

## Original Article

# Effectiveness of central venous pressure versus stroke volume variation in guiding fluid management in renal transplantation

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**Abstract:** Objective: The aim of this study was to compare the effectiveness of central venous pressure (CVP) versus stroke volume variation (SVV) to guide fluid management in renal transplantation. Methods: The clinical data of 97 patients who underwent allogeneic renal transplantation in our hospital were collected retrospectively. Based on the method of intraoperative infusion monitoring, they were divided into group A, which received guided fluid management by monitoring CVP, and group B which received guided fluid management by monitoring SVV. The changes in intraoperative hemodynamic indicators, urine volume, blood loss, and total blood transfusion volume, total fluid volume, urine output at different time points after surgery, renal function indicators, blood purification rate, length of stay, and postoperative complications were compared between the two groups. Results: CVP values at T1 (5 min before surgery), T2 (external iliac vein obstruction), T3 (establishment of vessel access), and T4 (end of surgery) in group B were higher than those in group A ( $P < 0.05$ ). The two groups showed no significant difference in intraoperative urine volume, blood loss and length of hospital stay ( $P > 0.05$ ). The total fluid volume and total infusion volume at 3 days after surgery in group B were less than those in group A ( $P < 0.05$ ). The urine volume did not differ at time points 0 h, 24 h, 48 h and 72 h postoperatively ( $P > 0.05$ ). Serum creatinine levels in group B at 0 h, 24 h, 48 h and 72 h postoperatively were lower than those in group A ( $P < 0.05$ ). After renal transplantation, the rate of blood purification was 4.08% in group B, which was lower than 25.00% in group A ( $P < 0.05$ ). The rate of respiratory failure in group B was 4.08%, which was not significantly different from 6.25% in group A ( $P > 0.05$ ). Conclusion: Compared with CVP, fluid management guided by monitoring SVV during renal transplantation can reduce intraoperative fluid volume, optimize the renal perfusion, reduce postoperative blood purification, and facilitate postoperative recovery.

**Keywords:** Central venous pressure, stroke volume variation, fluid management, renal transplantation, renal function, prognosis

## Introduction

Kidney failure, also known as end-stage renal disease (ESRD), is the last stage of chronic kidney disease. It is chronic progressive renal parenchymal damage caused by multiple factors for a long time, with significant renal atrophy and loss of basic function [1]. Renal transplantation is a common and effective method for the treatment of end-stage renal disease. As clinical medical technology progresses, experience in perioperative management has accumulated. The development of new immunosuppressants and more effective preservation of transplanted organs have significantly

improved the survival rate for patients undergoing renal transplantation [2, 3]. Despite all the clinical achievements of renal transplantation, kidney transplant recipients are more likely to develop renal failure compared to healthy controls. Basal renal function in the early stage after transplantation could influence the long-term survival [4, 5].

A variety of factors affect the recovery of transplanted renal function while good renal perfusion and intraoperative hemodynamic stability are beneficial to reduce incidence of tubulogenesis and effectively promote renal recovery [6]. In kidney transplant patients, endocrine hor-

mones and other harmful metabolic substances will accumulate in the body due to disruption of lipid metabolism, and at the same time, anemia, hypertension, water-electrolyte disturbance, acid-base imbalance, water retention and cardiovascular diseases and other physiopathologic changes will also occur [7, 8]. Therefore, good intraoperative fluid management is important to ensure adequate intraoperative vascular volume and prevent fluid overload to maintain renal function.

Studies have shown that advanced hemodynamic monitoring can lead to optimized hemodynamic management and improved renal and cardiac outcomes [9, 10]. In patients with chronic kidney disease and high cardiovascular risk, volume expansion should be carefully monitored to prevent pulmonary edema, cardiac ischemia, and tissue hypoperfusion [11]. Clinical indices used to guide monitoring include stroke volume variation (SVV) and central venous pressure (CVP) [12]. SVV has been shown to provide a more accurate reflection of cardiac preload, as well as a better prediction of volume responsiveness [13]. Therefore, this study investigated the effects of SVV-guided fluid management in renal transplantation, and made comparison with the efficiency of CVP. These measurements are innovative and feasible, and can provide an important reference for anesthesia and fluid management in the perioperative period of renal transplantation.

