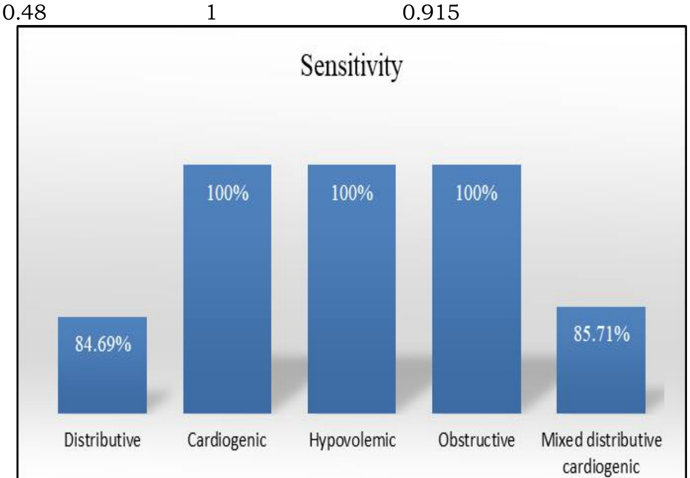

Figure 1. Sensitivity of shock diagnosis by

combined Echocardiography and Lung ultrasound in the studied cases.

4. Discussion

The present study incorporated structured lung ultrasound examinations assessing for pulmonary pathology findings that could help categorize shock type, standardized measurements of inferior vena cava diameter and collapsibility during the respiratory cycle obtained through ultrasound, which could provide insights into relative intravascular volume status, as well as routine echocardiography assessing cardiac structure, function and velocity time integral which could assist in visual identification of the cardiovascular abnormalities typically associated with specific shock subtypes.

The findings from these various point-of-care ultrasound modalities were analyzed in conjunction with the definitive diagnoses that the patients ultimately received after more extensive clinical evaluation and monitoring throughout their hospitalization for the shock.

The study done by Gargani et al.[12] examined whether a point-of-care ultrasound protocol could predict fluid responsiveness in 246 patients with undifferentiated shock. Their LUS and IVC-CI assessment correctly distinguished fluid responders with a sensitivity of 85% and specificity of 91%. The authors proposed an algorithm integrating LUS profiles, IVC-CI, and clinical findings to guide initial fluid resuscitation. The current study similarly demonstrated that LUS and IVC-CI provide complementary hemodynamic information to classify shock categories and predict volume responsiveness. However, the analysis of Gargani et al.[12] needed to integrate echocardiographic findings.

Conversely, Goudie et al.[13] focused specifically on echocardiography accuracy for diagnosing shock type. In their meta-analysis of 22 studies, they reported a pooled sensitivity of 80.7% and specificity of 91.4% for using echocardiography to detect cardiogenic shock. This aligns with the strong performance of echocardiography in combination with LUS and IVC-CI for diagnosing cardiogenic shock in the present study (sensitivity 100%, specificity 96.9%). Thus, multiple studies substantiate echocardiography's importance for assessing cardiac structure and function in shock evaluation.

With respect to implementation challenges, pension et al.[14] surveyed clinicians about barriers to applying a RUSH protocol for shock. Commonly reported obstacles included lack of training, limited machine availability, interference with resuscitation, and difficulty obtaining adequate images. Developing protocols suited to local resources and personnel capabilities is necessary for successful adoption. Ongoing quality improvement initiatives can also help troubleshoot issues over time.

The current study has several strengths. It combines three complementary ultrasound techniques to provide rapid diagnostic information from diverse hemodynamic perspectives. The inclusion of both emergency department and intensive care unit patients enhances the protocol's generalizability across acute care settings. With a sample size of 60 shock patients, the analysis had adequate power to assess test characteristics. The results demonstrate consistently strong accuracy across distributive, cardiogenic, hypovolemic, and obstructive shock categories.

However, there are limitations to acknowledge. As a single-center study performed at a specialized university hospital, the findings may be outside the realm of validation for different hospital settings and patient populations. The operators performing the ultrasound evaluations had expertise in critical care imaging, which could influence results. There is a need to validate the protocol among sonographers with varying skill levels. Additionally, the small sample of patients with mixed distributive cardiogenic shock reduces precision in estimating test performance for this subgroup. Finally, the study was not designed to correlate the use of the protocol with changes in therapeutic management or patient outcomes. Further research should examine whether this diagnostic approach leads to measurable clinical improvements.

The current study findings demonstrated reasonably high sensitivity ranging between 85 to 100% as well as high specificity ranging from 90 to 100% for the ability of the combined point-of-care ultrasound algorithm to correctly detect the diverse types of shock when compared to the post-hospitalization final diagnoses. Notably, the protocol was able to achieve 100% diagnostic accuracy for the detection of obstructive forms of shock in this cohort. These findings lend support to the potential utility of taking an integrative combined approach utilizing lung ultrasound examinations, inferior vena cava metrics assessing volume status through ultrasound, and echocardiography's ability to visualize cardiac function for rapid detection as well as identification of specific shock subtypes arising from an array of cardiovascular or hemodynamic faults.

CONCLUSION

This study concludes that an integrated point-of-care ultrasound incorporating lung ultrasound, inferior vena cava collapsibility metrics, and focused echocardiography provides a valuable tool for enhancing the rapidity and reliability of detecting shock and distinguishing between specific shock etiologies.

4. Conclusion

Intramedullary fixation of mid-shaft clavicular fractures with TENS is most appropriate for young patients who are medically free and have acute simple two-part middle 3rd clavicle fractures. The primary benefit of this methodology is that it is minimally invasive and has excellent functional outcomes; this method facilitates an earlier resumption of daily activities and a more rapid shoulder range of motion with protection of the supraclavicular nerve.

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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