The characteristics of echocardiography in ICU patients and its relationship with the outcomes

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Research

Abstract

Background Echocardiography is widely used for bedside monitoring in ICU. We aimed to describe the characteristics of echocardiography manifestations in different groups of ICU patients, and the association with the outcomes.

Methods This is a prospective multiple-center cohort study took place in 17 ICUs in China. A total of 1682 continuous adult patients admitted between August 31, 2017 to February 16, 2019 who had echocardiography performed within 24 hours in ICU were included. The echocardiography was performed and the echocardiography scores were calculated. Data was analyzed and compared between different outcome and primary indication groups.

Results The overall 28-day mortality was 15.76%. Left ventricle enlargement and other echocardiogram abnormalities were more common in the non-survivors than the survivors. The EF value was lower, and the decrease in EF value was more frequent in the non-survivors than the survivors. The echocardiography score was significantly higher in the non-survivors than the survivors. The incidence of right ventricle enlargement and EF decrease was high in ICU patients (26.52% and 26.93% respectively). The independent risk factors for 28-day mortality was APACHE II, the length of MV, the length of ICU stay, oxygenation index, right ventricle wall thickening, IVC diameter, IVC variability, and the echocardiography score.

Conclusions The incidence of cardiac dysfunction is high in ICU patients. The echocardiography score was significantly higher in the non-survivors than the survivors, and was an independent risk factor for 28-day mortality. Echocardiography is a convenient bedside monitoring method which deserves widely use in ICUs.

Trial registration: Chinese Clinical Trial Registry (ChiCTR-DDD-17012391). Registered 2017.08.17. http://www.chictr.org.cn/showprojen.aspx?proj=21127.

Background

Acute and chronic cardiac dysfunction is common in critically ill patients. Early detection of these signs is important for clinical management. Echocardiography is a very useful tool in the evaluation, treatment, and follow-up of intensive care unit (ICU) patients. Echocardiography is convenient for bedside monitoring to determine the type and state of shock, cardiac function, volume status, etc., therefore, it is increasingly widely used in ICUs.

In 2010, a statement on the subject of point-of-care cardiac evaluations being performed by non-cardiologists was issued[1], which termed the focused cardiac ultrasound (FOCUS). Later on, in 2013, the American Society of Echo decided that FOCUS should be used as an adjunct to the physical exam in an emergency setting[1]. Many different types of FOCUS exams for rapid evaluation of emergency or ICU patients have been introduced[2, 3], including the rapid ultrasound in shock (RUSH) protocol[4], the focus-

assessed transthoracic echocardiography (FATE) and the advanced FATE protocol[5], the fluid administration limited by lung sonography (FALLS) protocol[6], the focused assessment with sonography for trauma (FAST) and extended FAST (eFAST)[7], lung ultrasound study (CCROSS) protocol[8], and the critical care chest ultrasonic examination (CCUE) protocol[9], etc..

Most of these protocols use similar rapid echocardiography examinations including five standard views. Previous studies which applied these protocols reported early detection of etiology and complications, the improvement of the bedside treatment of critically ill patients, and reduce of the length of ICU stay[10−12]. However, most of these studies were singer center studies with relatively small sample size. The objectives of our study were to describe the characteristics of echocardiography manifestation in different groups of ICU patients, created a easy echocardiography score, and analyze their associations with outcomes.

Methods

Ethics statement

This prospective multiple-center cohort study was registered on the Chinese Clinical Trial Registry (ChiCTR-DDD-17012391), and was permitted by the Ethics Committee of each participating hospital. Informed consent was obtained from all participants or their family members.

Study design and patient selection

Data collection took place in 24 ICUs of tertiary public hospitals in China. Continuous adult patients admitted between August 31, 2017 to February 16, 2019 who had LUS performed within 24 hours in ICU were included. A total of 1913 patients were accrued during this time, twenty-four patients were exclude for age less than 18-years old and 187 patients were excluded for incomplete data records. Finally, the data of 1682 patients were used for analysis.

