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*Original Article*

# Application and significance of PiCCO monitoring technique combined with troponin I detection in fluid resuscitation of elderly patients with septic myocardial dysfunction

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**Abstract:** Objective: This study was designed to demonstrate the predictive value of Pulse indicate Contour Cardiac Output (PiCCO) monitoring technique combined with troponin I (cTnI) detection in septic myocardial dysfunction (SMD) of the elderly. Methods: One hundred and nineteen elderly patients with SMD treated in our hospital from March 2016 to September 2019 were enrolled and allocated into the joint group (JG; 64 cases) for capacity management of fluid resuscitation under the guidance of PiCCO monitoring technique and cTnI detection, and the control group (CG; 55 cases) for conventional capacity management. Clinical indicators, hemodynamics, improvement of myocardial injury markers and inflammatory factors 6 h and 36 h post intervention, fluid balance 6 h, 12 h and 36 h post intervention, drug consumption (norepinephrine), treatment effect and 28-day hospitalization mortality were compared between the two groups. Results: After resuscitation, the urine volume per hour and the fluid resuscitation volume were higher while the blood lactic acid (BLA) expression was lower in JG as compared to CG. JG presented a remarkably lower central venous pressure (CVP) than CG after resuscitation, with notably higher mean arterial pressure (MAP) and central venous oxygen saturation (ScvO2). In comparison with CG, JG displayed dramatically lower cTnI and N-terminal pro-brain natriuretic peptide (NT-ProBNP) 6 h and 36 h post intervention, as well as evidently reduced interleukin-6 (IL-6), procalcitonin (PCT) and high-sensitivity C-reactive protein (hs-CRP). After 36 h of intervention, the fluid balance was evidently lower in JG than in CG. JG showed statistically less use of norepinephrine, less time of mechanical ventilation and ICU stay, and noticeably lower incidence of multiple organ dysfunction syndrome (MODS), as well as dramatically lower 28-day hospitalization mortality than CG post intervention. Conclusions: PiCCO monitoring technique combined with cTnI detection is high-performing in fluid resuscitation of elderly patients with SMD, which can meliorate the myocardial function of patients, reduce medication and facilitate disease recovery.

**Keywords:** PiCCO monitoring technique combined with cTnI detection, elderly patients with septic myocardial dysfunction, fluid resuscitation

## Introduction

Cardiovascular disease, a major component of septic shock, is characterized by vasodilation and impaired cardiac function [1]. In sepsis, myocardial dysfunction is one of the most complex organ failures due to the dynamic adaptation of cardiovascular system to disease process, host response and resuscitation, with complicated and multifactorial pathophysiology [2]. With the development of society, elderly patients suffering from septic myocardial dysfunction (SMD) keeps increasing year by year [3]. Such patients usually have to receive a large amount of fluid intervention to ensure early adequate fluid resuscitation and sufficient perfusion pressure of tissues and organs [4]. However, the fluid resuscitation of the elderly SMD patients is particularly complicated, especially in those with poor basic cardiopulmonary

function and low fluid reactivity [5, 6]. Accordingly, reasonable fluid resuscitation carries huge implications for the treatment of this patient population.

Pulse indicate Contour Cardiac Output (PiCCO) is a minimally invasive technique that can monitor successive heartbeats, volume status, hemodynamic status and pulmonary edema [7]. Literature has shown that PiCCO is a viable and advanced hemodynamic monitoring system, which can realize continuous hemodynamic monitoring via great artery catheters and central venous catheters, and is mostly used for patients with septic shock in intensive care units (ICU) [8]. It is also shown that this technique fully reflects the changes of hemodynamic parameters and the systolic and diastolic functions of the heart [9]. Moreover, evidence has revealed that PiCCO is paramount in fluid resuscitation, fluid management, diuretic application and treatment evaluation [10]. For example, PiCCO monitoring for patients with severe acute pancreatitis who had early fluid resuscitation is reported to be able to improve tissue perfusion, reduce the duration of systemic inflammatory response syndrome, and shorten the length of stay in ICU [11]. While troponin I (cTnI) is a vital cardiac function marker, and a biomarker that reflects myocardial and cardiac injury with higher specificity and sensitivity. It has been regarded as the first choice and a vital reference for the diagnosis of myocardial infarction, which can also be employed to evaluate the severity of infarction and the prognosis of patients [12]. Besides, regular and effective examination of cTnI can timely feedback the condition of myocardial disease in patients, and provide a basis for follow-up treatment [13].

