BACKGROUND
Sepsis usually causes hemodynamic abnormalities. Hemodynamic index is one of the factors to identify the severity of sepsis and an important parameter to guide the procedure of fluid resuscitation. The present study investigated whether the assessment of hemodynamic indices can predict the outcomes of septic patients undergoing resuscitation therapy.

AIM
To evaluate the prognostic value of hemodynamic indices in patients with sepsis after fluid resuscitation.

METHODS
A retrospective study was conducted in 120 patients with sepsis at Hainan General Hospital/Hainan Affiliated Hospital of Hainan Medical University between October 2016 and October 2019. All patients were treated with sodium chloride combined with dextran glucose injection for fluid resuscitation. Patients’ hemodynamic parameters were monitored, including heart rate (HR), cardiac index (CI), systemic vascular resistance index (SVRI), mean arterial pressure (MAP), central venous pressure (CVP), and central venous oxygen saturation. The prognostic value of hemodynamic indices was determined based on the prognosis status.

RESULTS
During fluid resuscitation, 86 patients developed septic shock and 34 did not. Ninety-nine patients survived and 21 patients died at 28 d after the treatment. Heart rate, CI, mean arterial pressure, SVRI, and CVP were higher in patients with septic shock and patients who died from septic shock than in non-shock patients and patients who survived, and central venous oxygen saturation was lower in...
patients with shock and patients who died than in non-shock patients and the survivors \( (P < 0.05) \). When prognosis was considered as a dependent variable and hemodynamic parameters was considered as independent variables, the results of a logistic regression analysis showed that CI, SVRI, and CVP were independent risk factors for septic shock, and CI was an independent risk factor for 28-d mortality \( (P < 0.05) \).

**CONCLUSION**

Hemodynamic indices can be used to evaluate the prognosis of septic patients after fluid resuscitation.

**Key Words:** Sepsis; Fluid resuscitation; Cardiac index; Systemic vascular resistance index; Mean arterial pressure

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**INTRODUCTION**

Sepsis is a series of reactions that occur when an organism is in the state of being infected. Severe sepsis is usually complicated with organ dysfunction and even shock with a high fatality rate\([1,2]\). Clinical studies\([3,4]\) showed that treatment initiated as early as possible can effectively reduce the fatality rate. Currently, the most commonly used therapy for the treatment of sepsis is fluid resuscitation, which aims to maintain hemodynamic stability and slow progression of the disease\([5]\). During fluid administration, large amounts of fluids entering the body may increase the work load of the heart\([6]\). Hemodynamic monitoring helps to observe the heart’s pumping function and analyze patient outcomes\([7]\). The most frequently monitored hemodynamic indices probably include heart rate (HR), cardiac index (CI), mean arterial pressure (MAP), systemic vascular resistance index (SVRI), central venous pressure (CVP), and central venous oxygen saturation (ScvO2)\([8,9]\). The present study tried to discuss the prognostic value of hemodynamic indices in patients with sepsis after fluid resuscitation to provide data to promote the treatment for sepsis.

**MATERIALS AND METHODS**

**General information**

A retrospective analysis was conducted in 120 patients with sepsis treated at Hainan General Hospital/Hainan Affiliated Hospital of Hainan Medical University between October 2016 and October 2019. Sodium chloride combined with dextran glucose injection was administrated for fluid resuscitation in all the patients. Patients enrolled in the study included 40 with respiratory system infection, 30 with urinary system infection, 16 with digestive system infection, 15 with nervous system infection, and 19 with other infection. Patients were eligible for the study if they were diagnosed with
sepsis at the age of 18 to 70 years old and was informed and signed the consent form\(^1\). Non-sepsis patients with poor basic state and unable to cooperate in the study, patients with circulation system disease and unavailability of medical records, and patients unable to complete the treatment because of themselves or their families were excluded from the study.

Among the 120 patients, 76 were male and 44 were female with an average age of 63.23 ± 12.32 (range, 18-69) years old. Acute physiology and chronic health evaluation II score was 9 to 24 (mean, 14.23 ± 5.64).

