RESEARCH ARTICLE

# Analysis of volume management by comparing between critical care ultrasound examination and pulse indicator cardiac output in patients with septic shock

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## Abstract

**Objective:** To investigate volume management by comparing between critical care ultrasound examination and pulse indicator cardiac output (PICCO) in patient with septic shock.

**Method:** Patients with septic shock during July 2017 and June 2018 were included. Inferior Vena Cava (IVC), total end-diastolic volume index (GEDI), central venous pressure (CVP), lactic acid and oxygenation index were measured by ultrasound. First, the accuracy difference of IVC, GEDI and CVP estimation capacity was compared. According to the changes of IVCmin, IVCmax, and GEDI, they were divided into 5 groups to compare the differences of lactic acid and oxygenation index between the groups and the correlation of lactate and Oxygenation index (PaO2/FiO2) between IVC and GEDI was analyzed. The correlation of lactate and PaO2/FiO2 between B lines and extravascular pulmonary water index (ELWI) was noted.

**Results:** The accuracy of IVC and GEDI in volume estimation was greater than 75%, significantly higher than that of CVP (53.3%) ($P<0.05$). The correlation results showed that GEDI was significantly correlated with IVCmax and IVCmin ($P<0.05$), while there was a significant correlation between b-line area and oxygenation index, ELWI and lactic acid, ELWI and oxygenation index ($P<0.05$). IVCmin, IVCmax and GEDI were respectively divided into 5 groups for comparing the difference between lactic acid and oxygenation. It was found that there were significant differences between the two indicators of IVCmin in different groups ($P>0.05$). The oxygenation index of the group ≤IVCmax was significantly lower than that of the group 0.5 ≤IVCmax < 1.0cm ($P<0.05$). The oxgenation indexes of groups 500≤GEDI < 600mL/$m^2$; 600≤GEDI < 700mL/$m^2$. 700≤GEDI < 800mL/$m^2$ were significantly higher than that of group 0 < GEDI < 500mL/$m^2$ ($P<0.05$).

**Conclusion:** Critical care ultrasound examination and PICCO are better methods than in volume management, but PICCO is more individualized, and PICCO in patients with valvular heart disease is not recommended.

**Keywords:** Critical care ultrasound, PICCO, Septic shock. (JPMA 70: 51 [Special Issue]; 2020)

## Introduction

Infectious shock is one of the most common diseases in ICU[1] with fluid resuscitation being is the most important treatment strategy.[2,3] However, the shock guidelines of 2016 point out that conservative fluid therapy strategy is recommended in the absence of evidence of tissue hypo-perfusion.[4] Therefore, the evaluation and adjustment of the volume load is of great significance for the development and prognosis of septic shock patients. Pulse Indicator Continuous Cardiac Output (PICCO) is an invasive haemodynamic monitoring measure, which can accurately reflect body volume load and guide fluid therapy.[5] But it is expensive, and there are some limitations in the condition of intracardiac shunt. Critical care ultrasound has the advantages of fast, non-invasive, simple and reproducible in volume assessment.[6] The purpose of this study is to compare the advantages and disadvantages of critical care ultrasound and PICCO in volume management of septic shock patients, and to explore more suitable methods for volume assessment of septic shock patients. Thus the objective of this research was to investigate volume management by comparing between critical care ultrasound examination and PICCO in patients with septic shock.

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## Patients and Methods

A comparative study was conducted on patients transferred to ICU due to septic shock from July 2017 to June 2018. Inclusion criteria: were age ≥18 years, consistent with "The diagnostic criteria for septic shock based on the 2016 guidelines for SSC".[7] Exclusion criteria were those having contraindications for PICCO catheterization. All patients in whom inferior vena cava (IVC) could not be measured by critical care ultrasound and whose treatment time in ICU was less than 3 days.

