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Original Article

Effects of ultrasound-guided stellate ganglion block on the balance of the supply and demand of cerebral oxygen during permissive hypercapnia in patients undergoing shoulder arthroscopy in beach chair position

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Abstract: Objective: To investigate the effects of ultrasound-guided stellate ganglion block (SGB) on the supply and demand balance of cerebral oxygen in patients with permissive hypercapnia (PHC) undergoing shoulder arthroscopy in a beach chair position (BCP). Method: In this prospective study, a total of 86 patients who had shoulder arthroscopy were enrolled and divided into the stellate ganglion block group (SG group, n=43) and the control group (CN group, n=43) using a random number table method. Ultrasound-guided SGB was performed on patients' operation side at the 6th cervical vertebra (C6) anterior transverse tubercle level. Patients in the SG group were injected with 6ml mixture of 0.25% ropivacaine hydrochloride and 1% lidocaine hydrochloride, and those in the CN group with an equal amount of 0.9% normal saline (NS). The patients of both groups were placed in BCP for shoulder arthroscopy, and rapid induction of endotracheal intubation was performed for assisted or mechanical ventilation. Ventilation strategy was adjusted to gradually increase pulmonary end-tidal CO_2 ($P_{ET}CO_2$) during surgery. The rSO_2 levels of patients in both groups were recorded 10 min after being placed in supine position in the operation room (T0), 10 min after SGB (T1), 10 min after anesthesia induction in supine position (T2), 10 min after anesthesia induction in beach chair position (T3), 30 min after $P_{ET}CO_2$ was stabilized at 35 to 40 mmHg (T4) during surgery, and 30 min after $P_{ET}CO_2$ was stabilized at 45 to 50 mmHg (T5), respectively. The cerebral oxygen metabolic measures, including saturation of jugular bulb venous oxygen ($SjvO_2$), difference in artery-jugular venous oxygen content ($DajvO_2$) and cerebral oxygen extraction rate ($CERO_2$) of patients in the two groups at the time point mentioned above were compared. Hemodynamic parameters including arterial carbon dioxide partial pressure ($PaCO_2$), mean arterial pressure (MAP), heart rate (HR) and Saturation of Pulse Oxygen (SpO_2) were recorded. Cerebral desaturation episodes, nausea, vomiting and the use of vasoactive drugs during surgery were also recorded. The Mini-Mental State Examination score (MMSE) was recorded 1 day before and after surgery. Results: There was no significant difference in the comparison of $SjvO_2$, Da-jvO_2, $CERO_2$, $PaCO_2$, MAP, HR and SpO_2 between the two groups at T0-T5 (P>0.05); no significant differences were found in intra-group comparison of $SjvO_2$, Da-jvO_2, $CERO_2$ at T0-T4 (P>0.05); the level of $SjvO_2$ at T5 was higher than that at T4, and the levels of Da-jvO_2 and $CERO_2$ at T5 were markedly lower than those at T4 (P<0.05). No significant differences were found in the inter-group comparison of MAP, HR and SpO_2 at T0-T5 (P>0.05), while $PaCO_2$ was significantly higher at T4 than that at T5 (P<0.05). The rSO_2 levels of patients in both groups significantly decreased at T3, as compared with those at T0 (P<0.05); the rSO_2 levels markedly increased at T5 than those at T4 (P<0.05); and the rSO_2 levels showed more significant increase in SGB group than those in the CN group as the level of $P_{ET}CO_2$ rose. Conclusion: Permissive hypercapnia resulting from proper ventilation can significantly increase the rSO_2 levels in patients who undergo shoulder arthroscopy in BCP, the effect of which was enhanced by SGB on patients' operation side to maintain well-balanced demand and supply of cerebral oxygen. (China Clinical Trial Registry, registration number ChiCTR2000033385, https://www.chictr.org.cn).

