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Research article

Application of microcirculatory indicators in predicting the prognosis of patients with septic shock

Xiaoxu Ding [a,1], Yuanlong Zhou [b,1], Xin Zhang [a], Tao Sun [a], Na Cui [a], Shenghai Wang [a], Dan Su [a], Zhanbiao Yu [a,*]

[a] Department of Critical Care Medicine, Affiliated Hospital of Hebei University, Baoding 071000, China
[b] Department of Hepatobiliary Surgery, Affiliated Hospital of Hebei University, Baoding 071000, China

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ABSTRACT

Objective: The aim of this study is to investigate the predictive value of indicators associated with microcirculation, capillary refill time (CRT), perfusion index (PI), and mottling score, on the prognosis of patients with septic shock.
Method: A retrospective clinical study was conducted encompassing 78 patients diagnosed with septic shock and admitted to the Department of Critical Care Medicine at our hospital from January 2019 to January 2022. The study collated the clinical data of these patients, focusing on macrocirculatory hemodynamic parameters and microcirculatory indices. The parameters of interest were recorded at 0, 6, 24, and 48 h post-admission, including heart rate, mean arterial pressure (MAP), venous-to-arterial carbon dioxide partial pressure difference, superior vena cava oxygen saturation, lactic acid (LAC), CRT, PI, and mottling score. The enrolled patients were stratified into two cohorts based on the 28-day mortality rate: a survival group and a mortality group. A non-parametric statistical test was employed to compare the CRT, PI, and mottling score between the two groups. Furthermore, the predictive value of these microcirculatory indicators for mortality in septic shock patients was assessed using receiver operating characteristic (ROC) curve analysis. This methodology allowed for the evaluation of the prognostic accuracy of CRT, PI, and mottling score as indicators for mortality in the context of septic shock.
Results: The vasoactive drug dose, PI, LAC, mottling score, and CRT upon admission in the survival group were significantly better than those in the mortality group at hour 6 of treatment, hour 24 of treatment, and hour 48 of treatment ($P < 0.05$). The predictive value of the three microcirculatory indicators at various time points was highest for the Perfusion Index (PI) at 48 h of treatment, the mottling score at 24 h of treatment, and the Capillary Refill Time (CRT) upon admission. The Area Under the Curve (AUC) for PI at 48 h of treatment was 0.941 (0.885–0.996), with a sensitivity of 90.9 % and a specificity of 94.1 %. For the mottling score at 24 h of treatment, the AUC was 0.889 (0.805–0.972), with a sensitivity of 82.4 % and a specificity of 88.6 %. The AUC for CRT upon admission was 0.872 (0.788–0.956), with a sensitivity of 91.2 % and a specificity of 77.3 %. Among the three indicators: PI, mottling score, and CRT, PI at hour 48 of treatment had the highest predictive value for the prognosis of patients with septic shock.
Conclusion: Microcirculatory indicators have specific predictive value for the prognosis of patients with septic shock.

* Corresponding author. Department of Critical Care Medicine, Affiliated Hospital of Hebei University, No. 212 of Yuhua East Road, Baoding 071000, China.
E-mail address: yuzhanbiaoyzb0@outlook.com (Z. Yu).
[1] These authors contributed equally to this study.