The maximum and minimum diameters of inferior vena cava vessels were measured by critical care ultrasound. Under the xiphoid process, the point of indication was pointed to the head, and the inferior vena cava (IVC) section was obtained. Under M mode, the sampling line was placed at 2cm from IVC into the right atrium. The maximum and minimum internal diameters of the inferior vena cava vessels (IVCmax and IVCmin) were measured respectively. In supine position, the ultrasound probe was perpendicular to the chest wall and the indication point was facing the head. The B-line area of the lung was detected according to the standardized checkpoint in the BLUE process, and the number of B-line areas was recorded.

IVC, PICCO and central venous pressure (CVP) were measured at 7:00 a.m. on the 1st, 2nd and 3rd day after patients were transferred to ICU, and lactic acid and oxygenation index were recorded at the same time. IVC, PICCO and CVP were measured again at 16:00 on the first day.

The accuracy of IVC, PICCO and CVP in evaluating the volume was calculated by the volume change from 7:00 to 16:00 on the first day, and the similarities and differences of the accuracy were compared. According to the size of IVCmax, patients were divided into five groups: 0.5≤IVCmax<1.0cm, 1.0≤IVCmax<1.5cm, 1.5≤IVCmax<2.0cm, 2.0≤IVCmax<2.5cm, 2.5≤IVCmax; according to the size of IVCmin, patients were divided into five groups: 0<IVCmin<0.5cm, 0.5≤IVCmin<1.0cm, 1.0≤IVCmin<1.5cm, 1.5≤IVCmin<2.0cm, and 2.0≤IVCmin, respectively. According to the global end-diastolic volume index (GEDI), the patients were divided into five groups: 0<GEDI <500mL/$m^2$; 500≤GEDI <600mL/$m^2$; 600≤GEDI <700mL/$m^2$; 700≤GEDI <800mL/$m^2$; 800 mL/$m^2$ ≤GEDI.

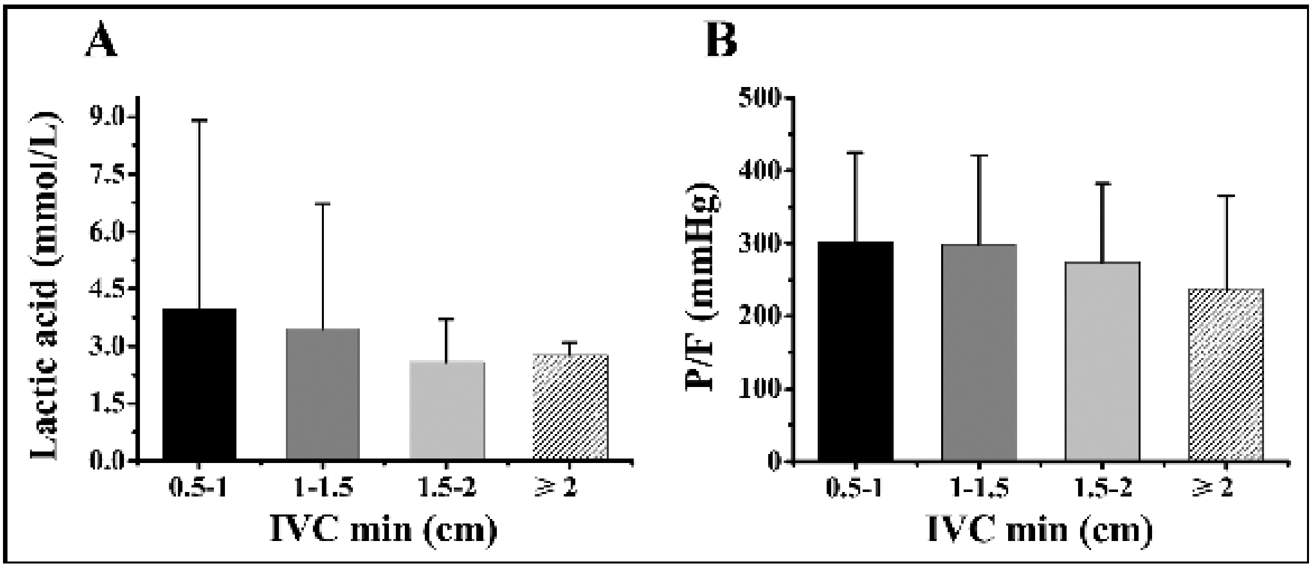
The correlation among the three groups and the similarities and differences of lactic acid and oxygenation index were compared. This gave the correlation between the number of B-line areas and Extravascular Lung Water Index (ELWI) and the correlation between them and lactic acid and oxygenation index.