### Materials and methods

#### *Clinical data*

The clinical data of 97 patients who underwent allogeneic renal transplantation were retrospectively analyzed and divided into two groups based on the monitoring method. The fluid management of 48 patients in group A was guided by monitoring CVP, and the fluid management of 49 patients in group B was guided by monitoring SVV. (1) Inclusion criteria: informed consent was signed and obtained from all patients; patients with water-electrolyte disorders, anemia, and hypertension to varying degrees; history of renal insufficiency for more than 1 year; patients received hemodialysis treatment 12-48 h prior to surgery. This study was approved by the medical ethics committee. (2) Exclusion criteria: patients with cardiac arrhythmias and aortic regurgitation;

patients with preoperative acute infection; patients with secondary renal transplantation; patients comorbid with other organ failure; patients with incomplete clinical data; patients with perioperative adverse events; and patients who underwent graft nephrectomy within a short period of time after transplantation.

#### *Methods*

*Anesthesia methods:* Preoperative fasting was performed in all patients. Under routine monitoring, peripheral venous access was established while avoiding arteriovenous fistula. Total intravenous anesthesia was induced using 0.5 µg/kg Sufentanil (H20113509 Jiangsu Enhua Pharmaceutical Co., Ltd. Specification: 10 ml: 0.5 mg), 0.3 mg/kg Etomidate (H32022992, Jiangsu Enhua Pharmaceutical Co., Ltd. Specification: 10 ml: 20 mg), 0.15 mg/kg homeopathic atracurium (H20090202, Zhejiang Xianju Pharmaceutical Co., Ltd. Specification: 5 mg), followed by oxygen inhalation and tracheal intubation in intermittent positive pressure breathing, with tidal volume (VT) = 8 ml/kg, respiratory ratio = 1:2, respiratory rate (RR) = 14 times/min. Analgesia was maintained by a continuous pump of propofol (H20123-138, Jiangsu Enhua Pharmaceutical Co. Specification: 20 ml: 0.2 g) and sevoflurane (Shanghai Hengrui Pharmaceutical Co., A000030209, Specifications: (120 ml). Homeopathic atracurium and sufentanil were administered as intermittent. Invasive blood pressure (IBP), end-expiratory carbon dioxide (PetCO<sub>2</sub>), RR, oxygen saturation (SpO<sub>2</sub>), and heart rate (HR) were continuously monitored. In both groups, central venous catheters were placed after induction of anesthesia to monitor CVP. In group B, SVV was monitored by transradial artery puncture after induction of anesthesia, and in group A, IBP was routinely monitored after transradial artery puncture.

*Intraoperative treatment:* Both groups of patients were rehydrated with sodium lactate injection (H44020203, Guangdong Otsuka Pharmaceutical Co: S19983040, Guangdong Weilun Biological Pharmaceutical Co., 20% 10 g/bottle). Infusion in group A was guided by monitoring CVP to maintain CVP between 6-9 mmHg. When CVP was below 6 mmHg, the infusion rate was increased appropriately. When mean arterial pressure (MAP) was <20% of

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**Table 1.** Comparison of baseline data

Data		Group A (n=48)	Group B (n=49)	t/X <sup>2</sup>	P
Gender	Male	35 (72.92)	37 (75.51)	0.085	0.770
	Female	13 (27.08)	12 (24.49)		
Age (years)		42.19±1.19	42.21±1.13	0.085	0.933
Height (cm)		161.25±2.52	161.28±2.49	0.059	0.953
Body weight (kg)		53.02±0.18	53.05±0.12	0.968	0.336
Operation time (h)		4.15±0.02	4.17±0.09	1.504	0.136
Extubation time (min)		228.96±12.52	228.99±12.49	0.012	0.991

basal value, patients were pumped with vasoactive drugs to ensure that MAP was  $\pm 20\%$  of basal value, and vasoactive drugs were used to maintain MAP at 90 mmHg and above before establishment of access. Infusion in group B was guided by monitoring SVV. When SVV  $>10\%$ , the infusion rate was increased to ensure adequate blood volume. During the operation, both groups were given intravenous infusion of 400 mg omeprazole (H20054388, Hainan Lingkang Pharmaceutical Co., Ltd., Specification: 20 mg\*5 bottles), 500 mg methylprednisolone (H33020824, Zhejiang Xianju Pharmaceutical Co., Ltd., Specifications: 0.125 g). When vascular access were established, 100 mg of urosemeide (H41021056, Suicheng Pharmaceutical Co., Ltd., Specifications: 2 ml: 20 mg) was infused intravenously, and 100 ml 20% mannitol injection was administrated at the same time. The hemoglobin and blood gas indicators were closely monitored. The acid-base balance was adjusted based on the monitoring results.