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1. Introduction

The comprehension of septic shock has progressed from a focus on reduced arterial blood pressure to an association with impaired tissue oxygen supply and the capability of cells to utilize oxygen. The management of blood pressure is significant in the diagnosis and treatment of septic shock. However it is important to note that blood pressure is determined by peripheral vascular resistance and cardiac output, rather than tissue and organ blood flow and perfusion. Organ perfusion mostly manifests through various indicators at the microcirculation level and is not entirely determined by blood pressure. For patients diagnosed with septic shock, characterized by severe capillary leakage, merely increasing mean arterial pressure (MAP) cannot prevent the reduction of blood flow in organs and tissues [1]. Therefore, the key to successfully improving the prognosis of patients with septic shock lies in improving organ blood flow distribution and optimizing oxygen supply to tissue cells [2,3], rather than improving blood pressure only. Improvement in organ blood perfusion is commonly observed through improvements in indicators associated with microcirculation. A study investigating the treatment of experimental animal models of septic shock revealed that, despite a tendency for hemodynamics to normalize, microcirculatory disorders continued to progress [4]. Therefore, for patients with septic shock, the assessment of microcirculatory disorders plays a decisive role, and improving microcirculation associated factors have become a significant therapeutic objective in the treatment of patients with septic shock. It also has an important value for the prognosis. In the treatment of patients with septic shock, there is poor synchronization between macro-circulatory clinical parameters and microcirculatory perfusion-related parameters [5,6]. Normalizing microcirculatory perfusion is the ultimate therapeutic goal. Therefore, monitoring of microcirculation-related indicators has become increasingly important in clinical practice. There are numerous indicators for assessing microcirculation, such as tissue oxygen saturation (SPO2), skin oxygen partial pressure and skin carbon dioxide partial pressure, peripheral perfusion index (PI), mottling score, and capillary refill time (CRT). In clinical practice, the mottling score, CRT, and PI are convenient and assessable indicators. In addition, the three indicators have been used to evaluate and predict the prognosis of patients with septic shock in previous studies, suggesting the clinical value of these three indicators [7,8]. However, in clinical practice, we often find discrepancies in the changes of these three indicators. Therefore, this study focuses on which indicator among the PI, mottling score, and CRT has stronger guiding significance for predicting the mortality rate of patients with septic shock. In this study, we did not use the three indicators of CRT, PI, and mottling score at the same time point to predict sepsis mortality, as the calculated predictive effect was poor. This corresponds with the clinical observation that the three indicators often diverge at the same time point. In fact, we are primarily concerned with the individual predictive value of the three indicators at different time points, and then integrate the predictive results of these three indicators at different time points to predict sepsis mortality.

2. Study materials and method

2.1. General information

The clinical data of 78 patients with septic shock admitted to the Department of Critical Care Medicine of our hospital between January 2019 and June 2023 were compiled. The group consisted of 44 males and 34 females, with an average age of 70 $\pm$ 14 years. The primary diagnosis included severe pneumonia, urinary tract infection, enterogenic infection, and postoperative abdominal infection. During the study, a total of 34 patients succumbed, resulting in a 28-day mortality rate of 43.6 %. The patients were categorized into a survival group (44 individuals) and a mortality group (34 individuals) based on the 28-day mortality rate.

2.2. Inclusion criteria

Inclusion criteria were as follows: (1) Clear site of infection. (2) Vasopressors were needed to maintain blood pressure and systolic blood pressure greater than 90 mmHg. (3) Blood lactate level greater than 2 mmol/L.

2.3. Exclusion criteria

Patients less than 18 years of age, pregnant women, and patients with known peripheral vascular disease (e.g., peripheral arterial occlusive disease, vasculitis) were excluded from the study.

2.4. Treatment methods

All the patients enrolled in the study underwent invasive arterial puncture and continuous monitoring of arterial blood pressure. They also had a central venous catheter inserted to monitor the central venous pressure (CVP). Additionally, their vital signs such as heart rate, finger pulse oxygen, PI, CRT, and mottling score, were monitored. We strictly followed the *2021 International Guidelines for the Treatment of Sepsis and Septic Shock*, which were jointly published by the European Society of Intensive Care Medicine (ESICM) and the Society of Critical Care Medicine (SCCM) in October 2021. The treatment approach included monitoring blood lactate level, conducting blood culture prior to administering antibiotics, infusion of broad-spectrum antibiotics, rapid intravenous infusion of crystalloid at 30 mL/kg for patients with the level of hypotension or blood lactate $\geq$4 mmol/L, administration of vasoconstrictor drugs to raise the MAP to $\geq$65 mmHg if the hypotension remains during fluid infusion or after fluid infusion, administration of hydrocortisone using a micro pump and pituitrin for patients who could not achieve a mean arterial pressure $>$65 mmHg with a norepinephrine infusion rate exceeding 0.5 μg/kg/minute.

2.5. Monitoring indicators

The data compiled at the time of study enrollment included information such as age, gender, body mass index, site of infection, etiological results, usage of antibiotics extensively, acute physiology score II, and Sequential Organ Failure Assessment (SOFA) score. The following indicators were measured at certain intervals of time at 0, 6, 12, 24, and 48 h: heart rate, MAP, CVP, arterial blood lactate, venous-arterial carbon dioxide difference, superior vena cava oxygen saturation ($ScvO_2$), vasoactive drug dose, mottling score, CRT, and PI. The mortality rate of the patients within 28 days was also calculated.

