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Original Article

Continuous renal replacement therapy is efficient for patients with acute hypernatremia following severe craniocerebral injury and cerebral encephalorrhagia

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Abstract: Continuous renal replacement therapy (CRRT) has been widely employed in the treatment of critically ill patients. This study aimed to compare the efficacy of CRRT such as continuous veno-venous hemofiltration (CVVH), continuous veno-venous hemodialysis (CVVHD) and continuous veno-venous hemodiafiltration (CVVHDF), in patients with acute hypernatremia following craniocerebral injury and cerebral encephalorrhagia. Seventy-six patients with acute hypernatremia were treated with CRRT by GAMBO blood purification system in five different modes, CVVHD, CVVH with preoperative dilution, CVVH with postoperative dilution, CVVHDF with preoperative dilution, and CVVHDF with postoperative dilution. With the increase of dialysis buffer flow rate, serum sodium clearance rate and creatinine clearance rate were significantly elevated in all CRRT groups. The peak of clearance rate was achieved in patients treated with CVVH with preoperative dilution or CVVHDF with preoperative dilution, with flow rate set as 3,500 mL/h. The clearance rates were higher in CVVHDF group and the cycle rates of dialysis buffer were higher in CVVHD group than in other groups. All types of CRRT increased the survival of patients and the prognosis of patients in CVVHDF group was better than in other CRRT groups ($P<0.05$). In conclusion, CRRT efficiently and safely decrease serum sodium level and improve the prognosis of patients with acute hypernatremia following severe craniocerebral injury and cerebral encephalorrhagia.

Keywords: Hemodialysis, hemofiltration, hemodialysis filtration, hypernatremia, prognosis

Introduction

Continuous renal replacement therapy (CRRT) is a form of dialysis used for intensive care unit (ICU) patients. CRRT is a gentle process with slower blood flow and the removal of waste and extra fluids [1]. Therefore, CRRT is used for patients who are too sick to have other forms of dialysis. CRRT is better tolerated than other forms of dialysis if the patients have low and unstable blood pressure. In particular, CRRT has been widely employed in the treatment of critically ill patients with severe electrolyte disorders to increase the survival of these patients [2, 3].

CRRT has been developed into a variety of modes from the initial arterial-venous hemofiltration mode, including continuous veno-venous hemofiltration (CVVH), continuous veno-venous hemodialysis (CVVHD), and continuous veno-venous hemodiafiltration (CVVHDF) [4-7]. However, how to choose the appropriate mode and the appropriate dose to achieve satisfactory therapeutic effects of CRRT treatment for hypernatremia is still a problem in the clinical [8]. This study aimed to compare the efficacy of CVVH, CVVHD and CVVHDF in patients with acute hypernatremia following craniocerebral injury and cerebral encephalorrhagia.

In this retrospective study we enrolled 76 critically ill patients with acute hypernatremia from intensive care unit (ICU) of our hospital who underwent different mode of CRRT treatment. The efficacy of CVVH, CVVHD and CVVHDF in these patients were analyzed.

Subjects and methods

Subjects

This study enrolled 76 cases of patients who were hospitalized at Huai'an First People's Hospital ICU from 2010 to 2014. The inclusion criteria were patients with hypernatremia (se-

Table 1. Comparison between CRRT and control groups

	Patients with increased serum sodium levels (n)	Patients with mortality (n)
Conservative treatment group	7/11 (65%)	6/11 (54%)
CRRT group	59/76 (78%)*	17/76 (22%)*

*P<0.01 versus Conservative treatment group.

rum sodium > 145 mmol/L) and brain injury; the exclusion criteria were patients with chronic hypernatremia such as caused by diabetes. They were all male, aged 27-54 years (mean 43±4.1 years), and APACHE score was 24.67±6.93. 58 cases had traumatic brain injury, 10 cases had cerebral vascular malformations caused by cerebral hemorrhage, 8 cases had cerebral vascular accident by other causes. 45 cases were in coma supported by mechanical ventilation, 5 cases had daze, and the other 26 cases were conscious.