Data collection

Data that was prospectively collected following inclusion. Briefly, these data included demographics, heart rate (HR), mean arterial pressure (MAP), lactate (Lac), Acute Physiology and Chronic Health Evaluation (APACHE) II scores, and measures of oxygenation indexes (PaO_2/FiO_2 ratio) within 24 hours of ICU admission, length of mechanical ventilation (MV), length of ICU stay and 28-day mortality.

Echocardiogram measurements

Echocardiogram measurements were performed using the portable ultrasound machine (GE, Mindray or Sonosite) with a phased-array probe (2.5 MHz). All patients were placed in the supine position for echocardiogram measurements. Five views were examined: parasternal view long axis, parasternal view short axis, apical view, subxiphoid view, and inferior vena cava (IVC) long axis. Left atrium enlargement is

defined as >33mm. Right atrium enlargement is defined as: >45×45mm from the apical view. Left ventricle (LV) enlargement is defined as >55mm for male and >50mm for female. Right ventricle (RV) enlargement is defined as the ratio of RV/LV (the end-diastolic area) >0.6. Left ventricular wall thickening is defined as >12mm. Right ventricular wall thickening is defined as >7mm. Ejection fraction (EF) is measured in the left ventricular long-axis view or papillary muscle short-axis view, with the cursor perpendicular to the interventricular septum. IVC diameter and variability were measured from subxiphoid, two centimeters distal from the right atrium[13]. IVC variability was defined as IVCmax-IVCmin)/IVCmax for spontaneous respiratory patients, and IVCmax-IVCmin)/IVCmin for MV patients. For spontaneous respiratory patients, IVC variability was classified as large when >50%, medium when 10-50%, and mall when <10%[9]. For spontaneous respiratory patients, IVC variability was classified as large when >18%, medium when 10-18%, and mall when <10%[14]. Other echocardiogram abnormalities including pericardial effusion, heart valve abnormalities, pulmonary hypertension, ventricular wall segmental dyskinesia, etc. The above mentioned abnormal findings in echocardiography were scored: (1) Left/Right atrium enlargement: score 1; (2) Left ventricle enlargement: score 1; (3) Right ventricle enlargement: RV/LV<0.6, score 0; RV/LV=0.6-1.0, score 1; RV/LV>1.0, score 2; (4)Left/Right ventricular wall thickening: score 1; (5) IVC diameter: 1.0-1.9, score 0; <1.0 or ≥2.0, score 1; (6) IVC variability: Medium: score 0; large or small: score 1; (7) EF: >55%, score 0; 30-55%, score 1; <30%, score 2; (8) Other echocardiogram abnormalities: score 1. The echocardiography score was calculated by the sum of these scores. All the measurements were performed by two constant intensivists who have been trained by Chinese Critical Ultrasound Study Group (CCUSG) in each participating ICUs. Echocardiography was first measured by one of them, and then confirmed by another person (blinded to the first). When their results were similar, the data was recorded; otherwise, a third person would perform the measurements again, and the two most similar results was record.

Statistics

Continuous variables were reported as mean ± standard deviation (SD), and were compared using the Student's t test or one-way analysis of variance (ANOVA) if a normal distribution or a homogeneity of variance was detected. Otherwise, the Mann-Whitney U test or Kruskal-Wallis test was used. Categorical variables were compared using the χ^2 test. A 2-tailed P <0 .05 was considered statistically significant.

Risk factors for 28-day mortality were assessed by multiple logistic regression based on the enter method. Results of the multivariate logistic regression analysis were summarized by estimating odds ratios (ORs) and respective 95% confidence intervals (CIs). The predictive power of ultrasound score for 28-day mortality was assessed by the area under the receiver operator characteristic (AuROC) curve. All statistical analysis was performed using SPSS version 19 for Windows (SPSS Inc., USA).