2.6. Statistical methods

SPSS 26.0 software was employed to conduct a comparison of the data at the group level, enabling the plotting of ROC curves. The normally distributed data are expressed as mean ± standard deviation ($\overline{X} \pm s$). Differences in indicators with normally distributed data between the two groups were assessed using the independent samples *t*-test. Non-normally distributed data are expressed as quartiles [p50 (p25, p75)], and the differences of the indicators with non-normally distributed data between the two groups were examined using the nonparametric Mann-Whitney *U* test. A difference was statistically significant when it had a p-value less than 0.05. We used the "Hmisc" package of the R software to calculate the correlations and p-values between indicators such as PI, mottling score, CRT, NE, SOFA and APACHE-II.

3. Results

3.1. General conditions of the patients

The age, gender, infection site, Acute Physiology Score II, SOFA score, and vasopressor dosage after 6 h of treatment of the 78 patients who met the criteria are presented in Table 1.

3.2. Hemodynamic parameters of the two groups of patients with septic shock after 6 h, 12 h, 24 h, and 48 h of treatment

Based on the results of the difference comparison (Table 2), it is evident that the indicator of heart rate exhibited a significantly higher level in the mortality group upon admission and at hour 48 of treatment than in the survival group ($P < 0.05$). However, the differences between the mortality group and the survival group at hour 6 of treatment and hour 24 of treatment were not found to be statistically significant ($P > 0.05$). The level of MAP between the mortality group and the survival group at the time of admission was not statistically significant ($P > 0.05$). However, it was significantly higher in the survival group at hour 6 of treatment, hour 24 of treatment, and hour 48 of treatment than in the mortality group ($P < 0.05$). The differences between the mortality group and survival group in terms of the vasoactive drug dose, $ScvO_2$% upon admission and at hour 6 of treatment were not significant ($P > 0.05$). However, these indicators at hour 24 of treatment and hour 48 of treatment in the survival group were significantly higher than those in the mortality group ($P < 0.05$). At the time admission, there was no statistically significant difference in the level of lactic acid (LAC) between the mortality group and the survival group ($P > 0.05$), but it was significantly higher in the survival group than in the mortality group after hour 6 of treatment, hour 24 of treatment, and hour 48 of treatment ($P < 0.05$). PI, mottling score, and CRT treatment at hour 6, hour 24, and hour 48 in the survival group were all significantly better than those in the mortality group ($P <$ 0.05).

Table 1
Basic information of patients with septic shock.

Item	Numerical value
Age [years, M (P_{25}, P_{75})]	70 (60.0,80.5)
Female/case (%)	34 (43 %)
Lung infection	32
Abdominal infection	14
Bloodstream infection	5
Biliary infection	11
Intracranial infection	2
Intestinal infection	4
Urinary tract infection	7
Infections in other parts of the body	3
SOFA [score, M (P_{25}, P_{75})]	13 (8,20)
APACHE II [score, M (P_{25}, P_{75})]	18 (12,23)
NE after 6 h of treatment [ug/kg/min, M (P_{25}, P_{75})]	0.6 (0.2,0.8)

Table 2
Hemodynamic indicators of 28-day mortality in patients with septic shock.

