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Original Article

Application of regional cerebral oxygen saturation monitoring with near-infrared spectroscopy in peri-anesthesia management of elderly hypertensive patients undergoing shoulder arthroscopic surgery

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Abstract: Objective: To explore the effect of using regional cerebral oxygen saturation ($rScO_2$) monitoring with near-infrared spectroscopy in peri-anesthesia management of elderly hypertensive patients undergoing shoulder arthroscopic surgery. Methods: Sixty elderly patients with hypertension undergoing shoulder arthroscopic surgery under general anesthesia were enrolled as the research objects for this prospective study, and they were randomly divided into an observation group and a control group. The observation group received bispectral index (BIS) + $rScO_2$, while the control group only adopted BIS. The changes in BIS, mean arterial pressure (MAP), heart rate (HR), and $rScO_2$ at 5 min after intubation (T1), 10 min after intubation (T2), immediately after changing position (T3), 5 min after changing position (T4), and 10 min after changing position (T5) of the two groups were recorded. The correlation between MAP and $rScO_2$ was analyzed. Preoperative and postoperative Mini-Mental State Exam (MMSE), Montreal Cognitive Assessment (MoCA) scores, serum neuron-specific enolase (NSE) and s100β levels were compared between the two groups. The incidence of postoperative cognitive dysfunction (POCD) at 1-3 days was recorded. Results: There were no significant differences in BIS, MAP, HR, or $rScO_2$ between the two groups at T1 and T2 (all $P>0.05$). At T3-T5, the levels of BIS, MAP, HR, and $rScO_2$ in the two groups decreased, and the control group had lower levels of the above indicators (all $P<0.05$). Correlation analysis showed that MAP and $rScO_2$ levels were positively correlated in the two groups ($r>0$, $P<0.05$). There were no significant differences in the MMSE or MoCA scores, NSE or s100β levels between the two groups before surgery (all $P>0.05$). After surgery, the MMSE and MoCA scores of the two groups were decreased (both $P<0.05$), while the NSE and s100β levels were increased (both $P<0.05$). The control group showed greater changes in the above four indexes (all $P<0.05$). The incidence of POCD in the observation group was lower than that of controls at 1, 2, and 3 days after surgery (all $P<0.05$). Conclusion: $rScO_2$ monitoring with near-infrared spectroscopy in peri-anesthesia management of elderly patients with hypertension undergoing shoulder arthroscopic surgery can effectively stabilize hemodynamics and reduce the incidence of postoperative POCD.

Keywords: Cerebral oxygen saturation monitoring with near-infrared spectroscopy, elderly, hypertension, shoulder arthroscopic surgery, perianaesthesia

Introduction

Shoulder arthroscopic surgery is recognized as a simple operation, with less trauma and remarkable efficacy [1-3]. Beach chair position is the main position used in shoulder arthroscopy, which has a negative impact on the patient's hemodynamic indicators and increases the risk of cerebral ischemia and hypoxia [4-9]. As a non-invasive monitoring biologic tissue oxygenation technology, near-infrared spectroscopy continuously monitors regional cerebral oxygen saturation ($rScO_2$) to reflect changes in blood flow and cerebral oxygen balance [10]. Studies have shown that $rScO_2$ is closely related to the occurrence and development of postoperative cognitive dysfunction (POCD) [11]. Thus, this study explored the safety of intraoperative controlled hypotension during shoulder arthroscopic surgery in elderly patients with hypertension under general anesthesia, and evaluated the application value of

$rScO_2$ monitoring with near-infrared spectroscopy in the anesthetic management and its preventive effects on the occurrence of intraoperative cerebral ischemia and hypoxia in those patients.

Materials and methods

General information

Sixty elderly patients with hypertension undergoing shoulder arthroscopic surgery under general anesthesia in Beijing Luhe Hospital, Capital Medical University from January 2019 to May 2020 were enrolled as the research subjects for this prospective study, and they were randomly divided into an observation group and control group according to the random number table method. This study was approved by the Medical Ethics Committee of Beijing Luhe Hospital, Capital Medical University.

Inclusion criteria: (1) Patients were no less than 60 years old. (2) Patients had combined with essential hypertension [12]. (3) Patients were within ASA classification grade III [13]. (4) Patients underwent shoulder arthroscopic surgery under general anesthesia and could tolerate surgery. (5) Patients had good compliance. (6) Patients had no cognitive dysfunction before surgery. (7) Patients had no other disease. (8) Patients and their family members had signed informed consent.