**Methods**

Septic patients were monitored for hemodynamic changes. Central venous catheters were inserted into the internal jugular or subclavian vein under the guidance of CVP test. Fiber optic catheters were then inserted into the central venous catheters to continuously monitor ScvO\(_2\). Catheters indwelled in the radial artery were connected with an Edwards Vigileo Monitor (produced by Edwards Lifesciences) to continuously monitor HR, CI, MAP, and SVRI by pulse contour analysis of waveform\(^{[11]}\).

**Measures**

Observation measures included: (1) Outcomes of patients with sepsis; (2) Analysis of relationship between hemodynamic indices and the outcomes in patients with sepsis after the treatment; and (3) Analysis of prognosis in septic patients after the treatment.

**Statistical methods**

SPSS22.0 was used to process the data. Measurement data with a normal distribution are expressed as the mean ± SD and inter-group difference was compared using Student’s \(t\) test. Enumeration data are expressed with percentages and inter-group difference was compared using \(\chi^2\) tests or Fisher’s exact test. Logistic analysis was used to estimate the prognosis. \(P < 0.05\) represented that there was a significant difference.

**RESULTS**

In terms of outcomes in the 120 patients undergoing fluid resuscitation, septic shock occurred in 86 patients and at 28 d after the treatment, 99 patients survived.

After analyzing the relationship between hemodynamic indices and the outcomes in patients with sepsis after the treatment, it was found that HR, CI, MAP, SVRI, and CVP were higher in septic shock patients and patients who died than non-shock patients and patients who survived. However, ScvO\(_2\) was lower in septic shock patients and patients who died than non-shock patients and patients who survived \((P < 0.05); \text{Table 1}\).

Hemodynamic parameters were used as the independent variables to analyze the prognosis using Logistic analysis. The results showed that CI, SVRI, and CVP were independent risk factors for the occurrence of septic shock and CI was an independent risk factor for 28 d mortality \((P < 0.05); \text{Table 2}\). Analysis of the relationship between hemodynamic indices and death at 28 d after the treatment revealed a B value of 0.314 and an SE value of 0.043 (odds ratio = 0.751, 95% confidence interval: 0.751-0.872, \(P = 0.01\)).

**DISCUSSION**

Sepsis is one of the most common causes of death in patients admitted in the intensive care unit. Clinical features of sepsis often include systemic inflammatory response and even damage to multiple organs. Severe cases of sepsis may develop into septic shock, which may further lead to multiple organ dysfunction with a fatality rate up to 35% to 70% \(^{[12-14]}\). Sepsis occurs when the body have a probable or confirmed infection or trauma. The development of infection and trauma will cause systemic inflammatory response, which in turn causes secretion of inflammatory mediators followed by cardiovascular dysfunction with the presence of decreased effective circulating volume, hemodynamic changes including fall of blood pressure, and septic shock \(^{[11]}\).

Hemodynamic monitoring, which is usually used in the diagnosis and treatment of cardiovascular dysfunction, could also be used in sepsis patients with septic shock whose hemodynamic stability is vulnerable to the influence of trauma and infection. Hemodynamic changes vary in different periods of development in patients with...
Table 1 Relationship between hemodynamic indices and outcomes in patients with sepsis after the treatment (mean ± SD)

| Prognosis     | n     | HR (bpm) | CI (L/min/m²) | MAP (mm Hg) | SVRI (dyn/s/cm⁵/m²) | CVP (mm Hg) | ScvO₂(%) |
|---------------|-------|----------|---------------|-------------|---------------------|-------------|----------|
| Short-term prognosis |       |          |               |             |                     |             |          |
| Shock         | 86    | 109.12 ± 9.53 | 4.48 ± 0.87  | 54.21 ± 20.12 | 1479 ± 297          | 4.46 ± 1.22 | 67.37 ± 19.35 |
| Non-shock     | 34    | 102.16 ± 7.34  | 4.17 ± 0.83  | 49.32 ± 19.59  | 1421 ± 243          | 4.12 ± 1.09  | 71.56 ± 21.22  |
| 28-d          |       |          |               |             |                     |             |          |
| Death         | 21    | 132.26 ± 11.23 | 4.85 ± 0.94  | 55.60 ± 22.16 | 1493 ± 276          | 4.82 ± 1.03  | 61.28 ± 17.75  |
| Survival      | 99    | 95.11 ± 9.14   | 4.28 ± 0.65  | 50.92 ± 19.33  | 1435 ± 239          | 4.23 ± 1.39  | 67.84 ± 25.56  |

*a* P < 0.05 compared with shock patients.