Keywords: SGB, permissive hypercapnia, rSO_2, shoulder arthroscopy in BCP

Introduction

With the advancement of clinical surgeries, shoulder arthroscopy, a surgery with possible indications like shoulder dislocation and cuff rupture, has been increasingly used in clinical practice in recent years [1]. The surgery does have its advantages, including minimal invasion, significant efficacy, reduced brachial plexus injury, and short postoperative recovery time. During surgery, patients are normally placed a in beach chair position (BCP) with their blood pressure (BP) being controlled to decrease the possibility of neural injury, bleeding in the joint cavity and to fully expose the surgical field [2]. BCP is close to the standing position while having the surgery. However, this particular position may affect cerebral blood perfusion, with the risks of damaging nerves in the brain and spines, which will probably cause surgical complications, and even endanger patients' lives [3, 4]. Stellate ganglion block (SGB) is capable of helping vasodilatation and improving blood circulation by regulating the autonomic nervous system [5]. It has been reported that SGB could reduce cerebrovascular tension and increase regional cerebral blood flow, thus increasing cerebral oxygen saturation (rSO_2) on the blocked side and decreasing that on the unblocked side [6, 7]. Therefore, SGB is often used to protect the brain perioperatively. However, whether rSO_2 can be used to protect the brain is still controversial. The effect of SGB on rSO_2 in patients with permissive hypercapnia (PHC) who have undergone shoulder arthroscopy in BCP hasn't been reported yet. This research aimed to assess the effects of SGB on the supply and demand balance of cerebral oxygen in patients with PHC, who also underwent shoulder arthroscopy in BCP, so as to provide clinical guidance to the anesthetic scheme during surgeries.

Materials and methods

General data

This is a prospective, randomized and controlled study approved by the Medical Ethics Committee of Suzhou Municipal Hospital (No.: SZSLYY202004152). All patients provided written informed consent. The sample size was calculated based on a pilot trial with 30 patients. It was estimated to need to be at 85 when detecting a 10% change of SGB in the supply and demand balance of cerebral oxygen in patients with PHC who underwent shoulder arthroscopy in BCP, with a significance level of 5% and a power of 85%. A total of 43 patients were assigned to each group, given that patients may withdraw or be excluded from the research due to other reasons. Finally, a total of 86 patients who were aged between 35 and 65 years old and had shoulder arthroscopy between April 2020 and October 2021 were included.

Patients were eligible if they were aged between 18 and 65 years old, with body mass index (BMI) ranging from 18.5 to 28.0 kg/m^2, and were classified at an American Society of Anesthesiologists grade of I-II without obvious cardiopulmonary diseases, and were diagnosed with shoulder cuff rupture before surgery. Patients were not eligible if they had contraindications to SGB puncture, with a history of infection, scar or trauma at the puncture site; they had a history of local anesthetic poisoning, local anesthetic allergy or other drug allergies; they had moderate to severe anemia or malfunction of coagulation before surgery; their hypertension was serious and uncontrolled [preoperative BP≥180 mmHg/110 mmHg (1 mmHg=0.133 kPa)]; or if they had craniocerebral trauma or cerebrovascular diseases. All included patients were divided into the SG group or CN group using a random number table, with 43 patients in each group.