All 76 patients had varying degrees of hypernatremia (serum sodium > 145 mmol/L), and 50 patients had significant renal insufficiency. Among 76 cases, 22 cases, 24 cases and 30 cases were treated with CVVH, CVVHD, and CVVHDF, respectively. The control group was 11 cases of traumatic brain injury patients with hypernatremia, who were also hospitalized at ICU, including eight cases in coma, two cases with confusion and one case with consciousness. Patients in the control group did not undergo CRRT treatment but received conservative treatment. Serum sodium level was detected by electrode assay at the laboratory.

Treatment methods

76 cases underwent deep vein catheterization with double lumen catheter. Fresenius AV600S blood filters were used, and blood purification device was from GAMBRO (China). The composion of the replacement fluid was as follows: 2000 mL saline, 500 mL water, 7-8 mL 10% potassium chloride, 10 ml 50% glucose, 4 mL 10% magnesium sulfate, 150 mL 5% sodium bicarbonate. Serum sodium level was adjusted by using 10% sodium chloride.

CVVH, CVVHD and CVVH treatments were performed at the bedside, treatment time was more than 24 hours, blood flow was 170-250 mL/min, the daily amount of replacement fluid used was 32-47 L.

Blood pressure, respiration, heart rate and oxygen saturation were measured every hour. Electrolytes were measured every 4 h.

Statistical analysis

Data were expressed as mean ± standard deviation, and data before and after treatment in each treatment method group were compared using paired t test. Analysis of variance was used to compare the impact of different treatment methods on the prognosis of patients. P<0.05 was considered statistically significant.

Results

The efficacy of CRRT treatments

Compared with patients with conservative treatment, serum sodium levels significantly improved and mortality rate significantly decreased in patients with CRRT treatment (P<0.01) (**Table 1**). After CVVH, CVVHD and CVVHDF treatment, serum levels of sodium and creatinine, and plasma osmolality decreased significantly (P<0.01) while $HCO3^-$ concentration increased and acidosis improved significantly. However, the heart rate and mean arterial pressure showed no significant changes. For all three modes of treatments, APACHE score was significantly lower after treatment than before treatment (P<0.01) (**Table 2**).

Comparsion of different modes of CRRT treatments

Among the three modes of CRRT treatments, the clearance of serum sodium was increased with the increase of the amount of fluid displacement for CVVHD and the highest clearance rate was achieved at 3500 mL/h for CVVH and CVVHDF. In addition, the solute clearance rate was significantly higher in post-dilution mode than in pre-dilution mode. At the same conditions, CVVHDF mode had the highest solute clearance rate (P<0.05, **Table 3**).

The prognosis of patients after CRRT treatments

After CRRT treatments 26 conscious patients and 5 daze patients returned to normal. Among the other 45 patients in coma, 21 cases had significant improvement in consciousness with

Table 2. Comparison before and after CRRT treatment

	Before treatment	CVVH	CVVHD	CVVHDF
Serum sodium (mmol/l)	156±12.3	138±11.1*	140±10.3*	141±11.2*
Creatinine (μmol/l)	201±22.3	134±22.3*	137±14.1*	138±20.1*
Plasma osmolality (mOsm)	343±34.3	313±35.3*	307±36.1*	324±41.3*
[$HCO3^-$] (mmol/l)	12±2.3	18±2.1*	19±2.0*	21±2.4*
Plasma pH	7.24±0.8	7.34±0.9	7.41±0.7	7.42±0.8
Heart rate (bpm)	105±11.3	101±11.2	109±10.2	110±12.1
MAP (mmHg)	99±10.3	102±10.1	101±10.4	105±10.1
APACHE score	24.67±6.93	9.67±1.93*	10.27±0.93*	11.61±1.13*

*P<0.01 versus before treatment. MAP: mean artery pressure, APACHE: Acute Physiology and Chronic Health Evaluation.