The statistical analysis software package SPSS 21.0 was used for statistical analysis. The experimental data were expressed by mean ± standard deviation (x±s), t-test and correlation test. The counting data were expressed by rate (%) and $\chi^2$ test was used. P<0.05 indicated that the difference was statistically significant.

## Results

A total of 30 patients were enrolled, including 12 males, with an average age of 38.87±7.66 years.

As shown in Table-1, the accuracy of CVP, IVCmax and IVCmin were 53.3%, 83.33% and 90.0% respectively. Accuracy of GEDI was 76.7%, and accuracy of GEDI* was 84.0%. The results of comparing the accuracy of estimated capacity showed that the accuracy of IVCmax and GEDI* was significantly higher than that of CVP (P<0.05). The estimation accuracy of IVCmin was significantly higher than that of CVP (P<0.01). In the correlation analysis of GEDI and IVC, there was no




**Note: the figure A was lactic acid index in different groups of IVCmin. Figure B was oxygenation index in different groups of IVCmin**

**Figure-1:** Comparison of lactic acid and oxygenation index in different groups of IVCmin.

**Table-1:** Comparison of GEDI, IVC and CVP in judging volume accuracy.

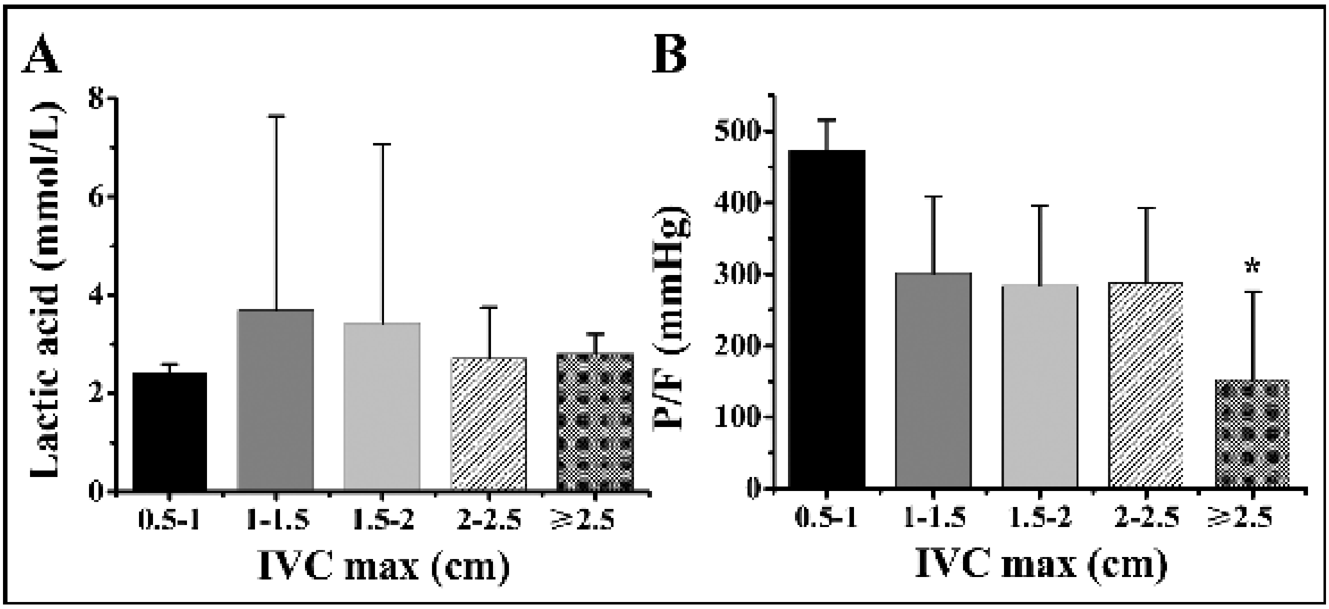
| | Yes | No | Accuracy (%) | $\chi^2$ | P |
|---|---|---|---|---|---|
| CVP | 16 | 14 | 53.3 | | |
| IVC max | 25 | 5 | 83.33 | 6.24 | 0.012 |
| IVC min | 27 | 3 | 90.0 | 9.93 | 0.002 |
| GEDI | 23 | 7 | 76.7 | 3.59 | 0.058 |
| GEDI* | 21 | 4 | 84.0 | 5.83 | 0.016 |

