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Application of ultrasound in goal-directed fluid management of anesthesia in elderly patients.

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Abstract

Objective: To investigate the effect of ultrasonography in goal-directed fluid management of anesthesia in elderly patients.

Methods: A total of 232 elderly patients with general anesthesia were selected from North China University affiliated Hospital from October 2012 to October 2014. These patietns were assigned into two groups by random digital table method. One hundred and sixteen patients who received goal-directed fluid management with guidance of central venous pressure (CVP) were assigned into control group. One hundred and sixteen patients who received goal-directed fluid management with guidance of ultrasonography were assigned into observation group. The effect of ultrasonography was compared between two groups.

Results: Cardiac index (CI), stroke volume variation (SVV), mean arterial pressure (MAP), central venous pressure (CVP), central venous oxygen saturation ($ScvO_2$), oxygen supply index (DO_2I), oxygen consumption index (VO_2I), oxygen uptake rate (ERO_2) were higher in observation group than control group at T1, T2, T3, T4 ,P<0.05. Lactate (Lac) were lower in observation group than control group at T1, T2, T3, T4, P<0.05. Urine volume and colloid fluid volume were higher in observation group than control group, P<0.05. Crystal liquid volume and total input were lower in observation group than control group, P<0.05. The incidence of complication was lower in observation group than control group, P<0.05.

Conclusion: In goal-directed fluid management, the guidance of ultrasonography is beneficial for stabilization of hemodynamic and metabolic markers in elderly patients, this could effectively maintain oxygen balance. The guidance of ultrasonography could also guarantee microcirculation perfusion.

Keywords: Ultrasonography, Elderly, Goal-directed fluid management.

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Introduction

Goal-directed fluid management is the common treatment for rescuing critically ill patients [1,2]. In treatment process, the liquid volume will impact the treatment of patients to varying degree. The recovery capacity of fluid is low with poor physical condition, thus rehydration therapy and diuretic therapy will become a difficult problem for clinicians. During surgeries, the liquid demand is also significantly different, which is affected by different conditions of the diseases [3]. Therefore, it is necessary to carry out goal-directed fluid management to ensure the smooth progress of surgeries. How to choose the best guidance is a hot topic for clinicians. Conventional rehydration were guided by CVP, and fluid requirements were calculated using the fluid replacement formula plus experience. However, individual perioperative need of fluid was not considered, leading to tissue perfusion, organ dysfunction and high risk of complications [4,5]. This study compared the effect of the guidance of CVP and ultrasonography for fluid management.

Materials and methods

General information

A total of 232 elderly patients with anesthesia from the North China University of Hospital Affiliated Hospital from October 2012 to October 2014 were included. Patients with a body mass index (BMI)>30 kg/m^2 or <18 kg/m^2 were excluded. Besides, patients with pre-existing severe cardiovascular and cerebrovascular diseases, liver and kidney dysfunction, mental disorder and intubation difficulties were also excluded. Using random number table method, the patients were assigned into two groups. The control group had 116 patients with 68 males and 48 females, mean age 68.7 ± 3.6 years and mean weight 63.4 ± 7.2 kg (48-89 kg). The surgery time was 214.3 ± 31.5 min (172~248 min) and the duration of anesthesia was 276.3 ± 42.8 min (229~315 min). According to ASA classification, 72 patients were Grade I and 44 patients were Grade II. There was no significant difference between the two groups (age, weight, sex, surgery time, duration of anesthesia, ASA classification), P>0.05. This study had obtained the consent of the patient's family, signed informed consent from the patient and approved by the Ethics Committee.

Methods

The patients were fasting for 8 h before surgery. Local anesthesia was performed in the operating room, and radial artery puncture was implanted. Patients were continuously monitored with a Philips MP40 multifunctional monitor. With guidance of color Doppler ultrasonography, the internal jugular vein was catheterized. The vein was connected to the Flotrac/ Vigileo monitoring system to monitor the hemodynamics. All patients received endotracheal intubation under general anesthesia. Induction of anesthesia was performed as follows: Midazolam Injection (Jiangsu Enhua Pharmaceutical Group Co., Ltd., H10980026) 0.06 mg/kg, IV, Tolomycin (Jiangsu Enhua Pharmaceutical Group Co., Ltd., H32022999) 0.30 mg/kg, IV, Fentanyl (Yichang Ren Fu Pharmaceutical Co., Ltd., H20030198) 4 μg/kg, and atracurium cis-benzenesulfonate (Jiangsu Hengrui Pharmaceutical Co., Ltd., Zhunzi H20060869) 0.2 mg/kg, IV. With the assistance of laryngoscope, tracheal intubation was performed. Then the trachea cannula was connected to Datex-Ohmeda 7100 anesthesia ventilator to control breathing. The parameter was set as follows: tidal volume 8-10 ml/kg, breathing ratio 1:2, respiratory rate 10-14 times/min. Inhalation of sevoflurane was set as 1% to 2% for maintenance of anesthesia. Sufentanil and atracurium cis-benzenesulfonate may be appropriately administered depending on the patient.