Exclusion criteria: (1) Patients had dysfunction of target organ. (2) Patients had anemia (hemoglobin <110 g/L). (3) Patients suffered from severe perioperative complications and surgical failure. (4) Patients or family members did not cooperate with the medical staff. (5) Patients had medical disputes.

Methods

All patients were managed by mechanical ventilation with tracheal intubation.

The observation group received bispectral index (BIS) + $rScO_2$. $rScO_2$ monitor (OXImeter near infrared optical parameter analyzer, American ISS Company) was used to monitor the $rScO_2$ during anesthesia, making the absolute value of $rScO_2$ during the operation not less than 50%, and the decrease not less than 80% of the value of $rScO_2$ when patients inhaled pure oxygen before the surgery.

The control group adopted BIS (BIS VISTATM Monitoring System, Covidien, USA) only as a management basis. $rScO_2$ was only recorded, but not applied in the anesthesia management. During the surgery, the anesthesiologist could see only the quality of $rScO_2$, instead of the absolute value. During the surgery, the BIS values of the two groups were maintained between 40-60 and the invasive arterial pressure of the contralateral radial artery was monitored in both groups to reflect the cerebral arterial pressure. In order to accurately reflect cerebral perfusion pressure, the zero point of arterial pressure during the operation in this study was set at the level of the external auditory canal [10, 11]. The initial value of the target mean arterial pressure (MAP) for intraoperative controlled hypotension was set to not less than 30% of the patient's basic blood pressure in both groups, and the absolute value was not less than 60 mmHg; the blood pressure value was also recorded. All patients were treated with intravenous patient-controlled analgesia lasting 48 hours after the surgery [10, 11].

Outcome measures

The changes in BIS, MAP, heart rate (HR), and $rScO_2$ at 5 min after intubation (T1), 10 min after intubation (T2), immediately after changing position (T3), 5 min after changing position (T4), and 10 min after changing position (T5) of the two groups were recorded [6, 14].

5 mL of venous blood was drawn before surgery and the next morning after the surgery. It was centrifuged at 3,000 r/min for 5 min, and serum was separated. Enzyme-linked immunosorbent assay (Spectra-MaxParadigm multifunctional microplate reader, Molecular Devices, USA) was used to detect neuron-specific enolase (NSE) and s100β levels.

The patients were surveyed with the Minimum Mental State Examination (MMSE) and the Montreal Cognitive Assessment Scale (MoCA) before surgery and the next morning after the surgery. The MMSE scale included memory, recall ability, orientation, language ability, attention and calculation ability, with a total score of 30 points. A lower score indicates more serious mental state disorder. Equal to or more than 27 points is regarded as normal [15]. The MoCA scale consists of visual space ability, attention, speech, abstraction, delayed memory, and orientation ability with the total

Table 1. Comparison of general information between the two groups ($\bar{x}$ ± sd)

Item	Observation group (n=30)	Control group (n=30)	χ^2/t	P
Age (years)	65.4±3.3	65.1±3.7	0.331	0.742
Gender			0.693	0.405
Male	19	22		
Female	11	8		
BMI (kg/m^2)	23.72±1.83	23.55±1.43	0.401	0.690
Preoperative hemoglobin (g/L)	131.79±7.82	134.52±7.33	1.395	0.168
Operative time (min)	108.54±6.91	105.21±8.22	1.696	0.095
Intraoperative fluid infusion (mL)	1722.35±34.58	1729.52±39.41	0.749	0.457
ASA classification			0.764	0.683
I	9	7		
II	13	12		
III	8	11		

Note: ASA: American Society of Anesthesiologists; BMI: body mass index.