### Outcome measurement

Intraoperative hemodynamic parameters: CVP, MAP and HR were compared at T1 (5 min before surgery), T2 (external iliac vein obstruction), T3 (establishment of vessel access) and T4 (end of surgery) between the two groups.

Intraoperative urine volume, blood loss, and total intraoperative infusion volume were compared between the two groups.

The total fluid volume and hospital stay at 3 d postoperatively were compared between the two groups.

The urine volume at 0 h, 24 h, 48 h, and 72 h after surgery were compared between the two groups.

Renal function index: The blood urea nitrogen (BUN), creatinine clearance rate (Ccr) and serum creatinine (SCr) levels in the two groups were measured by automatic biochemical analyzer (manufactured by Shenzhen Mindray Bio-Medical Electronics Co., Ltd.) at 0 h, 24 h, 48 h and 72 h after surgery, respectively .

The rate of blood purification after renal transplantation was recorded in the two groups.

The incidence of complications, including pulmonary edema, heart failure and respiratory failure was recorded in the two groups.

### Statistical methods

SPSS22.0 was used for data analysis. Measurement data were expressed as mean  $\pm$  standard deviation. *T* test was used for comparison of normally distributed data, while Mann-Whitney U test was used for non-normally distributed data. Count data were expressed as [n (%)] and compared by  $\chi^2$  test.  $P < 0.05$  indicated statistical significance.