CVP: Central Venous Pressure IVC: Inferior Vena Cava GEDI: Total End-Diastolic Volume Index; * shows exclusion of valvular heart disease.

significant correlation between GEDI and IVCmax (r = 0.048, P = 0.653), and no significant correlation between GEDI and IVCmin (r = 0.033, P = 0.755); after excluding patients with valvular heart disease, there was a significant correlation between GEDI and IVCmax (r = 0.311, P = 0.007), and there was a significant correlation between GEDI and IVCmin (r = 0.308, P = 0.007).

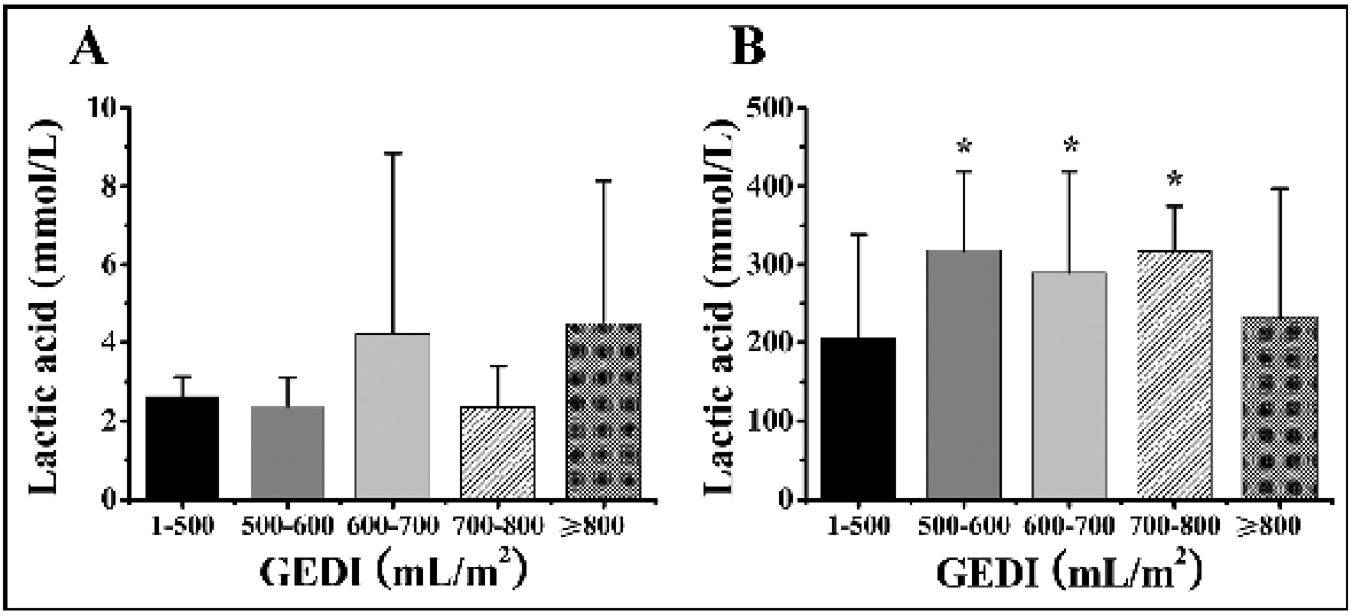
After comparing the different groups of IVCmin, IVCmax and GEDI in difference between lactic acid and oxgenation index, it was found that in Figure-1A, lactic acid indexes of 0.5 IVCmin < 1.0 cm, 1.0 or less IVCmin < 1.5 cm, 1.5 or less IVCmin < 2.0 cm and 2.0 or less IVCmin groups were 3.97, 3.45 + / - 3.27, 2.59 4.93 mm + / - 1.12 and 2.77 + / - 0.33, and there was no significant difference of lactic acid index for each group (p > 0.05). As seen from figure 1B, the oxgenation indices of IVCmin in different groups were 302.01±123.11, 298.61±122.7, 273.99±108.25 and 238.08±126.86, respectively, and there was no significant difference of the oxygenation index of each group (p>0.05). According to Figure-2A, lactic acid indexes of 0.5 IVCmax < 1.0 cm, 1.0 or less or less IVCmax < 1.5 cm, 1.5 or less IVCmax < 2.0 cm, 2.0 or less IVCmax < 2.5 cm, 2.5 or less IVCmax groups were 2.39, 3.69 + / - 3.94, 3.44 0.2 mm + / - 3.63, 2.71 and 2.8 0.41 mm 1.04 mm and there was no significant difference of lactic acid index between groups (p > 0.05). As seen from figure 2B, the oxgenation index of IVCmax in different groups was 471.98±43.16, 301.09±106.92, 283.79±112.04, 288.3±104.74 and 151.79±123.85, respectively. The oxygenation index of group 2.5≤IVCmax was significantly lower than that of group 0.5≤IVCmax < 1.0cm (p<0.05). According to Figure-3A, lactic acid indexes of 0 < GEDI < 500mL/m²; 500≤GEDI < 600mL/m²; 600≤GEDI < 700mL/m²; 700≤GEDI < 800mL/m²; 800 mL/m² GEDI or less were 2.62 + / - 0.51, 2.37, 4.24 + / - 4.61, 2.34 0.74 mm + / - 1.06 and 4.51 + / - 3.63, and there was no significant difference in lactic acid index of each group (p > 0.05). According to Figure-3B, the oxygenation index of groups of 500≤GEDI < 600mL/m²; 600≤GEDI < 700mL/m²; 700≤GEDI < 800mL/m² were significantly higher than that of group 0 < GEDI < 500mL/m² (p<0.05).