Results

A total of 1682 patients were included in this study. The mean age of the participants was 59.48±17.363 years, with male composing 58.32% of the cohort (n=981). The primary indications for ICU admission

included: respiratory failure (n=533, 31.69%), shock (n=288, 17.12%), post-operation (n=759, 45.12%), and others (n=265, 15.76%). The mean APACHE II score was 15.32±8.452. The mean length of MV was 91.12±213.319 hours, and the mean length of ICU stay was 13.58±60.156 days. The overall 28-day mortality was 15.76% (265/1682). (Table 1)

Differences between survivors and non-survivors

Among the overall patients, the ages of survivors were significantly younger than non-survivors (P=0.013). APACHE II scores and the length of MV were significantly lower in the survivors than the non-survivors (p<0.001 and p<0.001 respectively). The HR at admission was higher and the MAP was lower in the non-survivors than the survivors (p<0.001 and p<0.001 respectively). The Lac was higher and the oxygenation index was lower in the non-survivors than the survivors (p<0.001 and p<0.001 respectively). In echocardiography examination, left ventricle enlargement and other echocardiogram abnormalities were more frequent in the non-survivors than the survivors (p=0.041 and p<0.001 respectively). The EF value was significantly lower, and decrease in EF value is more frequent in the non-survivors than the survivors (p<0.001 and p<0.001 respectively). The echocardiography score was significantly higher in the non-survivors than the survivors (p=0.022). (Table 2)

For subgroup analysis, in patients with acute respiratory failure (n=533), APACHE II scores were significantly lower in the survivors than the non-survivors (p<0.001), while the age, length of MV and length of ICU stay were similar between groups. The Lac was higher in the non-survivors than the survivors (p<0.001). In echocardiography examination, IVC diameter <1.0cm was more frequent in the non-survivors than the survivors (p=0.002). IVC variability large or small was more frequent in the non-survivors than the survivors (p<0.001 and p=0.034 respectively). There was no significant difference on the echocardiography score between the non-survivors and the survivors (p=0.454). (Table 3)

In patients with shock (n=288), APACHE II scores were significantly lower in the survivors than the non-survivors (p<0.001), while the age, length of MV and length of ICU stay was similar between groups. The Lac was higher in the non-survivors than the survivors (p<0.001). In echocardiography examination, other echocardiogram abnormalities were more frequent in the non-survivors than the survivors (p=0.044). There was no significant difference on the echocardiography score between the non-survivors and the survivors (p=0.685). (Table 4)

In postoperative patients (n=759), ages, APACHE II scores, and the length of MV were significantly lower in the survivors than the non-survivors (p=0.010, P<0.001 and p<0.001 respectively). The HR and the Lac was higher in the non-survivors than the survivors (p=0.035 and p=0.023 respectively). In echocardiography examination, left ventricle enlargement, left ventricular wall thickening, right ventricular wall thickening and other echocardiogram abnormalities were more frequent in the non-survivors than the survivors (p<0.001, p=0.042, p=0.003 and p=0.006 respectively). The EF value was significantly lower, and EF<30% is more frequent in the non-survivors than the survivors (p=0.014 and p<0.001 respectively). The echocardiography score was significantly higher in the non-survivors than the survivors (p=0.001). (Table 5)

The risk factors of 28-day mortality

Using multivariate analysis, the independent risk factors for 28-day mortality was APACHE II (OR=0.903, p<0.001, 95% CI 0.873-0.933), the length of MV (OR=0.994, p<0.001, 95% CI 0.991-0.997), the length of ICU stay (OR=1.159, p<0.001, 95% CI 1.083-1.242), oxygenation index (OR=1.003, p=0.013, 95% CI 1.001-1.005), IVC diameter (OR=1.756, p=0.024, 95% CI 1.075-2.868), IVC variability (OR=1.797, p=0.017, 95% CI 1.112-2.904), and the echocardiography score (OR=0.443, p=0.016, 95% CI 0.228-0.861). To predict the 28-day mortality of ICU patients, the AuROC of the echocardiography score were 0.595. (Table 6)