	Survival group (n = 44)	Mortality group (n = 34)	z/t	p
Heart rate [p50 (p25, p75)]				
At admission to the department	94 (78,113)	108 (87,120.25)	-2.073^z	0.038
Hour 6 of treatment	78 (68,95.75)	87 (76.75,98.75)	-1.479^z	0.139
Hour 24 of treatment	76 (67,85.5)	78 (67.75,87.5)	-1.081^z	0.28
Hour 48 of treatment	68 (65,76)	77 (67,89)	-2.994^z	0.003
MAP [p50 (p25, p75)]				
At admission to the department	55 (54,57)	55 (45.75,56)	-1.235^z	0.217
Hour 6 of treatment	65.5 (65,67.75)	65 (56,65.25)	-3.289^z	0.001
Hour 24 of treatment	69 (67,75)	66 (64,67.25)	-3.638^z	<0.001
Hour 48 of treatment	75.5 (71.25,78)	68 (63,72.5)	-5.025^z	<0.001
Vasoactive drug dose [p50 (p25, p75)]				
At admission to the department	0.5 (0.4,0.6)	0.6 (0.5,0.8)	-1.52^z	0.025
Hour 6 of treatment	0.4 (0.3,0.5)	0.5 (0.4,0.7)	-1.293^z	0.03
Hour 24 of treatment	0.35 (0.2,0.5)	0.65 (0.4,0.93)	-4.498^z	<0.001
Hour 48 of treatment	0.2 (0.03,0.38)	0.7 (0.4,0.83)	-5.689^z	<0.001
PI [p50 (p25,p75)]				
At admission to the department	1.4 (1.1,1.5)	0.57 (0.14,1.13)	-4.765^z	<0.001
Hour 6 of treatment	1.7 (1.5,2.3)	0.73 (0.43,1.42)	-5.666^z	<0.001
Hour 24 of treatment	2.4 (2.1,3.2)	0.65 (0.4,1.4)	-6.259^z	<0.001
Hour 48 of treatment	2.95 (2.42,3.35)	1.1 (0.43,1.4)	-6.653^z	<0.001
LAC [p50 (p25,p75)]				
At admission to the department	2.8 (2.5,3.2)	3.4 (2.6,4.6)	-2.823^z	0.03
Hour 6 of treatment	1.85 (1.4,2.38)	2.8 (2.1,4.3)	-4.332^z	<0.001
Hour 24 of treatment	1.4 (1.2,1.6)	2.5 (1.5,4.38)	-4.899^z	<0.001
Hour 48 of treatment	1.1 (1,1.38)	2.05 (1.48,3.78)	-5.825^z	<0.001
Mottling score [p50 (p25, p75)]				
At admission to the department	0 (0,1)	3 (2,3)	-5.612^z	<0.001
Hour 6 of treatment	0 (0,1)	2 (1.75,3)	-5.795^z	<0.001
Hour 24 of treatment	0 (0,0)	2 (1,3)	-6.561^z	<0.001
Hour 48 of treatment	0 (0,0)	2 (1,3)	-6.501^z	<0.001
CRT [p50 (p25,p75)]				
At admission to the department	1 (1,1)	2 (2,3)	-6.03^z	<0.001
Hour 6 of treatment	1 (1,1)	2 (1,3)	-5.28^z	<0.001
Hour 24 of treatment	1 (1,1)	2 (1,3)	-5.188^z	<0.001
Hour 48 of treatment	1 (1,1)	2.5 (1,3)	-5.7^z	<0.001
ScVO2% [p50 (p25,p75)]				
At admission to the department	58 (54,65)	57 (54,65)	-0.877^z	0.381
Hour 6 of treatment	64 (59.5,65)	62 (55.5,64.25)	-2.683^z	0.007
Hour 24 of treatment	65 (63,67)	59 (54,65)	-4.539^z	<0.001
Hour 48 of treatment	65 (63,68)	55.5 (54,64.75)	-4.307^z	<0.001

Note: MAP: mean arterial pressure, PI: peripheral vascular perfusion index, LAC: lactic acid, CRT: capillary refill time, $ScvO_2$%: central venous oxygen saturation, $_Z$: the non-parametric Mann-Whitney *U* test, and t: independent sample *t*-test.

3.3. Correlation study among multiple indicators

This study compared the correlation between microcirculatory indicators (mottling score, CRT, and PI) at multiple time points and SOFA scores, APACHE-II, and the average dose of norepinephrine (NE) used. It was found that PI was negatively correlated with SOFA scores and APACHE-II, while the mottling score and CRT were positively correlated with SOFA scores and APACHE-II. The PI values at baseline (0 h), and at 6, 24, and 48 h post-treatment all exhibited negative correlations with the SOFA score, but the correlations were relatively low, with R values ranging from −0.26 to −0.36. Correlation studies between PI at the four time points and APACHE-II revealed negative correlations only at 6 and 24 h post-treatment, with R values of −0.23 and −0.26, respectively. The mottling score at 0, 6, and 24 h post-treatment showed positive correlations with the SOFA score, with R values of 0.31, 0.30, and 0.26, respectively. The mottling score at 6 h post-treatment was positively correlated with APACHE-II, with an R value of 0.24. CRT values at 24 and 48 h post-treatment were positively correlated with the SOFA score, with R values of 0.27 and 0.23, respectively, but showed no correlation with APACHE-II. All microcirculatory indicators, regardless of the time point, were correlated with the average dose of norepinephrine. Specifically, PI showed a negative correlation, while CRT and the mottling score showed positive correlations with the dose of NE. (Pictures of the attached materials)