In this study, elderly patients with SMD were treated with PiCCO monitoring technique combined with cTnI detection after fluid resuscitation management to explore the improvement of fluid balance and drug use, aiming at providing a better fluid resuscitation scheme for this patient population.

## Materials and methods

### *General information*

One hundred and nineteen elderly SMD patients consecutively treated in Changzhou Fourth People's Hospital from March 2016 to September 2019 were enrolled and allocated into the joint group (JG; n=64) for capacity management of fluid resuscitation under the guidance of PiCCO monitoring technique and cTnI detection, and the control group (CG; n=55) for conventional capacity management. Inclusion criteria: the enrolled patients 1) met the diagnostic criteria of SMD [14]; 2) had complete clinical data, and 3) aged ≥18 years. Ethics committee of our hospital approved this study, and the participants and their families had been informed and signed the full informed consent form. Exclusion criteria: 1) pregnant and lying-in woman; 2) patients with various heart diseases; 3) patients with malignant tumor, renal function or liver function damage; 4) patients treated with other regimens; 5) those who were allergic to the study medication; 6) referred patients; 7) those who withdrew from the experiment.

### *Intervention methods*

All the enrolled patients were given conventional treatment for SMD, mainly by means of anti-infection, fluid resuscitation, vasoactive drugs and oxygen inhalation. The vasoactive drugs used in this study were Dobutamine (Kelun Pharmaceutical Co., Ltd., Hunan, China, H43020080) and norepinephrine (Baiyunshan Mingxing Pharmaceutical Co., Ltd., Guangzhou, China, H44022396).

In JG, fluid resuscitation capacity management was carried out under the guidance of PiCCO monitoring technique combined with cTnI detection: referring to EGDT [15] scheme, patients were treated with central venous catheter combined with PICC catheter via femoral artery to detect the hemodynamic changes and give real-time feedback. Besides, cTnI was detected in stages. After admission, 5 ml of venous blood was collected every two days for cTnI detection, and was stored in a cryogenic refrigerator at -70°C for use after centrifugation at 1500×g and 4°C for 10 min. The treatment plan was adjusted according to the hemodynamic indexes of patients monitored by PiCCO combined with cTnI.

Patients in CG were given routine capacity management to: 1) prevent the changes of hemodynamics by central venous catheter, and 2) give medical care to patients according to the EGDT protocol and the resuscitation indicators of routine detection. Treatment plan: the vasoconstrictor norepinephrine was given if the patient's systemic resistance value was lower than the normal range.

*Outcome measures*

Clinical indicators: the urine volume per hour, blood lactic acid (BLA) and fluid resuscitation volume in the two groups were observed post intervention.

Hemodynamics: central venous pressure (CVP), mean arterial pressure (MAP) and central venous oxygen saturation (ScvO2) were observed and recorded post intervention.

Markers of myocardial injury and inflammatory factors: 5 mL of venous blood was drawn from patients in both groups 6 h and 36 h post intervention, and stored in a refrigerator at -70°C after 10 min of centrifugation at 1500×g and 4°C. Enzyme-linked immunosorbent assay (ELISA) [16] was applied for the examination of indicators such as troponin I (cTnI), human N-terminal pro-brain natriuretic peptide (NT-ProBNP), interleukin-6 (IL-6), procalcitonin (PCT) and high-sensitivity C-reactive protein (hs-CRP) (C-reagent Biotechnology Co. Ltd., Shanghai, China, CS-0735D, CS-13631E, CS-13629E, CS-ELISA3131, CS-12210E) following the manufacturer's protocol.

Fluid balance: in order to observe whether the patient's volume load was too heavy, or whether the patient had shock due to lack of fluid during early fluid resuscitation, the positive fluid balance was observed in the two groups 6 h, 12 h and 36 h post intervention.