Discussion

Critical care ultrasound has gained its place as an effective and convenient monitoring tool, which become the "visual stethoscope" of the 21st century[15,16]. Echocardiography is an important part of critical care ultrasound, which allows for an anatomical, functional, and hemodynamic assessment of the heart, and has revolutionized the bedside assessment of ICU patients. Many different types of FOCUS exams have been introduced to the emergency departments or ICUs. Previous studies have reported that FOCUS performed by emergency medicine residents is comparable to echocardiography performed by cardiologists. Therefore, echocardiography is a reliable tool and screening test for cardiac abnormalities[17]. After a brief standard training in using echocardiographic system, intensivists can successfully performed and correctly interpreted a focused TTE for critically ill patients[18]. Chest ultrasonography is a valid bedside diagnostic aid to the management of acute respiratory diseases in older patients[19]. FOCUS can be an important tool in the initial evaluation of emergency patients with suspected pulmonary embolism and abnormal vital signs[20]. In cardiac-arrest patients, after return of spontaneously circulation, FOCUS could be included in post-resuscitation care as an adjunctive diagnostic measure[21]. CCUE-plus protocol was effective in the etiological diagnosis in patients with dyspnea and/or hemodynamic instability caused by abdominal abnormalities[22]. However, the prognostic value of echocardiography in ICU patients is seldom studied. It was reported that CCUE protocol could improve the bedside treatment of critically ill patients, and reduce ICU stay[10].
A FOCUS examination for right ventricular strain performed by emergency care practitioners was a significant predictor of in-hospital adverse outcomes among patients diagnosed with pulmonary embolism in the Emergency Department[23]. But the role of echocardiography performed early during admission in general ICU patients has not been assessed in a multiple center cohort. In this study, we described the characteristics of echocardiography manifestation in different groups of ICU patients, and analyzed their associations with outcomes.

This study included 1682 patients from the ICUs in different parts of China. The mean age of the participants was 59.48±17.363 years, and the mean APACHE II score was 15.32±8.452. The overall 28-day mortality was 15.76% (265/1682), which is in line with the general level of ICU patients. We applied echocardiography to these general ICU patients with different primary indications, and analyzed its relationship with the 28-day mortality. Results showed APACHE II scores, the length of MV, HR, MAP and

Lac were significantly different between the non-survivors and the survivors. Left ventricle enlargement and other echocardiogram abnormalities were more frequent in the non-survivors than the survivors. The incidence of right ventricle enlargement (446/1682, 26.52%) and EF decrease (453/1682, 26.93%) was high in ICU patients. The EF value was significantly lower, and the decrease in EF value was more frequent in the non-survivors than the survivors. These results indicated that the incidence of cardiac dysfunction was high in ICU patients. Echocardiography at the admission of ICU helps early detection of cardiac abnormalities.

Then we analyzed the characteristic of echocardiography in subgroups with different primary diseases. In patients with acute respiratory failure, the incidence of right ventricle enlargement was even higher (178/533, 33.40%). IVC variability abnormal was more frequent in the non-survivors than the survivors. IVC diameter is a useful mirror of the right atrial pressure (RAP), and IVC variability is a reliable index for assessing fluid responsiveness[13,14]. This indicated that unsuitable volume status might be an important factor for the mortality of acute respiratory failure patients. However, the echocardiography score was not significantly different between the non-survivors and the survivors. A probable reason was that cardiac abnormalities were common in patients with acute respiratory failure, thus the difference was not obvious between groups.

In patients with shock, in echocardiography examinations, only other echocardiogram abnormalities were significantly different between the non-survivors than the survivors. Other cardiac abnormalities including pericardial effusion, heart valve abnormalities, pulmonary hypertension, ventricular wall segmental dyskinesia, were important clinical conditions leading to heart failure and deterioration of diseases. In shock patients, there was no significant difference on EF values between groups, probably because most of the shock patients included in this study were septic shock instead of cardiogenic shock. Also, the echocardiography score was not significantly different between the non-survivors and the survivors, probably because cardiac abnormalities were common in patients with shock.