3.4. Predictive value of microcirculation-related indicators on 28-day mortality

3.4.1. Predictive value of PI on 28-day mortality

The ROC curve for PI predicting outcomes was plotted (Fig. 1), revealing that PI exhibited a significant predictive value for determining the mortality of the patient within 28 days. The area under the curve (AUC) of PI measured at hour 48 was 0.941, and the confidence interval was 0.885–0.996. This revealed that PI within 48 h of treatment has the highest diagnostic accuracy.

3.4.2. Predictive value of mottling score on 28-day mortality of patients

The ROC curve for the mottling score predicting outcomes was plotted (Fig. 2), revealing that the mottling score demonstrated a significant predictive value for determining the mortality the patient within 28 days. The AUC of the mottling score measured at hour 24 was 0.889, and the confidence interval was 0.805–0.972. This showed that the mottling score measured at hour 24 after treatment has the highest diagnostic accuracy.

3.4.3. Predictive value of CRT on 28-day mortality

The ROC curve was plotted to evaluate the predictive performance of CRT in determining patient outcomes. The analysis indicated that CRT demonstrated significant predictive capability in determining the mortality of patients within 28 days. The AUC of CRT measured at admission was 0.872, and the confidence interval was 0.788–0.956. This revealed that the CRT at admission has the highest diagnostic accuracy.

3.5. Comparison of the predictive value of mottling score, CRT, and PI on 28-day mortality

The analysis of the three ROC curves in Figs. 1–3 showed that among the three indicators, namely PI at hour 48 of treatment, mottling score at hour 24 of treatment, and CRT, PI at hour 48 of treatment had significant effect on septic shock and exhibited the highest predictive value for patient prognosis.

3.6. Predictive value of SOFA score versus Apache II score for mortality

The study utilized the Sequential Organ Failure Assessment (SOFA) score and the Acute Physiology and Chronic Health Evaluation (APACHE) II score to plot the Receiver Operating Characteristic (ROC) curves. The associated parameters indicated that the SOFA score had an area under the curve (AUC) of 0.952 (0.902–1), a sensitivity of 0.932, and a specificity of 0.588. The APACHE II score had an AUC of 0.782 (0.6796–0.886), a sensitivity of 0.886, and a specificity of 0.735. Compared to Capillary Refill Time (CRT) and Sequential Monitoring of Sublingual Capillary Hemodynamics (SMS), Perfusion Index (PI), the SOFA score demonstrated superior sensitivity but lower specificity. The APACHE II score's sensitivity for predicting mortality was lower than that of CRT at admission and PI at 48 h, with a also lower specificity (Table 3 and Fig. 4).

4. Discussion

In our study, it was discovered that indicators related to microcirculation exhibit a high predictive value for patient prognosis, both upon admission and throughout the course of treatment. It was observed that mottling score, CRT, and PI are more predictive and more effective than the vital signs of patients such as heart rate, blood pressure, vasopressor dosage, and lactate level. Two decades ago, alterations in sublingual microvessels were initially observed in patients with sepsis, prompting the initiation of investigations into human microcirculation [5]. These changes include a decrease in microcirculatory vessel density and a decrease in the proportion of perfused vessels [9,10]. These changes are associated with poor patient prognosis [11–15]. There are differences in micro vascular