## Results

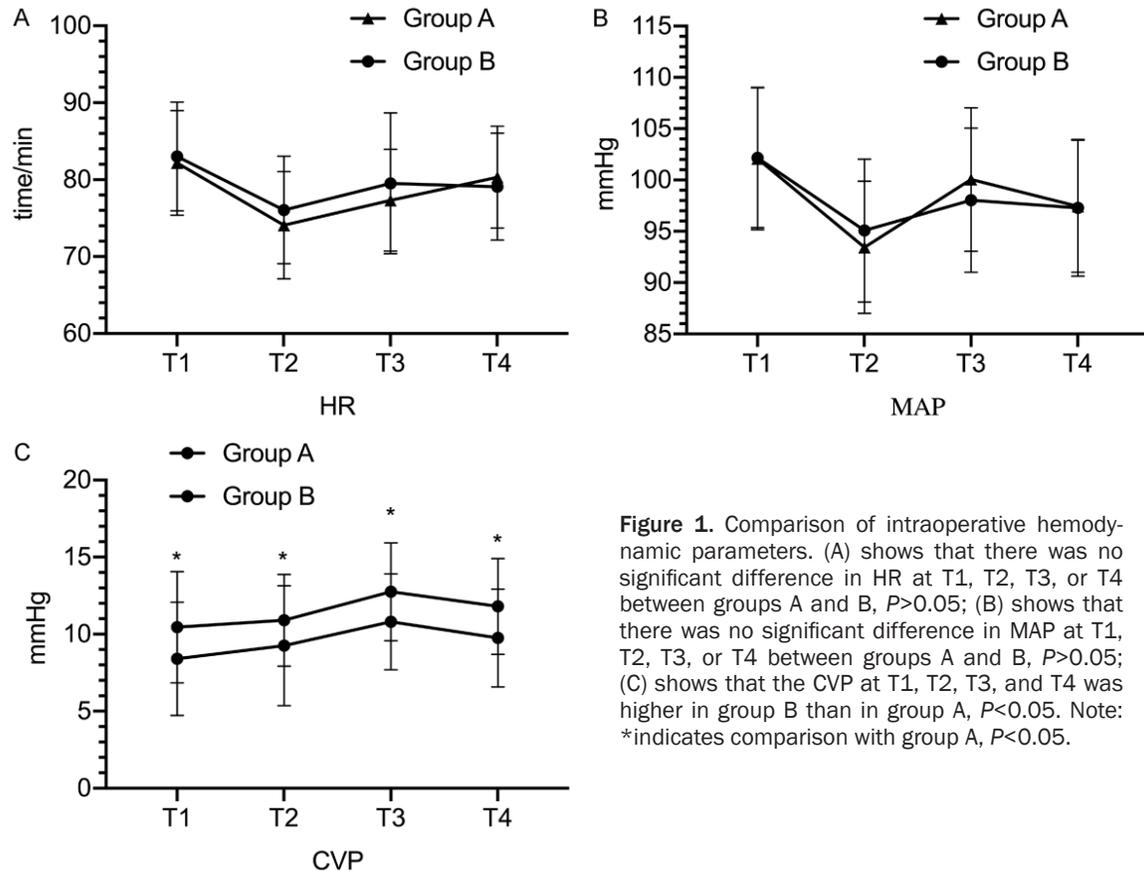
### Comparison of baseline data

There was no significance ( $P > 0.05$ ) (**Table 1**) in terms of age, sex, weight, height, operation time and extubation time between the two groups, which were comparable.

### Comparison of intraoperative hemodynamic parameters

The HR and MAP at T1, T2, T3, and T4 showed no difference between groups A and B ( $P > 0.05$ ). The CVP levels at T1, T2, T3, and T4 in group B were higher than those in group A ( $P < 0.05$ ). The MAP levels at T1, T2, T3, and T4 in group A

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**Figure 1.** Comparison of intraoperative hemodynamic parameters. (A) shows that there was no significant difference in HR at T1, T2, T3, or T4 between groups A and B,  $P > 0.05$ ; (B) shows that there was no significant difference in MAP at T1, T2, T3, or T4 between groups A and B,  $P > 0.05$ ; (C) shows that the CVP at T1, T2, T3, and T4 was higher in group B than in group A,  $P < 0.05$ . Note: \*indicates comparison with group A,  $P < 0.05$ .

were slightly higher than those in group B ( $P > 0.05$ ) (**Figure 1**).

### Comparison of intraoperative urine volume, blood loss, and total infusion

The intraoperative urine volume and blood loss did not differ between the two groups ( $P > 0.05$ ). Total infusion in group B was less than that in group A ( $P < 0.05$ ) (**Figure 2**).

### Comparison of total infusion volume and length of hospital stay

There was no significant difference in the length of hospital stay between groups A and B ( $P > 0.05$ ). The total infusion in group B was less than that in group A ( $P < 0.05$ ) (**Table 2**).

### Comparison of postoperative urine output

There was no significant difference ( $P > 0.05$ ) in the urine volume at 0 h, 24 h, 48 h, and 72 h postoperatively between groups A and B (**Figure 3**).

### Comparison of postoperative renal function

BUN and Ccr at 0 h, 24 h, 48 h and 72 h postoperatively showed no significant difference between the two groups ( $P > 0.05$ ). Scr in group B was lower than that in group A at these time points ( $P < 0.05$ ) (**Figure 4**).