The patients in control group received target fluid management with the guidance of central venous pressure. Surgical method was refered to "Miller Anesthesiology" (6th edition), and the ratio of input crystal liquid to colloid liquid ratio was 3:1 [6]. The observation group received ultrasonography-guided fluid management. The patient was in a supine position, then maximum and minimum diameter of inferior vena cava at the end of inspiratory and inhaled breath was measured by Philips bedside ultrasound machine. The inferior vena cava collapse index was calculated by (maximum internal diameter-minimum internal diameter)/maximum internal diameter × 100%. The collapse index<40% was used as the rehydration termination index. The inferior vena cava was measured by the same physician through a bedside ultrasound machine. Thermal blanket and continuous heating device were used in both groups to assure that the body temperature was above 36°C. If blood loss is greater than 25% of blood volume or blood cell backlog less than 25%, transfusion therapy was required. The bispectral index was used to monitor the depth of anesthesia during surgery.

Observational measurements

All patients were recorded at 5 time points: T0, 10 min after supine position, T1, 5 min after induction of anesthesia, T2, beginning of the surgery; T3, 1 h after beginning of the surgery; T4, the end of the surgery. The following parameters were recorded: 1) hemodynamic parameters (heart rate, cardiac output index, stroke variability, MAP, CVP); 2) body fluid capacity changes (blood loss, urine output, colloid volume, the amount of liquid crystals, the total input); 3) complications (nausea, vomiting, hypotension, arrhythmias, infection, delirium).

Statistical analysis

SPSS 16.0 software was used for statistical analysis. Measurement data were represented by mean ± SEM and analyzed by Student's t test. Categorical data were represented by rate (%) and analyzed by χ^2 test. Comparison of different time points between two groups was performed by repeated measures analysis of variance, and P<0.05 was considered statistically significant.

Results

Hemodynamics at different time points

The results are as shown in Table 1.

Table 1. *Hemodynamics at different time points.*

Index	Group	Case	T0	T1	T2	T3	T4	F	P
Heart rate (times/min)	Control	116	80.5 ± 2.1	76.9 ± 3.2	76.4 ± 1.7	78.6 ± 3.4	78.9 ± 1.8	1.536	>0.05
	Observation	116	80.3 ± 3.6	77.0 ± 2.8	76.8 ± 2.5	78.9 ± 3.0	79.3 ± 2.7	1.455	>0.05
F			0.249	0.130	0.523	0.381	0.506		
P			>0.05	>0.05	>0.05	>0.05	>0.05		
Cardiac output index (L/(min·m^2))	Control	116	6.1 ± 0.8	6.2 ± 0.9	6.4 ± 1.1	6.6 ± 1.0	6.9 ± 1.3	4.311	<0.05
	Observation	116	6.2 ± 0.7	6.8 ± 1.0	7.2 ± 1.3	7.5 ± 1.2	8.0 ± 1.4	5.903	<0.05
F			0.164	3.967	4.125	4.136	4.594		
P			>0.05	<0.05	<0.05	<0.05	<0.05		
Stroke variability (%)	Control	116	14.4 ± 1.8	11.2 ± 1.5	10.4 ± 1.6	9.9 ± 1.4	9.4 ± 1.3	8.569	<0.05