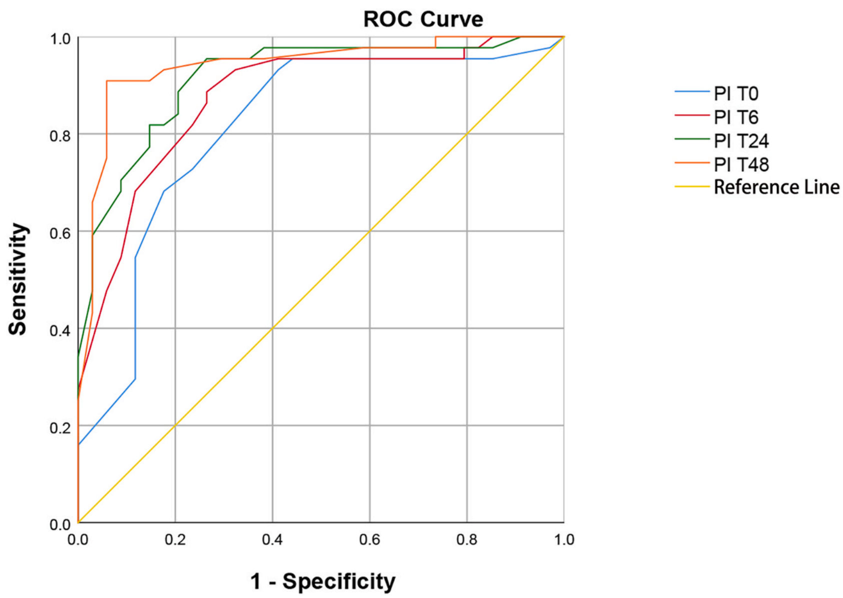

Fig. 1. ROC curve of PI predicting outcome.

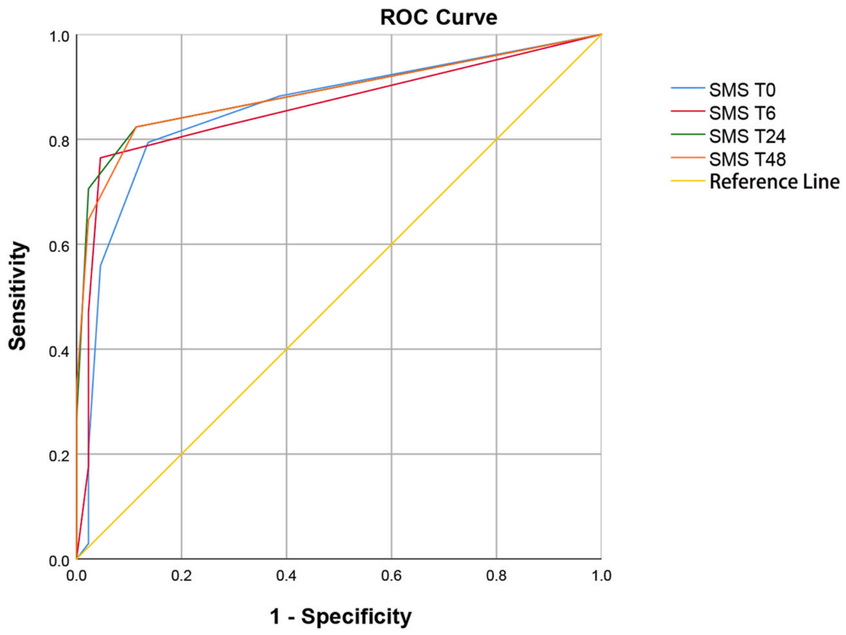

Fig. 2. ROC curve of mottling score predicting outcome.