Drug consumption: norepinephrine consumption during intervention was observed and compared between the two groups.

Evaluation of treatment efficacy: the time of mechanical ventilation and ICU stay, the incidence of multiple organ dysfunction syndrome (MODS), and the 28-day hospitalization mortality were observed and compared between the two groups.

*Statistical processing*

The statistical analysis was undertaken by SPSS22.0 (Easybio Technology Co., Ltd., Beijing, China). Recorded as the number of cases/percentage (n/%), the counting data were compared by the Chi-square test between groups. For those with theoretical frequency <5 in the Chi-square test, the continuous correction Chi-square test was applied. The measurement data were represented by mean ± standard deviation (mean ± SD); the inter-group comparison was conducted by the independent sample t-test, and the intra-group comparison before and post intervention was performed by the paired t-test. GraphPad Prism 6 was employed for data visualization. Significance was determined when probability (*P*) values were <0.05.

## Results

*General information*

Significant differences were absent between the two groups concerning the baseline data such as gender, age, body mass index, systolic blood pressure (SBP), diastolic blood pressure (DBP), residence, ethnicity, educational background, infection type, smoking history, drinking history and exercise history (P<0.05) (**Table 1**).

*Comparison of post-intervention clinical indexes between the two groups*

By observing the clinical indexes of the two groups after resuscitation, it was found that urine volume per hour and fluid resuscitation volume in JG were higher while the BLA expression was lower as compared to CG (P<0.05) (**Table 2**).

*Comparison of post-intervention hemodynamic indexes between the two groups*

The observation of the hemodynamics exhibited that after resuscitation, the CVP in JG was noticeably lower while MAP and ScvO2 were profoundly higher as compared to those in CG (P<0.05) (**Table 3**).

*Comparison of myocardial injury markers in different time periods post intervention between the two groups*

The expressions of myocardial injury markers in two *groups* were observed 6 h and 36 h post intervention. cTnI and NT-proBNP were observably lower in JG than in CG 6 h and 36 h post intervention, and their levels at 36 h post intervention were lower than those at 6 h post intervention (P<0.05) (**Figure 1**).

*Comparison of inflammatory factors in different time periods post intervention between the two groups*

IL-6, PCT and hs-CRP were observably lower in JG than in CG 6 h and 36 h post intervention, and their levels at 36 h post intervention were

**Table 1.** General clinical data of patients in the two groups [n (%)] (mean ± SD)

| Classification | Joint group (n=64) | Control group (n=55) | $t/\chi^2$ value | *P* value |
|---|---|---|---|---|
| Gender | | | 0.148 | 0.700 |
| Male | 36 (56.25) | 29 (52.73) | | |
| Female | 28 (43.75) | 26 (47.27) | | |
| Age (years old) | 71.27±6.36 | 72.67±6.39 | 1.195 | 0.234 |
| BMI (kg/m$^2$) | 24.78±2.18 | 25.15±2.21 | 0.917 | 0.360 |
| SBP (mmHg) | 114.65±10.03 | 114.86±10.06 | 0.113 | 0.909 |
| DBP (mmHg) | 74.34±6.75 | 72.86±7.03 | 1.170 | 0.244 |
| Residence | | | 0.072 | 0.788 |
| Urban | 33 (51.56) | 27 (49.09) | | |
| Rural | 31 (48.44) | 28 (50.91) | | |
| Ethnicity | | | 0.033 | 0.854 |
| Han | 35 (54.69) | 31 (56.36) | | |
| Ethnic minorities | 29 (45.31) | 24 (43.64) | | |
| Educational background | | | 0.011 | 0.916 |
| ≥High school | 25 (39.06) | 22 (40.00) | | |
| <High school | 39 (60.94) | 33 (60.00) | | |
| Type of infection | | | 0.125 | 0.988 |
| Lung infection | 13 (20.31) | 12 (21.82) | | |
| Catheter-associated infection | 19 (29.69) | 17 (30.91) | | |
| Abdominal cavity infection | 14 (21.88) | 12 (21.82) | | |
| Urinary infection | 18 (28.13) | 14 (25.45) | | |
| History of smoking | | | 0.226 | 0.634 |
| Yes | 38 (59.38) | 35 (63.64) | | |
| No | 26 (40.63) | 20 (36.36) | | |
| History of drinking | | | 0.514 | 0.473 |
| Yes | 39 (60.94) | 37 (67.27) | | |
| No | 25 (39.06) | 18 (32.73) | | |
| Exercise history | | | 0.197 | 0.657 |
| Yes | 37 (57.81) | 34 (61.82) | | |
| No | 27 (42.19) | 21 (38.18) | | |