Anesthesia

Patients were surveyed one day before surgery to collect their general data and relevant medical histories. Patients were screened to assess whether they met the inclusion criteria. Those who didn't meet the criteria were not recruited. Patients were restricted from food for 6 hours and from drink for 4 hours before the surgery. The mean arterial pressure (MAP), heart rate (HR), saturation of pulse oxygen (SpO_2) and electrocardiograph (ECG) of patients were monitored after they were sent to the operation room. The peripheral vein of the lower extremities was opened with an 18-gauge trocar (BD Company, USA). During the surgery, Bis-pectral Index (BIS) was applied to evaluate the depth of anesthesia with BIS-Vista monitor (BIS COMPLETE, Aspect Company, USA). The rSO_2 was detected with FORE-SIGHT near-infrared spectrometer (CAS Medical System Company, USA). Alcohol was applied on both sides of patient's forehead and two electrodes were placed at about 1.0 to 1.5 cm above patients' eyebrow, with each electrode containing two signal detectors and one near-infrared emitter. Invasive arterial blood pressure (ABP) was monitored using radial artery puncture on the non-operation side under local anesthesia. After the patient was sedated, ultrasound was applied on patients' neck to find a safe access for ultrasound-guided SGB puncture. Then, patients in the SG group were placed in supine position and given ultrasound-guided SGB on the operation side under adequate sedation before anaesthetic induction. Patients in the CN group received ultrasound-guided normal puncture under the same condition, but the anaesthetic drug used in the SG group was replaced with the same volume of normal saline (false positive results from the stimulation by the puncturing needle were excluded). The effect of blocking was assessed by the same doctor after operation, and complications caused by the puncture were also observed. After 10 min, surgeons made sure that SGB was in effect without any other severe complications caused by the puncture. Patients were anesthetized in supine position and received rapid endotracheal intubation. After inhaling oxygen for 3 to 5 min with the use of a facial mask, they were injected intravenously with 0.5 μg/kg sufentanil (Batch No.: 01A06191, Yichang Humanwell Pharmaceutical Co., Ltd.), 0.3 mg/kg etomidate (Batch No.: YT200708, Jiangsu Enhua Pharmaceutical Co., Ltd.) and 0.15 mg/kg cisatracurium (Batch No.: 20042621, Jiangsu Hengrui Medicine Co., Ltd.) in turn. Next, oxygen was ventilated through the endotracheal tube, with the concentration set at 60%, tidal volume (VT) at 6 to 8 mL/kg and inspiratory to respiratory ratio at 1:2. The frequency of the ventilator was adjusted to maintain $P_{ET}CO_2$ at 30 to 35 mmHg (1 mmHg=0.133 kPa). After 10 min, patients were placed in BCP, disinfected and draped for the operation.

Maintenance of anesthesia: 4 to 6 $mg \cdot kg^{-1} \cdot h^{-1}$ propofol (Batch No.: RL845, AstraZeneca Pharmaceutical Co., Ltd., Sweden) and 0.1 to 0.2 $ug \cdot kg^{-1} \cdot min^{-1}$ remifentanil (Batch number: 00A0-6271, Yichang Humanwell Pharmaceutical Co., Ltd.) were infused intravenously. Cisatracurium was added again for two times, half and one third of the amount of the first time, separately. BIS value was maintained at 40 to 60. During the surgery, fluid infusion rate was kept at 8 to 10 $ml \cdot kg^{-1} \cdot h^{-1}$, MAP was maintained at 80 to 100 mmHg. Then, the ventilator was adjusted to maintain the $P_{ET}CO_2$ at 35 to 40 mmHg, and later at 45 to 50 mmHg. Data were recorded when each $P_{ET}CO_2$ level was stabilized for 30 min. After data recording, $P_{ET}CO_2$ level was kept at 45 to 50 mmHg until the end of the surgery. Patients received 3 mg granisetron (Batch No.: 201003A03, Ningbo Tianheng Pharmaceutical Co., Ltd.) intravenously 30 min before the end of surgery to prevent postoperative nausea and vomiting. Cerebral desaturation events (CDE) were defined as a decrease in rSO_2 values greater than 20% of the baseline value or an absolute rSO_2 value of less than 55% for more than 15 s. Under the circumstance of MAP<60 mmHg or CDE, 5 to 10 μg phenylephrine (Batch No.: 201224, Everbright Pharmaceutical Co., Ltd.) was injected once or intermittently. Patients were switched to supine position when the surgery was done and was transferred to post-anesthesia care unit after extubation.