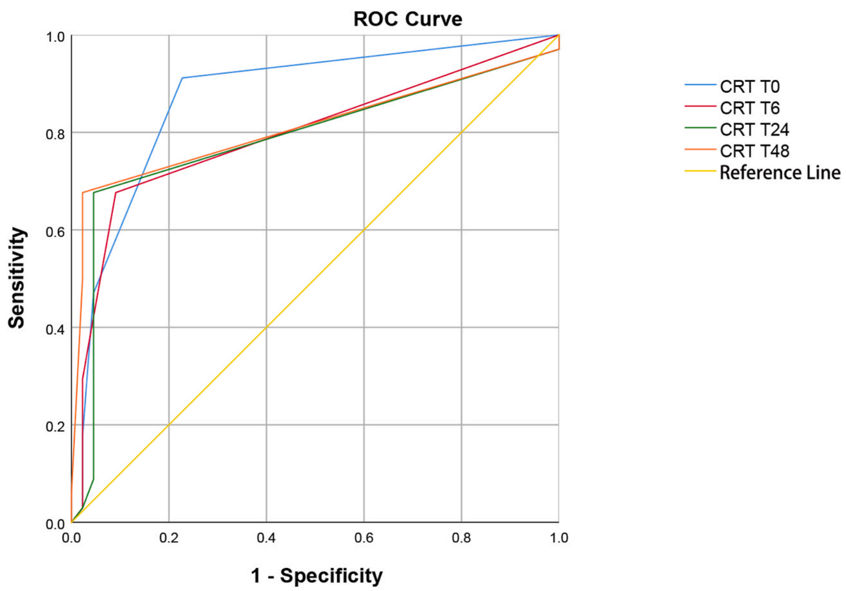

Fig. 3. ROC curve of CRT predicting outcome.

Table 3
Relevant parameters obtained from ROC curve drawed by SOFA score and APACHE II score.

Variables	Roc (95 % Ci)	Standard Error	Significance	Sensitivity	Specificity
SOFA	0.952 (0.902–1)	0.026	<0.001	0.932	0.588
APEACH II score	0.782 (0.6796–0.886)	0.053	<0.001	0.886	0.735

changes between patients whose condition improves and those whose condition does not improve after clinical intervention. In a study conducted by Hilty et al., it was identified that the microcirculation in sepsis is characterized by a substantial proportion of capillaries flowing at a low speed (100 μm/s), compared with other capillaries exhibiting a normal speed (400–500 μm/s) [16].

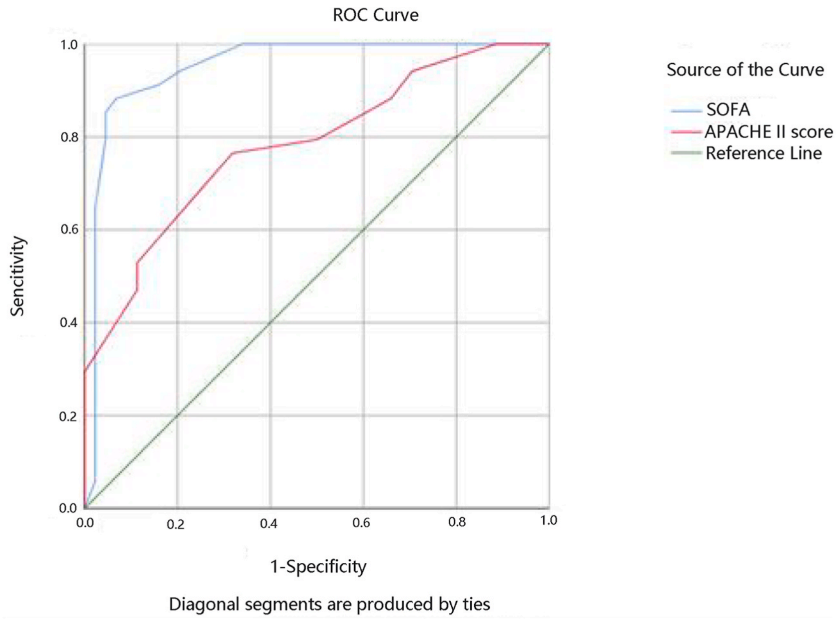

Fig. 4. Predictive value of SOFA score versus APACHE II score for mortality.

The approach employed to enhance microcirculation is termed fluid resuscitation, a method that has been substantiated to be effective in improving microcirculation in patients with septic shock. However, the amount of fluid required varies greatly between individuals [17]. Moreover, enhancement in microcirculation caused by fluid rehydration is often correlated with improvements in organ function over a span of 24 h [18]. Currently, the investigation of whether fluid resuscitation leads to improved circulation has emerged as a prominent area of research [18,19]. In addition, inotropes have a positive effect on improving microcirculation. For instance, low-dose dobutamine improves microcirculation in some patients and can lead to a decrease in LAC. These enhancements exhibit a direct correlation with the amelioration of microvascular perfusion [20,21]. Typically, vasodilator drugs, such as acetylcholine, nitroglycerin, prostacyclin, and others, are commonly employed to improve microcirculation [5,22,23]. However, current findings do not reflect optimal outcomes, and positive clinical results have yet to be confirmed. Clinical experiments have demonstrated that Vitamin C is effective in improving microcirculation in animal models of sepsis induced by peritonitis.