Table 2. Comparison of BIS, MAP, HR, and $rScO_2$ between the two groups at different time points ($\bar{x}$ ± sd)

Items	T1	T2	T3	T4	T5	F	P
BIS (%)							
Observation group	51.14±3.41	50.63±3.72	47.25±3.21^{a,b}	45.11±2.24^{a,b,c}	44.82±2.14^{a,b,c}	29.412	<0.001
Control group	51.12±3.35	50.81±3.54	43.91±2.83^{a,b}	41.82±1.52^{a,b,c}	41.23±1.15^{a,b,c}	99.267	<0.001
t	0.023	0.192	4.257	6.657	8.094		
P	0.982	0.848	<0.001	<0.001	<0.001		
MAP (mmHg)							
Observation group	80.74±5.26	80.44±5.83	76.95±3.81^{a,b}	74.27±3.43^{a,b,c}	73.75±3.51^{a,b,c}	16.298	<0.001
Control group	80.62±5.41	80.27±6.12	72.32±4.46^{a,b}	68.74±4.12^{a,b,c}	68.15±3.96^{a,b,c}	46.485	<0.001
t	0.087	0.110	4.323	5.650	5.796		
P	0.931	0.913	<0.001	<0.001	<0.001		
HR (bou/min)							
Observation group	62.88±5.24	62.53±4.55	60.32±3.21^{a,b}	58.34±2.33^{a,b,c}	58.01±3.73^{a,b,c}	8.018	<0.001
Control group	62.79±4.92	62.31±4.76	57.27±3.13^{a,b}	55.47±2.41^{a,b,c}	55.12±3.25^{a,b,c}	28.239	<0.001
t	0.069	0.183	3.726	4.689	3.200		
P	0.946	0.855	0.003	<0.001	0.002		
$rScO_2$ (%)							
Observation group	67.94±3.42	67.63±3.25	63.87±2.82^{a,b}	62.13±2.12^{a,b,c}	61.93±2.43^{a,b,c}	31.441	<0.001
Control group	67.69±3.46	67.40±3.31	60.12±2.54^{a,b}	55.45±2.31^{a,b,c}	54.90±2.54^{a,b,c}	140.683	<0.001
t	0.281	0.272	5.412	11.669	10.954		
P	0.779	0.787	<0.001	<0.001	<0.001		

Note: Compared with T1 in the same group, $^aP<0.05$; compared with T2 in the same group, $^bP<0.05$; compared with T3 in the same group, $^cP<0.05$. BIS: bispectral index; MAP: mean arterial pressure; HR: heart rate; $rScO_2$: regional cerebral oxygen saturation.

score of 30 points. The higher the score, the higher the overall cognitive function [16].

The Z-scoring method was used to record the postoperative cognitive dysfunction (POCD) at 1-3 days after the surgery of the two groups [17]. The incidence of POCD = the number of POCD occurrences/the total number of people * 100%.

Statistical analysis

SPSS 22.0 was used for statistical analysis. The count data was expressed as case/percentage (n, %). The comparison of counted data was performed by the χ^2 test; the measured data conforming to a normal distribution were expressed by the mean ± standard deviation ($\bar{x}$ ± sd). One-way analysis of variance was