*b* P < 0.05 compared with patients who died. HR: Heart rate; CI: Cardiac index; MAP: Mean arterial pressure; SVRI: Systemic vascular resistance index; CVP: Central venous pressure; ScvO₂: Central venous oxygen saturation.

Table 2 Relationship between hemodynamic indices and shock

| Variable | B value | SE value | P value | OR value | 95%CI    |
|----------|---------|----------|---------|----------|----------|
| CI       | 0.234   | 0.032    | 0.01    | 0.812    | 0.875-0.912 |
| SVRI     | 0.345   | 0.043    | 0.01    | 0.823    | 0.889-0.992  |
| CVP      | 0.145   | 0.023    | 0.01    | 0.762    | 0.712-0.896  |

CI: Cardiac index; SVRI: Systemic vascular resistance index; CVP: Central venous pressure.

In the early phase of sepsis, it is normally characterized by high output-normal resistance and increased cardiac output and CI, and normal or decreased SVRI specifically. As the disease progresses, it is characterized with high output-low resistance and accelerated heart rate, obviously increased cardiac output, and decreased SVRI. In view of this, hemodynamic indices could become one of the factors for prediction of disease state and prognosis in patients with severe sepsis.

Studies found that fluid resuscitation under the guidance of hemodynamic monitoring helps to improve the treatment efficacy and outcomes in septic patients with myocardial injury. Stimulated by endotoxin, the release of myocardial-depressant-factor increased and then causes unbalanced mechanisms of local blood flow regulation that finally may lead to myocardial ischemia and anoxia and decrease in SVRI, and a series of changes in hemodynamic indices.

In the present study, crystalloid and colloid solutions were added to sodium chloride injection and dextran glucose injection administered for fluid resuscitation to maintain plasma colloid osmotic pressure and increase blood volume and improve microcirculation. In addition, hemodynamic monitoring can prevent the occurrence of heart failure due to circulatory overload caused by a large quantity of liquid entering the body. The results of the present study suggested that HR, CI, MAP, SVRI, and CVP were higher and ScvO₂ was lower in the early phase of shock and patients who died than in patients without shock and patients who survived. Logistic regression analysis showed that CI, SVRI, and CVP were independent risk factors for the occurrence of septic shock and CI was an independent risk factor for the occurrence of death at 28 d after the treatment. This hinted that clinical manifestations such as hemodynamic abnormalities, decrease in ScvO₂, and microcirculatory hypoperfusion were frequent in patients with severe sepsis. The prognosis can be predicted through the use of hemodynamic monitoring.

**CONCLUSION**

Hemodynamic indices are associated with the prognosis in patients with sepsis and they can be used as the factors for the prediction of changes in patients’ conditions and prognosis. Moreover, hemodynamic indices can be used to guide the procedure of fluid resuscitation. Further studies are needed to compare the changes in hemodynamic indices.
ARTICLE HIGHLIGHTS

Research background
Sepsis is always associated with high mortality. Early diagnosis and appropriate treatment help to improve outcomes. Like markers such as body temperature, leukocyte count, C-reactive protein, and procalcitonin as well as tumor necrosis factor-alpha, interleukin (IL)-6, IL-8, IL-10, and HLA-DR expression, hemodynamic indices guide clinicians to make a reasonable decision. However, no specific markers for sepsis have been identified.

Research motivation
Hemodynamic monitoring is essential to the care of septic patients. By assessing the hemodynamic indices, patient condition is determined so that timely subsequent interventions will be given accordingly. Whether its role is as important as the above-mentioned markers or factors in the management of sepsis? The present study reported the performance of hemodynamic indices for predicting the outcomes including risk of shock and mortality in septic patients.

Research objectives
To discuss the potential predictive and prognostic value of hemodynamic indices for relevant clinical outcomes in patients with sepsis.

Research methods
Hemodynamic indices were monitored in patients with sepsis, including heart rate (HR), cardiac index (CI), mean arterial pressure (MAP), systemic vascular resistance index (SVRI), central venous pressure (CVP), and central venous oxygen saturation (ScvO2). The differences in hemodynamic indices were compared between patients with shock and patients without shock and between non-survivors and survivors.