Ultrasound-guided SGB

Patients were placed in supine position without a pillow underneath. A high-frequency linear probe (5-13 MHz) (Sonosite, USA) was evenly applied with ultrasound transmission gel and gently placed on patients' neck, forming an angle of 30° to 45° to the sagittal plan. The probe was slowly moved to locate the C6 anterior transverse tubercle. Then, the vertebral artery, carotid sheath, thyroid gland, esophagus and trachea were carefully located in this plane. After disinfecting the skin touched by the ultrasound probe with iodophor cotton, a 25 G puncture needle (Sonosite, USA) was inserted on the lateral side of the ultrasound probe, and sent to the deep of the prevertebral fascia with the aid of real-time ultrasound monitoring to ensure no injury of blood vessels and nerves. Subsequently, after the absence of blood was confirmed by repeated withdrawal of the syringe by an assistant, 6 ml of a mixture of 0.25% ropivacaine (Batch No.: PS16131, AstraZeneca Pharmaceutical Co., Ltd., Sweden) plus 1% lidocaine (Batch No.: 1B200829102, Hebei Tiancheng Pharmaceutical Co., Ltd.) was slowly injected into patients in the SG group, and the same volume of normal saline (Batch No.: 1G90A1, Otsuka Pharmaceutical Co., Ltd., China) was injected into patients in the CN group. Anesthetics and normal saline were seen spreading evenly between the transverse tubercle and the carotid artery when the injection was done. The puncture site was pressed to prevent hematoma and blood congestion. Horner's sign [8] was observed following successful blocking. Any 4 or more of the following symptoms such as miosis, enophthalmos, blepharophimosis, facial flushing, conjunctival congestion and elevated face temperature were defined as positive for Horner's syndrome.

Outcome measurements

Primary outcome measures: rSO_2 value: The levels of rSO_2, were recorded 10 min after patients were placed in a supine position in the operation room (T0), 10 min after SGB (T1), 10 min after anesthesia induction (T2), 10 min after anesthesia induction in a beach chair position (T3), 30 min after $P_{ET}CO_2$ was stabilized at 35 to 40 mmHg after surgery (T4) and 30 min after $P_{ET}CO_2$ was stabilized at 45 to 50 mmHg (T5).

Cerebral oxygen metabolic measures: 3 ml blood was collected from the jugular vein and radial artery at T1-T5 respectively for the detection of $SjvO_2$, $DajvO_2$ and $CERO_2$.

Secondary outcome measures: The values of $PaCO_2$, MAP, HR, SpO_2 were record at T1-T5. The intraoperative CDE, nausea, vomiting and the use of vasoactive drugs were recorded as well. Minimum Mental State Examination (MMSE) scores were recorded 1 day before and after the surgery. MMSE is a 30-point questionnaire that is used extensively to measure cognitive impairment. It examines functions including registration (repeating named prompts), attention, calculation, recall, language, ability to follow simple commands and orientation. Lower score indicates worse cognitive function and vice versa. MMSE scores greater than 27 is considered standard, between 21 and 26 mild dementia, between 10 and 20 moderate dementia, and less than 10 severe dementia.

Statistical analyses

Data were analyzed using SPSS 25.0 statistical software. Measurement data conforming to a normal distribution were expressed as mean ± standard deviation ($\bar{x}$ ± sd). Repeated-measures analysis of variance was used for intra-group comparison, Bonferroni method was further used for pairwise data comparison for difference. Two independent sample t-test was used for inter-group comparison. Chi-squared test was used for analyzing the enumeration data, which were expressed as rate. $P<0.05$ was considered statistically significant.

Results

Comparison of the general data of patients between the two groups

A total of 90 patient's eligibility was assessed before surgery. Two patients were excluded from the research due to changes in positions and surgery. The remaining 88 patients were divided randomly. One patient in the SG group was excluded due to severe complications and one in the CN group was excluded because the patient refused to continue the following evaluation. Finally, 86 patients in total were assessed (43 patients in each group). There was no significant difference in the general data and intraoperative indicators between the two groups ($P>0.05$), as shown in **Table 1**.

Comparison of the rSO_2 levels of patients in the two groups at different time point

The rSO_2 levels of patients in both groups at T3 significantly decreased compared to those at T0 ($P<0.05$); the rSO_2 levels at T5 markedly were elevated compared to those at T4 ($P<0.05$); the rSO_2 levels in the SG group showed more significant increase than those in the CN group as $P_{ET}CO_2$ level rose. There was no significant difference in the rSO_2 levels of patients in both groups at T1 and T2 in contrast to those at T0 ($P>0.05$), as shown in **Table 2** and **Figure 1**.