Table 3. Clearance rate of serum sodium under three different CRRT dialysate flow (ml/min)

	CVVHD	CVVH pre-dilution	CVVH post-dilution	CVVHDF pre-dilution	CVVHDF post-dilution
1000 mL/h	12±2.3	18±2.1	19±2.0	26±2.1	29±2.3*
2000 mL/h	19±2.3	23±2.0	26±2.1	31±2.2	37±2.1*
3500 mL/h	25±2.3	26±2.1	30±2.0	36±2.1	40±2.3*
5000 mL/h	26±2.3	27±2.1	29±2.0	35±2.1	39±2.3*

CVVH: continuous veno-venous hemofiltration, CVVHD: continuous veno-venous hemodialysis, CVVHDF: continuous veno-venous hemodiafiltration. *P<0.05 versus other group.

Table 4. The prognosis of coma patients after different treatments

	CVVH	CVVHD	CVVHDF
Significant improvement	6	6	9*
Improvement	1	0	3*
No improvement	0	1	2
Dead	8	8	1*
Total	15	15	15

CVVH: continuous veno-venous hemofiltration, CVVHD: continuous veno-venous hemodialysis, CVVHDF: continuous veno-venous hemodiafiltration. *P<0.05 versus other group.

response to painful stimuli, 4 cases had improved consciousness, 3 cases had no improvement in consciousness, and 17 cases were dead. Compared to control group, all three modes of CRRT treatment significantly improved the survival of patients (P<0.05), and CVVHDF led to the best prognosis of patients (**Table 4**).

Discussion

Currently the pathogenesis of craniocerebral trauma complicated with hypernatremia remains unclear. It was postulated that severe brain trauma would cause decreased secretion of antidiuretic hormone (ADH) and increased secretion of adrenocorticotropic hormone (ACTH) [9]. Severe hypernatremia caused by traumatic brain injury may be related to the dysfunction of osmoreceptors after the damage to the hypothalamus. Upon brain injury, the excitability of sympathetic nerves increases, and the level of excitability is correlated with the severity of brain injury. Consequently, sympathetic nerves release excessive norepinephrine which would act on neurons to inhibit the secretion of ADH, resulting in increased renal excretion. On the other hand, brain damage stimulates the stress response in the body, leading to increased levels of ACTH and glucocorticoids, which could decrease the excretion of sodium.

For conservative treatment of hypernatremia, diuretics have been used to increase urinary excretion of sodium, but it takes a long time and the efficacy is not stable, leading to high mortality, especially in patients with renal failure, oliguria, anuria, severe edema or heart failure. Moreover, rapid increase of serum sodium level can lead to cell swelling and cause serious neurological damage. Therefore, correct adjustment of serum sodium level is very important. It was suggested that for patients in coma the speed for sodium adjustment could be 1-3 mmol/L per hour [10]. In this study, we used CRRT for the treatment of hyponatremia, and had better control of sodium level in the body of the patients. We could adjust the speed for sodium adjustment according to serum sodium level of the patient and thus avoid a series of complications associated with high sodium level such as demyelinating lesions [11].

CVVHDF technique is the combination of hemodialysis (HD) and hemofiltration (HF), which can effectively remove the accumulated metabolic byproducts, toxic substances, and inflammation factors to correct the acid-base imbalance, water and electrolyte imbalance, hyponatremia, and hypokalemia [12-15]. CVVHDF could maintain the homeostasis and promote the recovery of patients with renal failure and organ dysfunction [16-20]. Consistent with the advantages of CVVHDF, in this study we found that CVVHDF achieved the highest solute clearance rate, and the patients got the best prognosis. These data indicate that CVVHDF is a safe, effective, safe, and practical method for the treatment of acute hypernatremia following traumatic brain injury and cerebral hemorrhage.

In conclusion, we analyzed the efficacy and prognosis of CRRT treatment for patients with hypernatremia following traumatic brain injury and brain hemorrhage. Our data suggest that CRRT efficiently and safely decrease serum sodium level and improve the prognosis of patients with acute hypernatremia.

Disclosure of conflict of interest

None.

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