Research results
The results revealed that HR, CI, MAP, SVRI, and CVP were higher in septic shock patients and non-survivors than in non-shock patients and survivors. However, ScvO2 was lower in septic shock patients and non-survivors than in non-shock patients and survivors.

Research conclusions
Patients with high HR, CI, MAP, SVRI, and CVP levels and low ScvO2 level probably develop severe disease or experience worsening disease. Hemodynamic indices may have predictive value for the outcomes and prognosis in patients with sepsis.

Research perspectives
Recently, studies showed that static measures were replaced by dynamic measures for the prediction of fluid responsiveness and cardiac performance. In view of this, studies in the future should take the dynamic markers into consideration.

REFERENCES
1 Corl KA, Prodromou M, Merchant RC, Gareen I, Marks S, Banerjee D, Amass T, Abbasi A, Delcompare C, Palmisciano A, Aliotta J, Jay G, Levy MM. The Restrictive IV Fluid Trial in Severe Sepsis and Septic Shock (RIFTS): A Randomized Pilot Study. Crit Care Med 2019; 47: 951-959 [PMID: 30985449 DOI: 10.1097/CCM.0000000000003779]
2 Rochwerg B, Alhazzani W, Sindi A, Heels-Ansdell D, Thabane L, Fox-Robichaud A, Mbuagbaw L, Szczeklik W, Alshamsi F, Alsayyari S, Ip WC, Li G, Wang M, Wdarczyk A, Zhou Q, Guyatt GH, Cook DJ, Jaeschke R, Annane D; Fluids in Sepsis and Septic Shock Group. Fluid resuscitation in sepsis: a systematic review and network meta-analysis. Ann Intern Med 2014; 161: 347-355 [PMID: 25047428 DOI: 10.7326/M14-0178]
3 Macdonald SPJ, Taylor DM, Keijzers G, Arends G, Fatovich DM, Kinnear FB, Brown SGA, Bellomo R, Burrows S, Fraser JF, Litton E, Ascencio-Lane JC, Anstey M, McCutcheon D, Smart L,
Xu HP et al. Prognostic value of hemodynamic indices in sepsis patients

Vlad I, Winearls J, Wibrow B. REstricted Fluid REsuscitation in Sepsis-associated Hypotension (REFRESH): study protocol for a pilot randomised controlled trial. Trials 2017; 18: 399 [PMID: 28851407 DOI: 10.1186/s13063-017-2137-7]

4 Byrne L, Van Haren F. Fluid resuscitation in human sepsis: Time to rewrite history? Ann Intensive Care 2017; 7: 4 [PMID: 28305897 DOI: 10.1186/s13613-016-0231-8]

5 Bhatia PK, Biyani G. Fluid resuscitation in severe sepsis and septic shock: Shifting goalposts. Indian J Anaesth 2015; 59: 269-271 [PMID: 26019350 DOI: 10.4103/0019-5049.156862]

6 Rochwerg B, Wudarczyk A, Szczeklik W, Alhazzani W, Sindi A, Alshamsi F, Ip WC, Wang M, Altayyar S, Li G, Fox-Robichaud A, Guyatt G; FISSH group. Fluid resuscitation in severe sepsis and septic shock: systematic description of fluids used in randomized trials. Pol Arch Med Wewn 2013; 123: 603-608 [PMID: 24185099 DOI: 10.20452/pamw.1972]

7 Tigabu BM, Davari M, Kebrizaezzadeh A, Motjahedzadeh M. Fluid volume, fluid balance and patient outcome in severe sepsis and septic shock: A systematic review. J Crit Care 2018; 48: 153-159 [PMID: 30199843 DOI: 10.1016/j.jccr.2018.08.018]

8 Marik PE, Linde-Zwirble WT, Bittner EA, Sahatjian J, Hansell D. Fluid administration in severe sepsis and septic shock, patterns and outcomes: an analysis of a large national database. Intensive Care Med 2017; 43: 625-632 [PMID: 28130687 DOI: 10.1007/s00134-016-4675-y]