In the correlation analysis between the number of B-line areas and ELWI, there was a significant correlation between the number of B-line areas and ELWI (r=0.737, P<0.001), the number of B-line areas and lactic acid




**Note: the figure A was lactic acid index in the company groups of IVCmax. Figure B showed oxygenation index in different groups of IVCmax.**
*** indicated that there was a significant difference between the groups of 0.5-1cm, P<0.05**

**Figure-2:** Comparison of lactic acid and oxygenation index in different groups of IVCmax.




**Note: the figure A was lactic acid index in the company groups of GEDI. Figure B showed oxygenation index in different groups of GEDI. * indicated that there was a significant difference between the 1-500ml /m2 group, P<0.05**

**Figure-3:** Comparison of lactic acid and oxygenation index in different groups of GEDI.

(r=0.606, p<0.001), the number of B-line areas and oxygenation index (r=-0.590, p<0.001), ELWI and lactic acid (r=0.886, p<0.001), and ELWI and oxygenation index (r=-0.553, p < 0.001).

## Discussion

Septic shock, also known as septic or toxic shock, is a medical condition caused by severe infection and sepsis. Early detection, timely diagnosis and effective treatment are the key to prevention. Fluid resuscitation is an indispensable treatment for patients with septic shock, but the control of fluid volume is constantly changing with the update of research. Current guidelines recommend the use of conservative fluid therapy strategy which brings more stringent requirements for the control of fluid volume. At present, there are many commonly used monitoring methods in the clinic, the most common one is the measurement of CVP, but CVP as an indicator of capacity load still has obvious shortcomings. Whether it is appropriate to use CVP as an indicator of capacity regulation is still controversial.8,9

Haemodynamic monitoring is very important in patients with severe shock or acute respiratory distress syndrome (ARDS). PICCO (pulse index contour cardiac output, pulse medical systems, Germany) system has been developed and used in critical care environment for several years. PICCO is an invasive haemodynamic monitoring measure, which can accurately reflect the body volume load and guide fluid therapy. Under the monitoring and guidance of PICCO technology, patients with septic shock were treated with EGDT combined with early fluid resuscitation and positive inotropic drugs, rather than using vasoconstrictor drugs alone, resulting in high blood pressure. Using PICCO haemodynamics to monitor the patients with severe septic shock can obtain more comprehensive indices such as blood volume, systemic vascular resistance, cardiac function, etc., and guide the selection of fluid resuscitation, antidiuretic drugs and inotropic drugs.