**Table 2.** Comparison of post-intervention clinical indexes between the two groups (mean ± SD)

| Groups | n | Urine volume per hour (mg/kg) | Fluid resuscitation volume (mL) | Blood lactic acid (mmol/L) |
|---|---|---|---|---|
| Joint group | 64 | 0.53±0.04 | 2146.23±20.78 | 1.03±0.04 |
| Control group | 55 | 0.41±0.03 | 1748.74±19.63 | 1.98±0.13 |
| t | - | 18.260 | 106.700 | 55.520 |
| P | - | <0.001 | <0.001 | <0.001 |

**Table 3.** Comparison of post-intervention hemodynamic indexes between the two groups (mean ± SD)

| Groups | n | CVP (mmHg) | MAP (mmHg) | ScvO2 (%) |
|---|---|---|---|---|
| Joint group | 64 | 10.29±1.36 | 72.68±6.37 | 76.36±7.24 |
| Control group | 55 | 11.26±1.17 | 70.01±6.33 | 62.57±7.15 |
| t | - | 4.135 | 2.286 | 10.420 |
| P | - | <0.001 | 0.024 | <0.001 |

lower than those 6 h post intervention (P<0.05) (**Figure 2**).

*Comparison of fluid balance in different time periods post intervention between the two groups*

The fluid balance 6 h, 12 h and 36 h post intervention was observed. No evident dif-

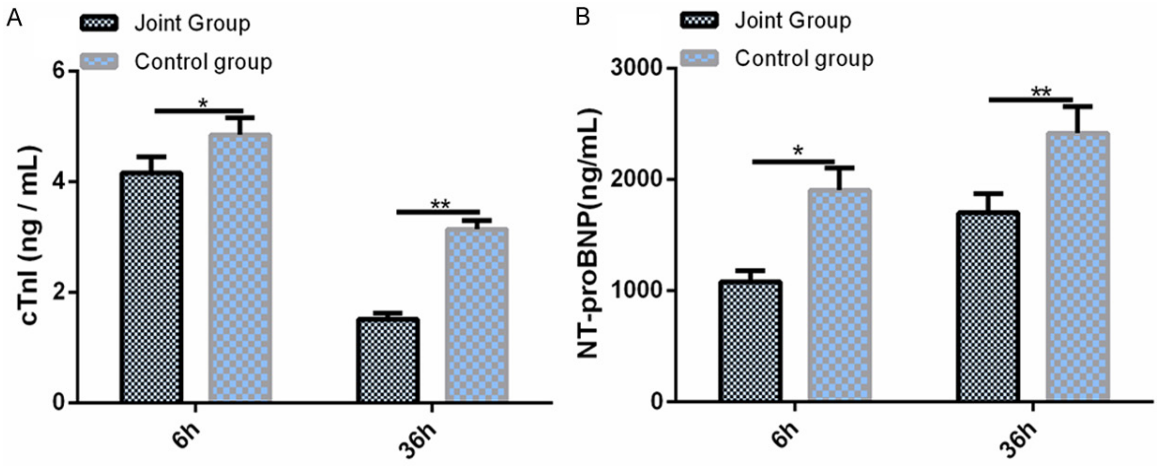


**Figure 1.** Comparison of myocardial injury markers in different periods post intervention between the two groups. A: cTnI was observably lower in joint group than in control group 6 h and 36 h post intervention. B: NT-proBNP was noticeably lower in joint group than in control group 6 h and 36 h post intervention. Note: * indicates P<0.05 compared between the two groups, and ** indicates P<0.01 compared with that 6 h post intervention.