In summary, the impact of organ dysfunction on microcirculation and its ability to predict clinical prognosis have gradually attracted significant interest. The direction of fluid resuscitation guided by pertinent microcirculatory indicators has emerged as a focal point of research. However, it may be premature to use microcirculatory indicators to guide septic shock management at the bedside or even in clinical trials. There is a lack of therapies that can effectively and consistently enhance microcirculation in the majority of the patients. Even when significant results are observed within a study population, the effects of the intervention vary widely between individuals. Secondly, there are numerous microcirculation-related indicators. According to observational studies, persistent abnormal PI after fluid resuscitation is correlated with severe organ failure [24] and high mortality [25]. CRT is a practical and noninvasive technique used for assessing peripheral perfusion [8,26]. CRT exhibits rapid response to fluid resuscitation [26,27], and monitoring of CRT can provide guidance for treatment [28]. Nevertheless, the question persists as to whether the objective should be the normalization of microcirculation or merely a specific degree of improvement. Determining which variable should attain a specific target value to achieve the desired outcome of fluid resuscitation poses a challenge. Of course, limited by the sample size of this study, we studied more single indicators and failed to increase indicators such as the duration of vasoactive drug use and length of hospital stay. Concurrently, we implemented a series of measures to address the challenge of a small sample size. For instance, we utilized the SPSS 26.0 statistical analysis software for comparative analysis of data and to plot ROC curves. Independent samples t-tests were employed for difference comparisons, and non-parametric Mann-Whitney U tests were used for non-parametric comparisons. The R package 'Hmisc' was utilized to calculate correlations and p-values, which offer greater objectivity in handling small sample data. Therefore, even with a limited sample size, our study results still demonstrated the predictive value of microcirculation-related indicators at different time points for mortality rates. We will increase the sample size to further investigate more observation indicators in future studies. In addition to the above, we must acknowledge that, as always, determining the causal relationships between influencing factors in this study is challenging. These microcirculatory indicators—PI, mottling score, and CRT—might be the result of vasoactive medications. So their relationship to the ultimate outcome of death is actually largely unknown. Due to the limited sample size of this study, further interventional research or the use of marginal structural models combined with inverse probability weighting methods [29] is needed to explore the causal relationships between them. Caution should be exercised when interpreting the conclusions of this study.

5. Conclusion

In the treatment of patients with septic shock, the primary objective is to promptly identify and address tissue hypo-perfusion. The mottling score, CRT, and PI are all reliable indicators in assessing microcirculation disorders in patients with septic shock. Furthermore, they demonstrate significant predictive value for determining the prognosis of patients with septic shock. The 48-h PI has the highest predictive value for the prognosis of patients with septic shock.

Ethics approval and consent to participate

This study was conducted with approval from the Ethics Committee of Affiliated Hospital of Hebei University. This study was conducted in accordance with the declaration of Helsinki. Written informed consent was obtained from all participants.

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Data availability

Data associated with our study hasn't been deposited into a publicly available repository. Data will be made available on request.

CRediT authorship contribution statement

Xiaoxu Ding: Writing – original draft, Formal analysis, Conceptualization. **Yuanlong Zhou:** Writing – review & editing, Formal analysis, Data curation. **Xin Zhang:** Formal analysis, Data curation. **Tao Sun:** Formal analysis, Data curation. **Na Cui:** Funding acquisition, Formal analysis. **Shenghai Wang:** Formal analysis, Data curation. **Dan Su:** Funding acquisition, Formal analysis. **Zhanbiao Yu:** Writing – review & editing, Funding acquisition, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

List of abbreviations

MAP	mean arterial pressure
CVP	central venous pressure
PI	perfusion index
ROC:	Receiver Operating Characteristic
LAC	lactic acid
CRT	capillary refill time
SBP	systolic blood pressure
ESICM	European Society of Intensive Care Medicine
SCCM	Society of Critical Care Medicine

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e38035.

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