	Observation	116	14.5 ± 1.6	13.9 ± 1.7	13.0 ± 1.9	12.7 ± 1.8	12.5 ± 1.4	4.623	<0.05
F			0.694	5.412	5.526	5.828	6.297		
P			>0.05	<0.05	<0.05	<0.05	<0.05		
MAP (kPa)	Control	116	11.3 ± 0.4	9.7 ± 0.5	9.5 ± 0.8	9.3 ± 0.7	9.8 ± 0.6	5.151	<0.05
	Observation	116	11.3 ± 0.5	11.0 ± 0.7	10.8 ± 0.5	10.7 ± 0.6	11.1 ± 0.7	3.028	<0.05
F			0.012	4.340	4.368	4.505	4.325		
P			>0.05	<0.05	<0.05	<0.05	<0.05		
CVP (kPa)	Control	116	0.81 ± 0.13	0.84 ± 0.16	0.86 ± 0.15	0.88 ± 0.17	0.90 ± 0.18	3.987	<0.05
	Observation	116	0.82 ± 0.09	0.93 ± 0.10	0.95 ± 0.17	1.01 ± 0.15	1.04 ± 0.16	5.623	<0.05
F			0.123	4.081	4.046	4.477	4.556		
P			>0.05	<0.05	<0.05	<0.05	<0.05		

Metabolic measurements at two different time points

As shown in Table 2, the oxygen saturation, DO_2I, VO_2I, ERO_2 of the central vein at T1, T2, T3, T4 were higher in the observation group than the control group, P<0.05. The arterial lactate was lower than that the control group, P<0.05 (Table 2).

Table 2. *Metabolic measurements at two different time points.*

Index	Group	Case	T0	T1	T2	T3	T4	F	P
$ScvO_2$ (%)	Control	116	71.0 ± 2.4	68.2 ± 3.0	68.9 ± 2.3	69.1 ± 3.5	68.6 ± 2.4	0.739	>0.05
	Observation	116	71.2 ± 2.8	75.1 ± 3.4	77.0 ± 1.9	78.2 ± 2.1	77.2 ± 2.6	3.985	<0.05
F			0.281	4.029	4.325	4.304	4.253		
P			>0.05	<0.05	<0.05	<0.05	<0.05		
Arterial lactate (mmol/L)	Control	116	1.0 ± 0.2	1.3 ± 0.2	1.4 ± 0.4	1.3 ± 0.3	1.3 ± 0.2	7.154	<0.05
	Observation	116	1.0 ± 0.1	1.1 ± 0.3	1.0 ± 0.2	0.9 ± 0.4	1.0 ± 0.3	5.223	<0.05
F			0.036	4.818	7.026	7.445	6.028		
P			>0.05	<0.05	<0.05	<0.05	<0.05		
Oxygen for the index (ml/(min·m^2))	Control	116	520 ± 17	530 ± 26	541 ± 42	562 ± 37	576 ± 35	4.038	<0.05
	Observation	116	519 ± 23	596 ± 35	637 ± 40	676 ± 31	697 ± 41	6.529	<0.05
F			0.192	4.245	4.673	4.964	5.105		
P			>0.05	<0.05	<0.05	<0.05	<0.05		
VO_2I (ml/(min·m^2))	Control	116	117 ± 10	131 ± 16	150 ± 15	163 ± 14	165 ± 13	5.821	<0.05
	Observation	116	116 ± 11	175 ± 12	198 ± 17	207 ± 16	224 ± 15	10.069	<0.05
F			0.085	6.358	6.203	5.699	6.576		
P			>0.05	<0.05	<0.05	<0.05	<0.05		
ERO_2 (%)	Control	116	20.2 ± 1.0	21.8 ± 1.2	22.6 ± 1.3	23.1 ± 1.0	23.8 ± 1.2	4.287	<0.05
	Observation	116	20.3 ± 1.4	24.7 ± 1.5	25.4 ± 1.0	25.9 ± 0.9	26.0 ± 1.0	6.103	<0.05
F			0.495	4.428	4.460	4.512	4.304		
P			>0.05	<0.05	<0.05	<0.05	<0.05		

Changes of body fluid volume between two groups

As shown in Table 3, the urine volume and colloid volume of the observation group were higher than that of the control group. The amount of crystal fluid and the total input were lower than that in the control group.

Table 3. Changes of body fluid volume between two groups (ml).

Group	n	Blood loss	Urine output	Colloidal fluid volume	Crystal liquid volume	Total input
Control	116	831 ± 102	396 ± 30	821 ± 98	2603 ± 215	3424 ± 308
Observation	116	835 ± 126	574 ± 42	1204 ± 143	1457 ± 169	2661 ± 259
t		0.481	7.615	7.630	11.571	6.077
P		>0.05	<0.05	<0.05	<0.05	<0.05

Complications in the two groups

As shown in Table 4, the incidence of complications in the observation group was lower than that in the control group, P<0.05.

Table 4. Complications in the two groups (Case (%)).