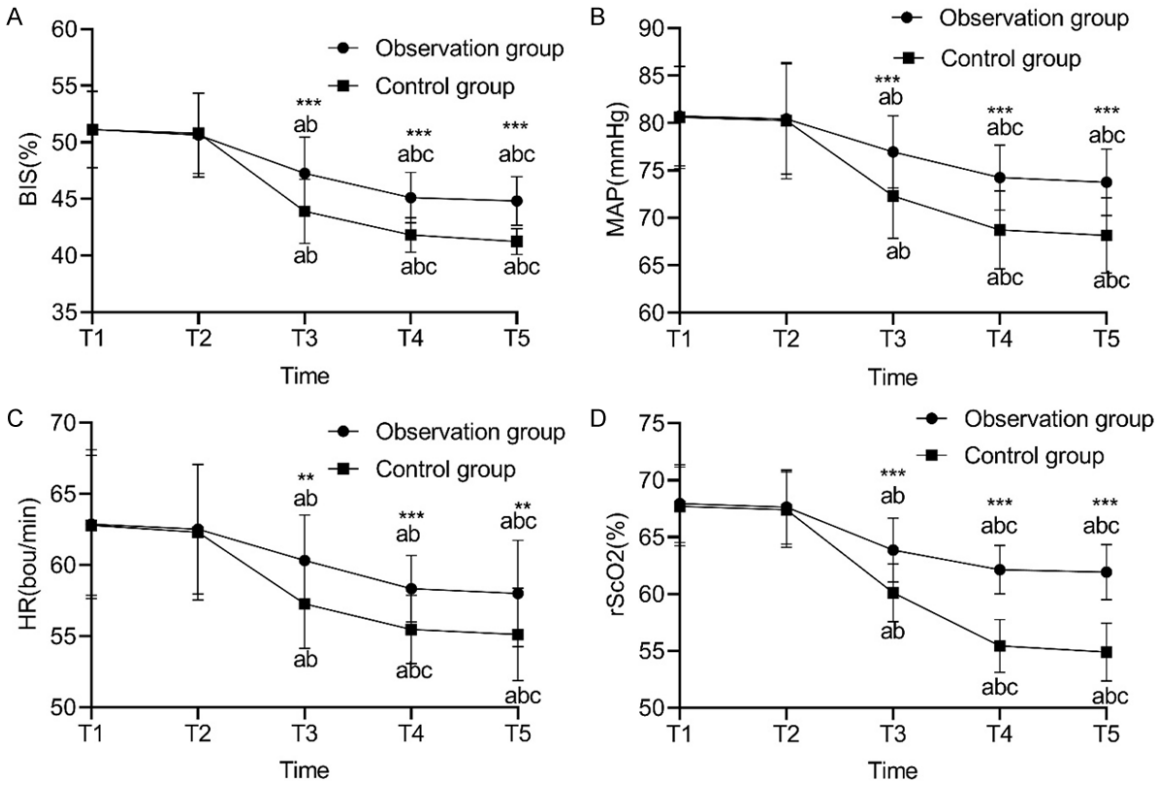

Figure 1. Comparison of BIS, MAP, HR and $rScO_2$ between the two groups at different time points. A: BIS; B: MAP; C: HR; D: $rScO_2$. Compared with the control group at the same time point, **P<0.01, ***P<0.001; compared with T1 in the same group, [a]P<0.05; compared with T2 in the same group, [b]P<0.05; compared with T3 in the same group, [c]P<0.05. BIS: bispectral index; MAP: mean arterial pressure; HR: heart rate; $rScO_2$: regional cerebral oxygen saturation.

Table 3. Correlation of MAP and $rScO_2$

Statistic	Observation group	Control group
r	0.317	0.228
P	0.004	0.017

Note: MAP: mean arterial pressure; $rScO_2$: regional cerebral oxygen saturation.

used for comparison among indexes at different time points, and t-test was used for pairwise comparison between groups. The correlation between MAP and $rScO_2$ adopted Pearson correlation method. P<0.05 was considered significant.

Results

Comparison of general information

There were no statistical differences in general data such as gender, age, body mass index, preoperative hemoglobin, operative time, intraoperative fluid infusion, and ASA classification between the two groups, and they were comparable (all P>0.05). See **Table 1**.

Comparison of BIS, MAP, HR, and $rScO_2$ between the two groups at different time points

There were no significant differences in BIS, MAP, HR, and $rScO_2$ between the two groups at T1 and T2 (all P>0.05). At T3-T5, the levels of BIS, MAP, HR, and $rScO_2$ in the two groups were decreased (all P<0.05), and the control group had lower levels of the above indicators (all P<0.05). See **Table 2** and **Figure 1**.

Correlation of MAP and $rScO_2$

The results showed that MAP and $rScO_2$ were positively correlated in the both groups (r>0, P<0.05). See **Table 3**.

Comparison of MMSE, MoCA scores, NSE and s100β levels between the two groups before and after surgery

There were no significant differences in MMSE or MoCA scores, NSE, and s100β levels between the two groups before the surgery (all P> 0.05). After the surgery, the MMSE and MoCA

Table 4. Comparison of MMSE, MoCA scores, NSE, and s100β levels between the two groups before and after surgery ($\bar{x} \pm sd$)

Variable	Group		t	P
	Observation group	Control group		
MMSE (scores)				
Before	25.56±1.78	25.43±1.48	0.308	0.759
After	23.48±1.23*	21.11±0.82*	8.781	<0.001
MoCA (scores)				
Before	25.85±1.26	25.61±1.14	0.774	0.442
After	23.32±1.41*	21.81±1.23*	4.420	<0.001
NSE (ng/mL)				
Before	6.47±1.34	6.41±1.33	0.174	0.862
After	9.56±1.57*	11.85±1.83*	5.202	<0.001
S100β (ng/mL)				
Before	298.61±74.43	296.72±73.12	0.099	0.921
After	435.69±69.94*	486.22±71.32*	2.771	0.008

Note: Compared with the same group before surgery, *P<0.05. Before: before surgery; after: after surgery; MMSE: Mini-Mental State Exam; MoCA: montreal cognitive assessment; NSE: neuron-specific enolase.