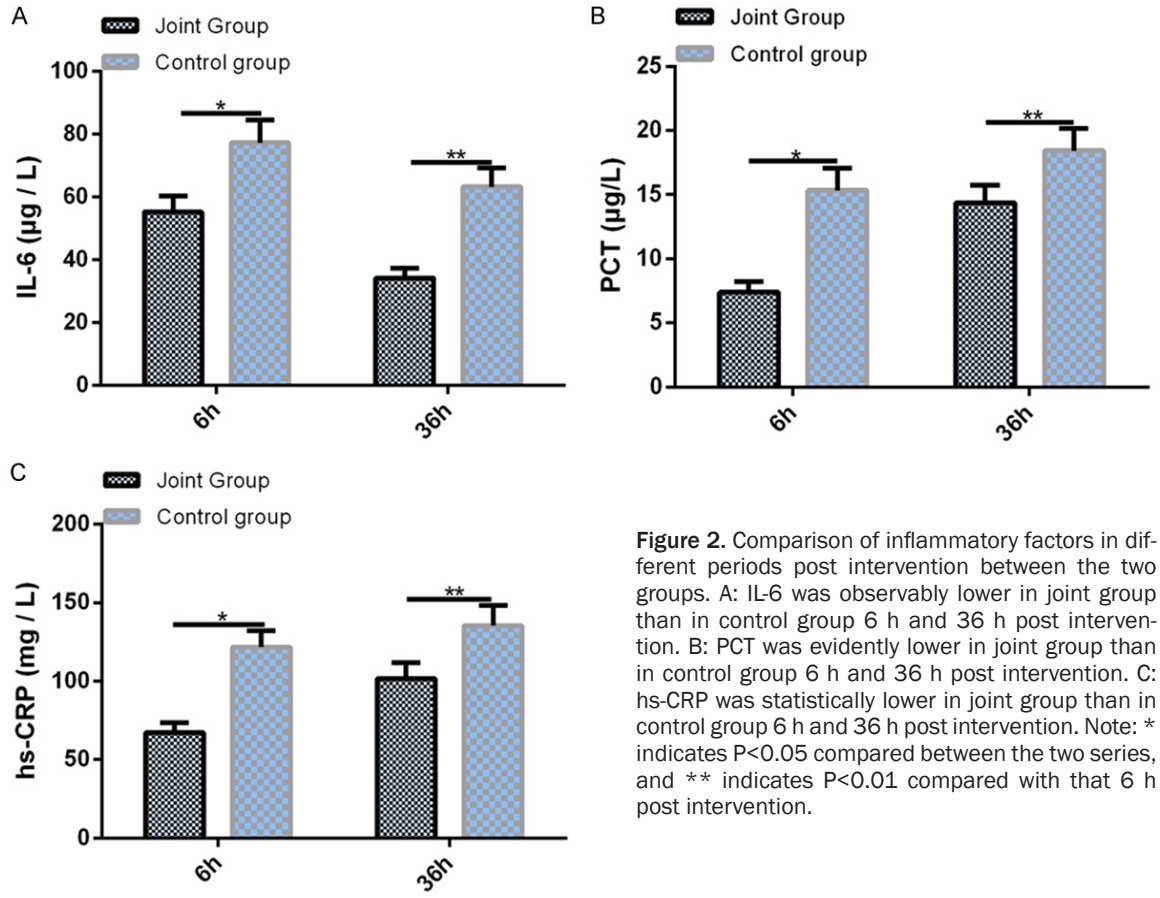


**Figure 2.** Comparison of inflammatory factors in different periods post intervention between the two groups. A: IL-6 was observably lower in joint group than in control group 6 h and 36 h post intervention. B: PCT was evidently lower in joint group than in control group 6 h and 36 h post intervention. C: hs-CRP was statistically lower in joint group than in control group 6 h and 36 h post intervention. Note: * indicates P<0.05 compared between the two series, and ** indicates P<0.01 compared with that 6 h post intervention.

ference was observed between the two *groups* 6 h and 12 h post intervention, but the fluid balance in JG was observably lower than that in CG 36 h post intervention (P<0.05) (**Table 4**).