In postoperative patients, left ventricle enlargement, left ventricular wall thickening, right ventricular wall thickening and other echocardiogram abnormalities were more frequent in the non-survivors than the survivors, indicating that primary heart diseases were important factors for the mortality of postoperative patients. The EF value was significantly lower, and EF<30% is more frequent in the non-survivors than the survivors, indicating that cardiac systolic dysfunction was also important for the outcome of patients. Previous studies has reported that LV ejection fraction <45% was associated with the absence of early recovery and less favorable 1-year outcome in patients with Takotsubo Syndrome[24]. A scoring system including EF is a predictor of 30-day mortality risks for ST-Elevation Myocardial Infarction patients[25]. The echocardiography score was significantly higher in the non-survivors than the survivors. These results indicated that echocardiography screen was important for post-operative patients. And abnormal findings in echocardiography may help divide the non-survivors and survivors.

When analyzing the risk factors for 28-day mortality, the independent risk factors was APACHE II, the length of MV, the length of ICU stay, oxygenation index, right ventricular wall thickening, IVC diameter, IVC variability and the echocardiography score. These data indicated that volume status and fluid responsiveness were critical for the mortality of ICU patients. However, a previous study using IVC variability <20% as the end-point of fluid resuscitation in septic shock requiring ventilatory support did not found significant difference in the amount of fluid infused, time to reach end-point and mortality with the regular care group. As there are few studies on the relationship between IVC variability and mortality, it deserves further study.

In this study, we developed a scoring system by assessing atrium and ventricle enlargement, ventricular wall thickening, IVC diameter and variability, EF, and other echocardiogram abnormalities, therefore to generally evaluate the structural, systolic, diastolic and volumic abnormalities. We found that the echocardiography score was significantly higher in the non-survivors than the survivors. Also, it was an independent risk factor for 28-day mortality. These results indicated that echocardiography makers that reveal the general cardiac function could help to predict the outcome. However, the AuROC of echocardiography score for predicting the 28-day mortality was only 0.595, indicating that it is not a reliable outcome predicting marker. Therefore, this echocardiography score may be better used in combination with other risk factors of mortality.

This study is a multiple center study that comprehensively investigated the characteristics of echocardiography manifestations and their prognostic importance in a larger cohort of ICU patients. However, our study has some limitations. First, as many clinical indicators were not completely recorded in different participating sites, we only analyzed the most complete baseline data including the age, gender, primary indications, HR, MAP, Lac, APACHE II scores, length of MV, length of ICU stay, and 28-day mortality. However, many laboratory indexes were not analyzed because of too many missing data. Second, most participating ICUs are general ICUs, with relatively more surgical patients and fewer internal medical patients. Therefore, a large proportion of the included patients were postoperative patients with less severe conditions.

Conclusions

This large multiple center study demonstrated that the incidence of cardiac dysfunction is high in ICU patients. the IVC variability is an independent risk factors for 28-day mortality. Echocardiography is a convenient bedside monitoring method which deserves widely use in ICUs.

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List Of Abbreviations

Focused cardiac ultrasound (FOCUS); rapid ultrasound in shock (RUSH); focus-assessed transthoracic echocardiography (FATE); fluid administration limited by lung sonography (FALLS); focused assessment with sonography for trauma (FAST); critical care chest ultrasonic examination (CCUE); heart rate (HR); mean arterial pressure (MAP); lactate (Lac); Acute Physiology and Chronic Health Evaluation (APACHE); mechanical ventilation (MV); inferior vena cava (IVC); left ventricle (LV); right ventricle (RV); ejection fraction (EF); standard deviation (SD); one-way analysis of variance (ANOVA); odds ratios (ORs); confidence intervals (CIs); area under the receiver operator characteristic (AuROC).

Declarations

- -Ethics approval and consent to participate: This prospective multiple-center cohort study was registered on the Chinese Clinical Trial Registry (ChiCTR-DDD-17012391), and was permitted by the Ethics Committee of each participating hospital.

- -Consent for publication: This paper has not been published elsewhere in whole or in part. All authors have read and approved the content, and agree to submit it for consideration for publication in your journal.

- -Availability of data and materials: Available.