GEDI is a direct reflection of the state of cardiac capacity, which can more accurately reflect the true situation of cardiac capacity. Many experiments show that GEDI reflects cardiac preload better than CVP and other related indicators.[10,11] However, the procedure is complicated and expensive, and catheter-related complications may occur with invasive catheterization. The catheter-related blood flow infection will increase the mortality of critically ill patients.[12] GEDI targeted fluid resuscitation is better than central venous pressure in the treatment of septic shock, but it cannot reduce the mortality.

As one of the last stations for blood to flow into the heart, IVC's inner diameter and collapse degree have been used to evaluate the volume status of severe patients. Some studies suggest that the IVC diameter of patients with hypovolaemia is smaller than that of patients with normal blood volume while dilated and fixed IVC usually indicates that patients are in a state of volume overload.[13-15] Because IVC changes with blood flow and has a good correlation with blood volume, more and more clinicians use bedside ultrasound to assess volume load. The index of inferior vena cava collapse is one of the dynamic indexes for diagnosing hypovolemia in patients with septic shock, which is related to delta cardiac output after leg raising test. We believe that, based on the experience of clinicians, observing one of these two parameters is enough to determine the hypovolaemia of patients with septic shock.

Subsequently, the consistency between GEDI and IVC further proves this view. In the analysis of IVC and lactic acid and oxygenation index, it can be seen that the ideal range of IVC min control is $1.5 \leq IVC < 2cm$, and the ideal range of IVC max control is $2 \leq IVC < 2.5cm$. The farther away from this range, the worse the lactic acid and oxygenation index obtained. It proves that the volume of fluid can be adjusted by specific value of IVC during volume resuscitation, so as to achieve an ideal liquid load and conform to the current conservative fluid therapy strategy. In the analysis of GEDI and lactic acid and oxygenation index, it can be seen that the range of $700 \leq GEDI < 800mL/m^2$ is an ideal control range, which is consistent with the normal value of GEDI, but the trend of lactic acid and oxygenation index is not regular like IVC, which indicates that GEDI may be more individualized and not in the normal range of GEDI. It requires more consideration how to adjust the liquid volume. The correlation between the number of B-line areas and ELWI and the correlation between B-line areas and ELWI, lactic acid and oxygenation index showed that the two were meaningful in judging "lung water", and the severity changed proportionally with the change of index, so the volume of liquid could be adjusted by them. The study showed that the accuracy rate of CVP was lower than 50% when evaluating capacity, suggesting that the application of CVP in evaluating capacity is of limited significance and may lead to misleading clinical evaluation of capacity.[16-19] Both GEDI and IVC are more accurate than CVP and can be used as guidance for volume assessment. However, the evaluation of GEDI is also affected by specific diseases of patients. The accuracy of GEDI in patients with valvular heart disease is also lower, which cannot be used as a basis for volume assessment.[20-24]

## Conclusion

Fluid resuscitation needs to be guided by volume assessment in patients with septic shock. Critical care ultrasound and PICCO are both more ideal methods for volume assessment, but PICCO needs more individualized assessment, and PICCO is not recommended for patients with heart valve disease.

**Disclaimer:** I hereby declare that this research paper is my own and autonomous work. All sources and aids used have been indicated as such. All texts either quoted directly or paraphrased have been indicated by in-text citations. Full bibliographic details are given in the reference list which also contains internet sources. This work has not been submitted to any other journal for consideration.

**Conflict of Interest:** We declare that all contributing authors of this paper have no conflict of interest and all have contributed equally for this research work.

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