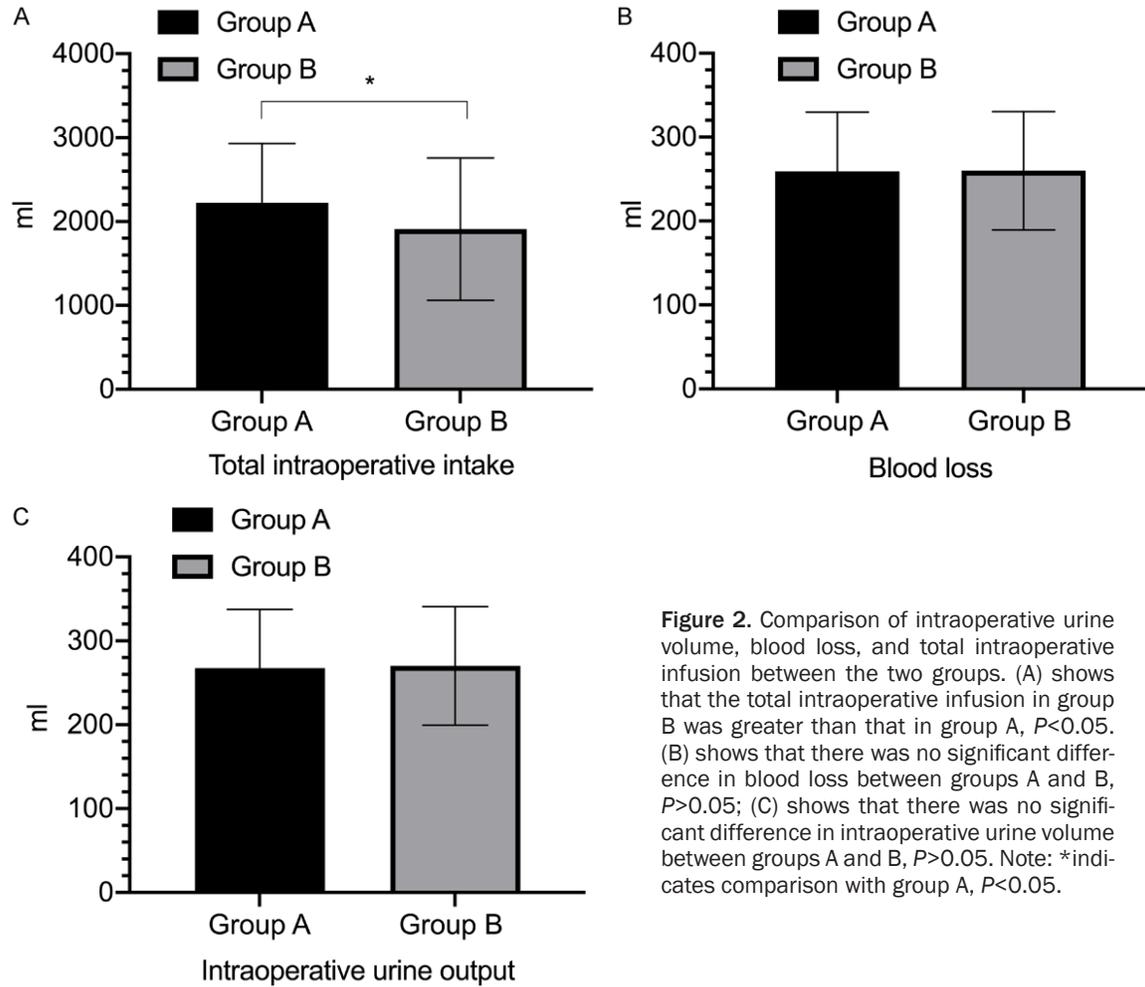
### Blood purification rate after renal transplantation

A total of 12 patients and 2 patients underwent blood purification after renal transplantation in groups A and B, respectively. The rate of blood purification in group B was 4.08%, which was lower than 25.00% in group A ( $P < 0.05$ ) (**Table 3**).

### Comparison of incidence of complications

The incidence of pulmonary edema was 2.04% in group B and 4.17% in group A, respectively ( $P > 0.05$ ). The incidence of heart failure in was 0.00% in group B and 0.00% in group A ( $P > 0.05$ ). The incidence of respiratory failure

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**Figure 2.** Comparison of intraoperative urine volume, blood loss, and total intraoperative infusion between the two groups. (A) shows that the total intraoperative infusion in group B was greater than that in group A,  $P < 0.05$ . (B) shows that there was no significant difference in blood loss between groups A and B,  $P > 0.05$ ; (C) shows that there was no significant difference in intraoperative urine volume between groups A and B,  $P > 0.05$ . Note: \* indicates comparison with group A,  $P < 0.05$ .

**Table 2.** Comparison of the total infusion volume and the length of hospital stay ( $\bar{x} \pm s$ )

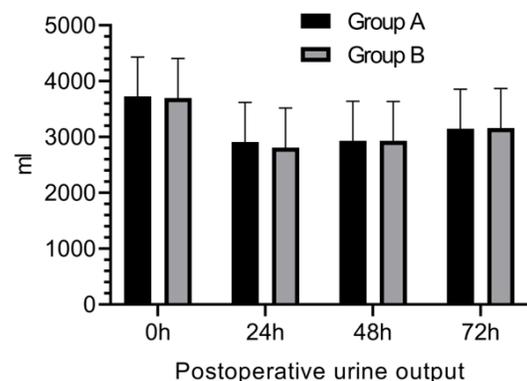
Group	Total infusion volume (ml) at 3 d postoperatively	Length of hospital stay (d)
Group A (n=48)	11896.39±12.08	27.02±0.48
Group B (n=49)	10921.58±11.15*	26.88±0.52
t	413.113	1.377
P	0.000	0.172

Note: \* indicates comparison with group A,  $P < 0.05$ .

was 4.08% in group B and 6.25% in group A ( $P > 0.05$ ) (Table 4).