9 Cheung WK, Chau LS, Mak II, Wong MY, Wong SL, Tiwari AF. Clinical management for patients admitted to a critical care unit with severe sepsis or septic shock. Intensive Crit Care Nurs 2015; 31: 359-365 [PMID: 26292920 DOI: 10.1016/j.iccn.2015.04.005]

10 Leisman D, Wie B, Doerfler M, Bianculli A, Ward MF, Akerman M, D’Angelo JK, Zemmel D’Amore JA. Association of Fluid Resuscitation Initiation Within 30 Minutes of Severe Sepsis and Septic Shock Recognition With Reduced Mortality and Length of Stay. Ann Emerg Med 2016; 68: 298-311 [PMID: 27085369 DOI: 10.1016/j.annemergmed.2016.02.044]

11 Leisman DE, Goldman C, Doerfler ME, Masiek KD, Dries S, Hamilton E, Narasimhan M, Zaidi G, D’Amore JA, D’Angelo JK. Patterns and Outcomes Associated With Timeliness of Initial Crystalloid Resuscitation in a Prospective Sepsis and Septic Shock Cohort. Crit Care Med 2017; 45: 1596-1606 [PMID: 28671898 DOI: 10.1097/CCM.0000000000002573]

12 Kuttab HI, Lykins JD, Hughes MD, Wroblewski K, Kneas EP, Kukoiy O, Kopeck JA, Hall S, Ward MA. Evaluation and Predictors of Fluid Resuscitation in Patients With Severe Sepsis and Septic Shock. Crit Care Med 2019; 47: 1582-1590 [PMID: 31393324 DOI: 10.1097/CCM.0000000000003960]

13 Espinosa-Almanza CJ, Sanabria-Rodriguez O, Riao-Forero I, Toro-Trujillo E. Fluid overload in patients with septic shock and lactate clearance as a therapeutic goal: a retrospective cohort study. Rev Bras Ter Intensiva 2020; 32: 99-107 [PMID: 32401993 DOI: 10.5935/0103-507x.20200015]

14 Latham HE, Bengtson CD, Satterwhite L, Stites M, Subramaniam DP, Chen GJ, Simpson SQ. Stroke volume guided resuscitation in severe sepsis and septic shock improves outcomes. J Crit Care 2017; 42: 42-46 [PMID: 28672146 DOI: 10.1016/j.jccr.2017.06.028]

15 Coba V, Whitmill M, Mooney R, Horst HM, Brandt MM, Digiovine B, Mlynarek M, McLellan B, Boleski G, Yang J, Conway W, Jordan J; (The Henry Ford Hospital Sepsis Collaborative Group). Resuscitation bundle compliance in severe sepsis and septic shock: improves survival, is better late than never. J Intensive Care Med 2011; 26: 304-313 [PMID: 21220270 DOI: 10.1177/0885066610392409]

16 Liu CC, Hsieh WA, Hsu SC, Huang HY, Bih ZL. Emergency Physician Compliance with Quality Indicators of Septic Shock and Severe Sepsis in Eastern Taiwanese Community Hospital. J Acute Med 2017; 7: 135-140 [PMID: 32995187 DOI: 10.6705/j.jacme.2017.0704.001]

17 Jozwiak M, Hamzaoui O, Monnet X, Teboul JL. Fluid resuscitation during early sepsis: a need for individualization. Minerva Anestesiol 2018; 84: 987-992 [PMID: 29444562 DOI: 10.23736/S0375-9393.18.12422-9]

18 Allen JM, Feidl C, Shoulders BR, Voils SA. Recent Updates in the Pharmacological Management of Sepsis and Septic Shock: A Systematic Review Focused on Fluid Resuscitation, Vasopressors, and Corticosteroids. Ann Pharmacother 2019; 53: 385-395 [PMID: 30404539 DOI: 10.1177/1060028018812940]

19 Sirvent JM, Ferri C, Baró A, Murcia C, Lorenzo C. Fluid balance in sepsis and septic shock as a determining factor of mortality. Am J Emerg Med 2015; 33: 186-189 [PMID: 25483379 DOI: 10.1016/j.ajem.2014.11.016]

20 Sirvent JM, Murcia C, Lorenzo C. Fluid balance in sepsis: a single parameter does not provide the solution. Am J Emerg Med 2015; 33: 471-472 [PMID: 25682577 DOI: 10.1016/j.ajem.2015.02.003]