**Table 4.** Comparison of fluid balance in different time periods post intervention between the two groups (mean ± SD)

| Groups | n | Fluid balance (mL) | | |
|---|---|---|---|---|
| | | 6 h | 12 h | 36 h |
| Joint group | 64 | 3351.27±30.16 | 6251.67±60.26 | 7503.16±70.17 |
| Control group | 55 | 3341.57±30.15 | 6239.17±60.15 | 8653.68±80.78 |
| t | - | 1.749 | 1.129 | 83.150 |
| P | - | 0.082 | 0.261 | <0.001 |

**Table 5.** Comparison of drug consumption between the two groups (mean ± SD)

| Groups | n | Dosage of norepinephrine (mg) |
|---|---|---|
| Joint group | 64 | 50.21±4.78 |
| Control group | 55 | 56.78±4.82 |
| t | - | 7.447 |
| P | - | <0.001 |

*Comparison of drug consumption between two groups*

The drug use of the two *groups* was observed, and the norepinephrine use in JG post intervention was observably lower than that in CG (P<0.05) (**Table 5**).

*Therapeutic effect evaluation in the two groups*

After observing the therapeutic effect in the two *groups* post intervention, it was found that in comparison with CG, the time of mechanical ventilation and ICU stay were observably less, and the incidence of MODS was lower in JG (P<0.05) (**Table 6**).

*Comparison of 28-day hospitalization mortality between the two groups*

The 28-day hospitalization mortality was 15.63% in JG, which was statistically lower than 41.82% in CG (P<0.05) (**Table 7**).

## Discussion

Sepsis is one of the dominant conditions in ICU patients and is associated with multiple organ dysfunctions [17]. This is particularly true in patients complicated with myocardial injury and acute liver and kidney damage, and myocardial dysfunction is one of the pathophysiological mechanisms of septic shock [18]. Hence, effective prevention and treatment of SMD is vital in sepsis treatment in the elderly [19]. Fluid resuscitation intervention is commonly used in clinic, but rapid infusion can easily lead to fluid overload and cardiac insufficiency, which requires dynamic evaluation of patients' hemodynamic status, pulmonary water and cardiac function changes [20]. Therefore, attention has been paid to fluid resuscitation and hemodynamic monitoring.

PiCCO is a valid and advanced procedure for continuous monitoring of hemodynamic status in clinical practice, which is based on the use of specific thermodilution arterial catheter and central venous line; besides, because it is minimally invasive, it can also quantify different hemodynamic parameters such as vascular tension and cardiac function [21]. Studies have shown that early identification of myocardial injury related to sepsis is crucial for developing appropriate treatment regimens [22]. cTnI can reflect the severity of septic myocardial injury, and its increase indicates increased severity and adverse prognosis [23]. Our research showed that in comparison with CG, the urine volume per hour and fluid resuscitation volume in JG were higher while the BLA expression was observably lower. It indicates that the application of PiCCO monitoring technique combined with cTnI detection to guide early fluid resuscitation in elderly patients with SMD has a good curative effect, and can profoundly ameliorate the tissue hypoperfusion of patients. Studies have shown that hemodynamic parameters during fluid resuscitation enjoy significant predictive value in patients with septic shock, and that hemodynamic parameters such as MAP and Extra Vascular Lung Water Index (EVLWI) monitored by PiCCO are independent prognostic factors for short-term prognosis of septic patients [24]. In the present study, CVP after resuscitation in JG was statistically lower while MAP and ScvO2 were notably higher as compared to CG, demonstrating that the early and sufficient fluid resuscitation in JG corrected the perfusion of tissues and organs in time, and after monitoring patients' hemodynamics, the treatment scheme of fluid resuscitation was precisely adjusted based on the clinical performance, so that the hemodynamic parameters were better improved. NT-proBNP is generally