- -Competing interests: There was no conflict of interest to be declared.

- -Authors' contributions:

Qian-Yi Peng drafted this paper, performed lung ultrasound, collected and analyzed the data. Li-Xia Liu, Qian Zhang, Ying Zhu, Hong-Min Zhang, Wan-Hong Yin, Wei He, Xiu-Ling Shang, Yan-Gong Chao, Li-Wen Lv, and Xiao-Ting Wang performed lung ultrasound and collected data in their ICUs. Li-Na Zhang designed and supervised this study, and modified the paper.

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Tables

Table 1 Baseline characteristics and outcomes of patients included.

Variable	Number (percentage)	
Age (y)	59.48±17.363 (Mean±SD)	
Age groups		
<50	468	27.82%
50-59	289	17.18%
60-69	391	23.25%
≥70	534	31.75%
Gender		
Male	981	58.32%
Female	701	41.68%
Primary indication		
Respiratory failure	533	31.69%
Shock	288	17.12%
Postoperation	759	45.12%
Others	265	15.76%
APACHEII	15.32±8.452	
Length of MV (h)	91.12±213.319	
Length of ICU stay (d)	13.58±60.156	
28-day mortality	265/1682	15.76%

Table 2 Clinical characteristics, outcomes and echocardiography manifestations stratified by survival status 28 days after ICU admission in ICU patients.

Variable	Non-survivors	Survivors	P
Age (y)	61.89±17.022	59.03±17.395	0.014*
HR	101.99±26.193	91.74±24.195	<0.001*
MAP	87.131±17.9910	91.174±16.6552	<0.001*
Lac	3.529±3.8676	2.187±2.4502	<0.001*
Oxygenation Index	201.657±146.1023	263.172±115.2306	<0.001*
APACHEII	23.13±8.687	13.86±7.562	<0.001*
Lenth of MV (h)	147.74±143.597	80.53±222.406	<0.001*
Lenth of ICU stay (d)	16.15±70.217	13.10±58.097	0.450
Left Atrium Enlargement	31/265 (11.70%)	165/1417 (11.64%)	0.980
Right Atrium Enlargement	32/265 (12.08%)	139/1417 (9.81%)	0.263
Left Ventricle Enlargement	26/265 (9.81%)	90/1417 (6.35%)	0.041*
Right Ventricle Enlargement			0.075
RV/LV<0.6	180/265 (67.92%)	1062/1417 (74.95%)	
RV/LV=0.6-1.0	76/265 (28.68%)	324/1417 (22.87%)	
RV/LV>1.0	9/265 (3.40%)	37/1417 (2.61%)	
Left Ventricular Wall Thickening	50/265 (18.87%)	202/1417 (14.26%)	0.053
Right Ventricular Wall Thickening	22/265 (8.30%)	75/1417 (5.29%)	0.054
IVC diameter (cm)			0.065
<1.0	60/265 (22.64%)	261/1417 (18.42%)	
1.0-1.9	135/265 (50.94%)	830/1417 (58.57%)	
≥2.0	70/265 (26.42%)	326/1417 (23.01%)	
IVC variability			0.076
Large	77/265 (29.06%)	322/1417 (22.72%)	
Medium	105/265 (39.62%)	631/1417 (44.53%)	
Small	83/265 (31.32%)	464/1417 (32.75%)	
EF			<0.001*
>55%	160/265 (60.38%)	1069/1417 (75.44%)	<0.001*
30-55%	86/265 (32.45%)	324/1417 (22.87%)	0.001

<30%	19/265 (7.17%)	32/1417 (2.26%)	<0.001*
EF value	53.288±15.7779	59.119±13.2880	<0.001*
Other Echocardiogram Abnomalities	45/265 (16.98%)	145/1417 (10.23%)	0.001*
Echocardiography Score	2.69±1.905	2.10±1.809	0.022*

Table 3 Clinical characteristics, outcomes and echocardiography manifestations stratified by survival status 28 days after ICU admission in patients with acute respiratory failure (N=533)