Group	n	Nausea and vomiting	Hypotension	Arrhythmia	Infection	Delirium	Complications
Control	116	8 (6.9)	3 (2.6)	1 (0.9)	3 (2.6)	1 (0.9)	16 (13.8)
Observation	116	2 (1.7)	1 (0.9)	0 (0.0)	1 (0.9)	0 (0.0)	4 (3.4)
χ^2							7.879
P							0.005

Discussion

Body fluid management is particularly important in elderly patients under general anesthesia [7,8]. Traditional body fluid management is targeted liquid management under the guidance of CVP, and it is necessary to preset the liquid dosage. But this cannot meet the individual needs, causing insufficient tissue perfusion, organ dysfunction and other adverse events [9,10]. The traditional capacity assessment methods include straight leg raising test, clinical experience, CVP measurement, etc. However, these methods have disadvantages, such as deviation from experience, limited patients and insufficient fluid. Therefore, there is a need for clinicians to find more secure and feasible assessment methods. Ultrasonography-guided goal-directed fluid management is a new approach to capacity assessment. According to the patient's perioperative systemic capacity and detailed hemodynamic parameters, real-time adjustment is available for implementation of effective individualized fluid replacement program. It can maintain the stability of hemodynamics indicators to ensure smooth surgery. There is a certain correlation between blood volume and CVP [11,12]. When CVP is below 7 mmHg, an inferior vena cava collapse index>40% can ensure better response to liquid therapy. When the index is <40%, it turns out to be poor response to liquid treatment.

The results showed that cardiac output index, stroke variability, mean arterial pressure and CVP of the observation group at T1, T2, T3 and T4 were significantly higher than those in the control group, while the differences were not significant at other time points. This suggested that the guidance of ultrasonography could help stabilize hemodynamics in elderly patients who received goal-targeted fluid management. The Flotrac/Vigileo system was a method based on arterial pressure of cardiac output. Through arterial waveform analysis of the radial artery or femoral artery catheter, indirect measurement of cardiac output and other hemodynamic parameters was obtained. It had the advantage of simple operation, small trauma of patients and continuous access to hemodynamic indicators. Ultrasonography-guided fluid management was a non-invasive procedure for patients. It could clearly show maximum and minimum diameter of inferior vena cava at the end of inspiratory and inhaled breath. This management could accurately obtain the inferior vena cava collapse index, thereby regulating the rehydration.

The oxygen saturation, DO_2I, VO_2I and ERO_2 of the central vein at T1, T2, T3 and T4 in the observation group were higher than those in the control group. The arterial lactate was lower in the observation group than the control group, while the difference was not significant at other time points. It indicated that the guidance of ultrasonography could help to stabilize the metabolic profile of elderly patients in goal-targeted fluid management. The patients in observation group had high levels of oxygen supply, thus could maintain the body's oxygen supply and oxygen consumption balance without fluid overload. Lac was one of the important enzymes of sugar anaerobic glycolysis and glycolysis, which catalyzed the reduction and oxidation of pyruvic acid and L-lactic acid. By monitoring the arterial lactate, we could have an insight of the patient's anaerobic metabolism.

The urine volume and colloid volume of the observation group were higher than those in the control group, while the amount of liquid crystal and the total input were lower than those in the control group. This indicated that in the goal-targeted fluid management, the guidance of ultrasonography could ensure microcirculation perfusion. Colloidal fluid volume and fluid volume should not be considered as simple reciprocal substitutions during treatment. Crystalloid fluid replenished intravascular loss of capacity, causing most of the crystals remaining in the blood vessels. This increased the risk of tissue edema, hypotension, delayed healing and pulmonary infection, and was not beneficial for postoperative recovery. Similarly, the colloid solution was not always reasonable, and large-scale use would cause different degrees of renal damage. Therefore, taking into account the indications and contraindications of drugs, the rational use of drug dose should be considered, ensuring the safety of treatment. The incidence of complications in the observation group was lower than that in the control group, indicating that the guidance of ultrasonography was safe and reliable in targeted liquid management, and would not cause many complications. From the therapeutic point of view, ultrasonography-guided liquid management could improve the prognosis of patients.

In summary, for goal-targeted fluid management, the guidance of ultrasonography helped to stabilize hemodynamics and metabolic markers in elderly patients. It could effectively maintain the body oxygen supply and demand balance, and ensure microcirculation perfusion. However, the sample size of this study was small, and further study was needed to establish the best fluid management plan.

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