**Table 6.** Therapeutic effect evaluation in the two groups [n (%)] (mean ± SD)

| Groups | n | Mechanical ventilation time (d) | ICU stay time (d) | Incidence of MODS (%) |
|---|---|---|---|---|
| Joint group | 64 | 11.67±1.53 | 13.57±1.36 | 9 (14.06) |
| Control group | 55 | 16.34±1.78 | 18.47±1.73 | 17 (30.91) |
| t | - | 15.390 | 17.280 | 4.917 |
| P | - | <0.001 | <0.001 | 0.026 |

**Table 7.** Comparison of 28-day hospitalization mortality between the two groups [n (%)]

| Groups | n | 28-day hospitalization mortality | |
|---|---|---|---|
| | | Alive | Dead |
| Joint group | 64 | 54 (84.38) | 10 (15.63) |
| Control group | 55 | 32 (58.18) | 23 (41.82) |
| t | - | - | 10.131 |
| P | - | - | 0.001 |

elevated in sepsis and is closely associated with septic myocardial injury [25]. Also, literature has exhibited that myocardial dysfunction induced by sepsis gives rise to reversible organ dysfunction, which influences hemodynamics, organ function and prognosis of patients to a great extent [26]. Our findings displayed that 6 h and 36 h post intervention, cTnI and NT-proBNP were reduced observably in JG than in CG, suggesting that fluid resuscitation without monitoring may result in shock or acute cardiac insufficiency due to insufficient fluid. PiCCO monitoring combined with cTnI detection can efficiently correct shock, and effective body fluid management can also eliminate interstitial edema, meliorate myocardial microcirculation and reduce myocardial damage. Furthermore, IL-6, PCT and hs-CRP in patients in JG were observed to be evidently lower than those in CG 6 h and 36 h post intervention, which also indicated that the fluid management implemented after PiCCO monitoring combined with cTnI detection can not only maintain the internal environment of patients, but also better remove inflammatory factors and metabolites.

It is reported that fluid management in critically ill patients is a great challenge, and adequate initial fluid resuscitation is essential to avoid systemic imbalance between oxygen supply and oxygen demand, otherwise it will lead to hypoperfusion and shock [27]. Therefore, reasonable monitoring is the key to treatment. In our research, the fluid balance was lower in JG than in CG 36 h post intervention, which indicated that PiCCO monitoring combined with cTnI detection could correct the fluid status as soon as possible, ameliorate the cardiac output and oxygen delivery capacity of patients, and reduce the risk of fluid overload. Also, it is shown that fluid resuscitation may not be able to maintain effective perfusion in many cases, so vasoconstrictors will be used to maintain certain circulatory resistance; however, excessive circulatory resistance may aggravate the left cardiac load, thus leading to cardiac insufficiency in patients [28, 29]. Our results exhibited that JG had notably less norepinephrine use, indicating that PiCCO monitoring combined with cTnI detection could reflect the preload state of the heart, and the accurate detection of hemodynamic state could guide clinicians to make correct treatment plans, thus reducing the use of vasoconstrictors and alleviating the myocardial injury of patients. What's more, the mechanical ventilation time, ICU stay time and MODS incidence in JG were dramatically less than those in CG, demonstrating that PiCCO monitoring combined with cTnI can help clinicians integrate the clinical manifestations of patients and adjust the treatment intervention plan in time, thus reducing the hospitalization time in ICU and the mechanical ventilation time of patients with SMD. The present study also observed the mortality of the two patients after 28 days of humoral resuscitation intervention. It showed that the mortality in JG after 28 days of intervention was profoundly lower than that in CG, which demonstrated that PiCCO monitoring combined with cTnI in patients with early fluid resuscitation can ameliorate the treatment efficiency, thereby reducing the 28-day hospitalization mortality.

Although this study confirmed that the use of PiCCO monitoring technique combined with cTn I detection can bring better benefits to fluid resuscitation in elderly patients with SMD, there is still some room for improvement. For example, we can include more subjects and analyze the factors affecting PiCCO monitoring technique, which will help nurses to identify risk factors that need special attention. In the

future, supplementary studies from the above perspectives will be carried out gradually.

To sum up, PiCCO monitoring technique combined with cTnI detection is vital in fluid resuscitation in elderly patients with SMD, which can meliorate their myocardial function, reduce medication and speed up recovery.

## Disclosure of conflict of interest

None.

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