### Discussion

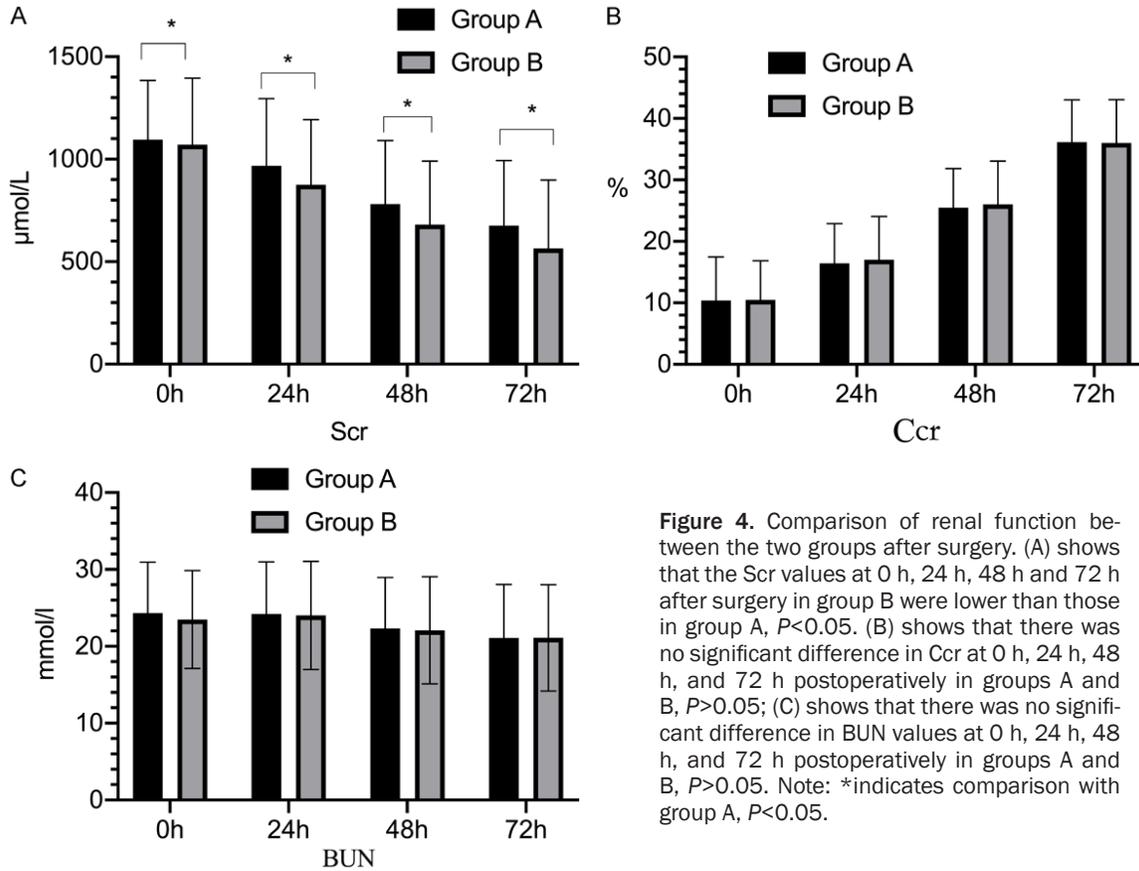
Anesthesia management during the perioperative period of renal transplantation should focus on intravenous fluid infusion to prevent dehydration in patients, ensure effective circu-



**Figure 3.** Comparison of the postoperative urine volume between the two groups. A and B,  $P > 0.05$  at 0 h, 24 h, 48 h and 72 h postoperatively.

lating volume, and prevent tissue hypoperfusion [14]. Central venous pressure (CVP) is a volume index and is widely used in fluid management [15]. With the development of moni-

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**Figure 4.** Comparison of renal function between the two groups after surgery. (A) shows that the Scr values at 0 h, 24 h, 48 h and 72 h after surgery in group B were lower than those in group A,  $P < 0.05$ . (B) shows that there was no significant difference in Ccr at 0 h, 24 h, 48 h, and 72 h postoperatively in groups A and B,  $P > 0.05$ ; (C) shows that there was no significant difference in BUN values at 0 h, 24 h, 48 h, and 72 h postoperatively in groups A and B,  $P > 0.05$ . Note: \*indicates comparison with group A,  $P < 0.05$ .