Variable	Non-survivors	Survivors	P
Age (y)	61.94±17.658	61.29±17.473	0.700
HR	103.45±26.721	100.91±25.000	0.303
MAP	87.131±17.9910	91.174±16.6552	0.055
Lac	3.173±3.2847	2.171±2.2137	0.001*
Oxygenation Index	173.700±143.2742	200.006±98.7661	0.090
APACHEII	23.69±8.415	17.89±7.231	<0.001*
Lenth of MV (h)	162.52±138.278	181.40±370.008	0.392
Lenth of ICU stay (d)	13.66±46.614	25.27±96.707	0.063
Left Atrium Enlargement	16/150 (10.67%)	60/383 (15.67%)	0.138
Right Atrium Enlargement	16/150 (10.67%)	46/383 (12.01%)	0.663
Left Ventricle Enlargement	15/150 (10.00%)	32/383 (8.36%)	0.547
Right Ventricle Enlargement			0.906
RV/LV<0.6	102/150 (68.00%)	253/383 (66.06%)	
RV/LV=0.6-1.0	41/150 (27.33%)	112/383 (29.24%)	
RV/LV>1.0	7/150 (4.67%)	18/383 (4.70%)	
Left Ventricular Wall Thickening	22/150 (14.67%)	51/383 (13.32%)	0.683
Right Ventricular Wall Thickening	16/150 (10.67%)	45/383 (11.75%)	0.724
IVC diameter			0.008*
<1.0	33/150 (22.00%)	44/383 (11.49%)	0.002*
1.0-1.9	74/150 (49.33%)	209/383 (54.57%)	0.276
≥2.0	43/150 (28.67%)	130/383 (33.94%)	0.242
IVC variability			0.045*
Large	40/150 (26.67%)	71/383 (18.54%)	<0.001*
Medium	60/150 (40.00%)	146/383 (38.12%)	0.689
Small	50/150 (33.33%)	166/383 (43.34%)	0.034*
EF			0.341
>55%	89/150 (59.33%)	242/383 (63.19%)	
30-55%	53/150 (35.33%)	130/383 (33.94%)	

<30%	8/150 (5.33%)	11/383 (2.87%)	
EF value	53.536±14.8293	56.171±14.3183	0.168
Other Echocardiogram Abnomalities	22/150 (14.67%)	46/383 (12.01%)	0.408
Echocardiography Score	2.65±1.876	2.59±1.939	0.454

Table 4 Clinical characteristics, outcomes and echocardiography manifestations stratified by survival status 28 days after ICU admission in patients with shock (N=288)

Variable	Non-survivors	Survivors	P
Age (y)	59.69±18.011	59.36±16.725	0.891
HR	108.84±25.129	97.18±34.914	0.015
MAP	78.651±15.8965	81.504±15.8202	0.210
Lac	5.960±5.4784	3.091±2.7834	<0.001*
Oxygenation Index	169.530±149.5003	247.037±113.2802	0.002
APACHEII	24.63±8.884	17.57±8.214	<0.001*
Lenth of MV (h)	153.12±160.247	150.66±432.526	0.964
Lenth of ICU stay (d)	26.23±125.323	17.15±51.011	0.389
Left Atrium Enlargement	10/62 (16.13%)	30/226 (13.27%)	0.565
Right Atrium Enlargement	8/62 (12.90%)	34/226 (15.04%)	0.672
Left Ventricle Enlargement	8/62 (12.90%)	19/226 (8.41%)	0.282
Right Ventricle Enlargement			0.280
RV/LV<0.6	39/62 (62.90%)	156/226 (69.03%)	
RV/LV=0.6-1.0	21/62 (33.87%)	56/226 (24.78%)	
RV/LV>1.0	2/62 (3.23%)	14/226 (6.19%)	
Left Ventricular Wall Thickening	10/62 (16.13%)	29/226 (12.83%)	0.501
Right Ventricular Wall Thickening	5/62 (8.06%)	15/226 (6.64%)	0.695
IVC diameter			0.103
<1.0	15/62 (24.19%)	34/226 (15.04%)	
1.0-1.9	31/265 (50.00%)	106/226 (46.90%)	
≥2.0	16/62 (25.81%)	86/226 (38.05%)	
IVC variability			0.276
Large	14/62 (22.58%)	38/226 (16.81%)	
Medium	26/62 (41.94%)	83/226 (36.73%)	
Small	22/62 (35.48%)	105/226 (46.5%)	
EF			0.203
>55%	29/62 (46.77%)	129/226 (57.08%)	
30-55%	25/62 (40.32%)	81/226 (35.84%)	