Table 5. Comparison of the incidence of POCD between the two groups after surgery

Group	1 d after surgery	2 d after surgery	3 d after surgery
Observation group (n=30)	0 (0.00)	0 (0.00)	1 (3.33)
Control group (n=30)	3 (10.00)	5 (16.67)	6 (20.00)
χ^2	4.286	5.455	4.043
P	0.038	0.020	0.044

Note: POCD: postoperative cognitive dysfunction.

scores of the two groups were decreased (both P<0.05), while the NSE and s100β levels were increased (both P<0.05). The MMSE and MoCA scores in the observation group were significantly higher than those in the control group, while the NSE and s100β levels were lower than those in the control group (both P<0.01). See **Table 4**.

Comparison of the incidence of POCD between the two groups after the surgery

The incidence of POCD in the observation group was lower than that in the control group at 1, 2, and 3 days after the surgery (all P< 0.05). See **Table 5**.

Discussion

It is reported that when a patient in the beach chair position changes position, blood flows to the lower extremities due to the effect of gravity. This can affect the patient's cardiovascular self-regulation ability after anesthesia, thereby leading to a decrease in the patient's MAP and HR levels, and finally the change in BIS [14]. The $rScO_2$ monitoring level can reflect the state of cerebral ischemia and hypoxia. Studies have also shown that when the patient adopts a beach chair position, the $rScO_2$ level decreases, which is in positive correlation with MAP, emphasizing the clinical significance of $rScO_2$ monitoring [15]. Near-infrared spectroscopy is a tissue structure property and dynamic detection technology developed in recent years. It helps physicians to effectively evaluate brain injury through real-time and accurate monitoring of brain tissue oxygen. In a specific wavelength range, near-infrared light can penetrate the skull, scalp, and brain parenchyma, and the difference in optical properties of different tissues can accurately reflect the structural properties of tissues [18]. In this study, compared with traditional monitoring methods, lesser changes in MAP, BIS, HR, and $rScO_2$ levels of patients were achieved through $rScO_2$ monitoring with near-infrared spectroscopy, which also confirmed its advantages in stabilizing patients' hemodynamic indicators and $rScO_2$. Moreover, patients' MAP and $rScO_2$ levels were positively correlated both in the observation group and control group. This was also consistent with the above-mentioned research results.

POCD refers to the cognitive decline of patients due to factors such as the stress reaction caused by surgery and the use of anesthetics, with the symptoms of memory impairment, anxiety, and mental stress. At present, the pathogenesis of POCD remains unclear, although it may relate to anesthesia medication, age, and type of surgery. The risk of POCD after the surgery may be explained by the intraoperative $rScO_2$ being lower than 50%, or the $rScO_2$ level being decreased by more than

20% of the baseline value [19]. A decrease in $rScO_2$ was suggested as an independent risk factor for the occurrence of POCD [20]. Based on this, in this study, MMSE and MoCA scales were used as the evaluation indicators, and the incidence of POCD within 3 days after surgery were recorded [21, 22]. The results showed that the MMSE and MoCA scores in the two groups were decreased after the surgery, but those in patients with traditional monitoring methods were lower. In addition, within 3 days after the surgery, only 1 case of POCD occurred in the observation group on the third day. The incidence of POCD in the control group within 1-3 days was significantly higher than that of the observation group. The above results indicated that the $rScO_2$ monitoring with near-infrared spectroscopy and management can significantly improve the postoperative cognitive dysfunction of patients. In this study, the changes in patients' NSE and s100β levels, which were the biologic indicators to assess brain injury, were detected before and after the surgery. Results showed that the NSE and s100β levels of the two groups were increased after the surgery, but the control group showed significantly higher levels. This suggests that $rScO_2$ monitoring can help reduce brain damage in patients, but the specific mechanism still needs further exploration.

There were some shortcomings in this study. The single-centered sample source resulted in a small sample size and the long-term impact of this method on patients were not discussed. Therefore, large samples and multi-center studies are still needed to confirm the results.

In summary, $rScO_2$ monitoring with near-infrared spectroscopy in peri-anesthesia management of elderly patients with hypertension undergoing shoulder arthroscopic surgery can effectively stabilize hemodynamics and reduce the incidence of postoperative POCD.

Disclosure of conflict of interest

None.

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