**Table 3.** Comparison of blood purification rates

Group	Number	Cases of blood purifications (n)	Purification rate (%)
Group A	48	12	25.00
Group B	49	2	4.08*
$\chi^2$			8.591
$P$			0.003

Note: \*indicates comparison with group A.  $P < 0.05$ .

**Table 4.** Comparison of the occurrence of complications [n (%)]

Group	Number	Pulmonary edema	Heart failure	Respiratory failure
Group A	48	2 (4.17)	0 (0.00)	3 (6.25)
Group B	49	1 (2.04)	0 (0.00)	2 (4.08)
$\chi^2$		0.366	-	0.233
$P$		0.545	-	0.629

Note: -indicates none.

toring techniques, studies have found that a series of static pressure indicators such as CVP can be indirectly reflected by blood pressure

and volume, but are highly susceptible to mechanical ventilation, vascular tone, myocardial contractility, and ventricular compliance [16, 17]. It has been found that CVP is primarily used to guide volume management of the right cardiac system and cannot reflect preload of left ventricular [18]. Most patients with end-stage renal disease experience pathophysiological changes involving various organs, and have relatively poor ventricular compliance. Therefore, CVP will increase significantly after mechanical ventilation [19]. This, together with abdominal pressure, tricuspid valve regurgitation, and surgical procedures, will further affect the accuracy of CVP [20]. A more accurate and simpler index should be explored to guide intraoperative fluid management.

Goal-oriented fluid therapy provides individualized rehydration therapy according to perioperative fluid needs of patients, optimizes perioperative hemodynamics, ensures oxygen supply and perfusion to organs and tissues, prevents perioperative circulatory overload and insufficiency as well as tissue edema, and reduces

patient mortality and complication rates [21, 22]. Clinically, SVV is defined as the left ventricular stroke volume variation in a certain period of time. SVV not only reflects the preload state of the circulatory system, but also can be used to predict fluid responsiveness [23]. The greater the SV variability, the less the effective circulating volume. When the volume load is greater than the optimal preload state, the cardiac output will no longer change with the increase of capacity load. Therefore, when SVV is less than 10%, the volume load is already in the optimal preload state. SVV ranging 12%-15% indicates effective fluid management [24, 25]. In this study, the SVV of patients in group B was maintained below 10%, and when it was >10%, it indicated that the volume of the circulatory system was insufficient, and fluid should be supplemented in time. In this study, CVP and SVV were monitored during renal transplantation to guide fluid management. The results showed that group B had a higher CVP value and more fluid infusion than group A, and neither groups had heart failure, suggesting that more fluid infusion in group B did not increase the incidence of heart failure, and the volume management guided by CVP was not the optimal option. Patients in group A had intraoperative tissue hypoperfusion and acute kidney injury due to high volume of fluid infusion after surgery. The total infusion volume and Scr at 0 h, 24 h, 48 h and 72 h in group B were lower than those in group A. This may be due to the hemodialysis treatment in the preoperative period, coupled with the emergency surgery, the majority of the patients were mildly dehydrated. Patients will experience renal insufficiency in early stage after transplantation. Due to preoperative water retention and inadequate intraoperative rehydration, the recovery of renal function was delayed, so patients in group A had higher postoperative Scr values [26]. Patients in group A had a higher 3-day total transfusion volume after surgery, which may be due to inadequate tissue perfusion combined with massive postoperative transfusions, resulting in acute kidney injury. The rate of blood purification after renal transplantation in group B was lower than that in group A. This may be related to the early administration of vasoactive drugs and insufficient intraoperative transfusion, and may also be influenced by factors such as acute rejection, ischemia time, comorbid diabetes and hyper-

tension, and the specific mechanism remains to be further investigated. Zhang [27] also found that compared with the CVP, SVV-guided fluid management could maximize intraoperative renal perfusion and help improve the postoperative outcomes of patients after renal transplantation, which is consistent with the results of this study.

In summary, compared with CVP, fluid management guided by SVV monitoring during renal transplantation can reduce intraoperative fluid infusion, optimize renal perfusion, reduce postoperative blood purification rate, and promote rehabilitation.

However, there are some limitations to this study, such as the small sample size; only the renal function index and urine volume were recorded at 0-72 h after surgery. If the observation time is extended, more findings may be obtained.

### Disclosure of conflict of interest

None.

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