<30%	8/62 (12.90%)	16/226 (7.08%)	
EF value	49.153±16.9019	53.569±15.6674	0.136
Other Echocardiogram Abnomalities	14/62 (22.58%)	28/226 (12.39%)	0.044*
Echocardiography Score	3.03±1.916	2.73±1.990	0.685

Table 5 Clinical characteristics, outcomes and echocardiography manifestations stratified by survival status 28 days after ICU admission in post-operation patients (N=759)

Variable	Non-survivors	Survivors	P
Age (y)	64.50±12.298	59.40±16.873	0.010*
HR	92.22±23.108	87.44±20.966	0.035*
MAP	89.203±16.3577	92.787±16.0762	0.144
Lac	3.661±4.1440	2.201±2.6389	0.023*
Oxygenation Index	266.145±181.8949	304.781±102.4192	0.372
APACHEII	19.91±7.927	11.59±6.732	<0.001*
Lenth of MV (h)	118.00±128.558	36.93±82.924	<0.001*
Lenth of ICU stay (d)	9.74±7.350	7.08±32.379	0.578
Left Atrium Enlargement	5/46 (10.87%)	72/713 (10.10%)	0.867
Right Atrium Enlargement	9/46 (19.57%)	64/713 (8.98%)	0.263
Left Ventricle Enlargement	3/46 (6.52%)	41/713 (5.75%)	<0.001*
Right Ventricle Enlargement			0.174
RV/LV<0.6	30/46 (65.22%)	550/713 (77.14%)	
RV/LV=0.6-1.0	15/46 (32.61%)	150/713 (21.32%)	
RV/LV>1.0	1/46 (2.17%)	13/713 (1.82%)	
Left Ventricular Wall Thickening	12/46 (26.09%)	106/713 (14.87%)	0.042*
Right Ventricular Wall Thickening	0/46 (0%)	19/713 (2.66%)	0.003*
IVC diameter			0.491
<1.0	7/46 (15.22%)	152/713 (21.32%)	
1.0-1.9	29/46 (63.04%)	442/713 (61.99%)	
≥2.0	10/46 (21.74%)	119/713 (16.69%)	
IVC variability			0.716
Large	13/46 (28.26%)	167/713 (23.42%)	
Medium	20/46 (43.48%)	347/713 (48.67%)	
Small	13/46 (28.26%)	199/713 (27.91%)	
EF			<0.001*
>55%	32/46 (69.57%)	590/713 (82.75%)	0.024*
30-55%	10/46 (21.74%)	117/713 (16.41%)	0.348

<30%	4/46 (8.70%)	6/713 (0.84%)	<0.001*
EF value	53.379±16.0122	61.467±11.0724	0.014*
Other Echocardiogram Abnomalities	10/46 (21.74%)	66/713 (9.26%)	0.006*
Echocardiography Score	2.54±2.105	1.84±1.681	0.001*

Table 6 Risk factors of 28-day mortality

Item	R value	P value	95% CI
APACHEII	0.903	<0.001	0.873-0.933
Length of MV	0.994	<0.001	0.991-0.997
Length of ICU Stay	1.159	<0.001	1.083-1.242
Oxygenation Index	1.003	0.013	1.001-1.005
Right ventricular wall thickening	4.800	0.009	1.470-15.670
IVC diameter	1.756	0.024	1.075-2.868
IVC variability	1.797	0.017	1.112-2.904
Echocardiography Score	0.443	0.016	0.228-0.861