Comparison of cerebral oxygen metabolic measures of patients in the two groups

There was no significant difference in the comparison of $SjvO_2$, $Da\text{-}jvO_2$, $CERO_2$ between the two groups at T0-T5 ($P>0.05$); no significant differences were found in intra-group comparison of $SjvO_2$, $Da\text{-}jvO_2$, $CERO_2$ at T0-T4 ($P>0.05$); the level of $SjvO_2$ at T5 was significantly higher than that at T4, and the levels of $Da\text{-}jvO_2$ and $CERO_2$ were markedly lower at T5 than those at T4 ($P<0.05$). See **Table 3**.

Comparison of hemodynamics of patients in the two groups

There was no significant difference in the comparison of $PaCO_2$, MAP, HR and SpO_2 at T0-T5

Table 1. Comparison of the general date and intraoperative indicators between the two groups

Indicators	SG group (n=43)	CN group (n=43)	t/χ^2	*P* value
Gender (n)			0.047	0.829
Male	20	19		
Female	23	24		
Blood pressure (n)			0.422	0.516
High	18	21		
Normal	25	22		
Age (years)	51.3±5.4	53.2±5.7	0.618	0.539
Height (cm)	167.62±9.55	169.33±10.4	1.018	0.314
Weight (Kg)	65.41±12.57	67.11±8.78	0.541	0.591
BMI (kg/m^2)	22.61±4.23	23.23±3.81	0.534	0.596
Hb before the surgery (g/L)	129.32±9.56	128.67±8.21	0.253	0.802
MAP during the surgery (mmHg)	101.51±12.56	100.36±11.82	0.327	0.745
Heart rate during surgery (beats/min)	72.35±7.84	73.62±8.13	0.551	0.584
Surgical time (min)	98.37±21.51	102.78±20.13	0.733	0.467
Anesthesia time (min)	124.42±21.22	127.25±19.68	0.479	0.634
Crystalloid solution (mL)	1010.53±268.37	1050.69±311.72	0.478	0.634
Blood loss (mL)	56.34±10.23	60.54±8.52	1.546	0.129
Urine (mL)	515.56±165.26	529.71±174.35	0.289	0.774

Note: SG group: stellate ganglion block group; CN group: Control group; BMI: Body Mass Index; MAP: mean arterial pressure; χ^2 denotes for the result of chi-square test and t for t test.

Table 2. Comparison of the rSO_2 levels of patients in both groups at different time point (%, n=43, $\bar{x}$ ± sd)

Indicators	Group	T0	T1	T2	T3	T4	T5
Operation side	SG group	77.63±5.25	78.15±6.42	79.14±7.10	73.82±5.46*	75.63±5.65$^{\Delta}$	84.69±5.58$^{*,\#,\Delta}$
rSO_2	CN group	76.71±6.14	75.93±5.57	78.49±6.81	70.57±5.43*	72.78±4.93*	80.73±5.91$^{*,\#}$
non-operation side	SG group	76.78±5.47	75.73±4.89	77.52±5.95	71.67±4.73*	72.65±4.82*	81.56±4.84$^{*,\#}$
rSO_2	CN group	77.63±6.31	76.34±5.92	78.34±6.33	70.42±5.91*	71.31±4.43*	79.65±5.26$^{*,\#}$

Note: Compared with T0, $^{*}P<0.05$; compared with T4, $^{\#}P<0.05$; compared with CN group, $^{\Delta}P<0.05$. SG group: stellate ganglion block group; CN group: control group; t denotes for the result of t test; T0: 10 min after patients were placed in supine position in the operation room; T1: 10 min after SGB; T2: 10 min after anesthesia induction in supine position; T3: 10 min after anesthesia induction in beach chair position; T4: 30 min after $P_{ET}CO_2$ was stabilized at 35 to 40 mmHg, and T5: 30 min after $P_{ET}CO_2$ was stabilized at 45 to 50 mmHg; SGB: stellate ganglion block.

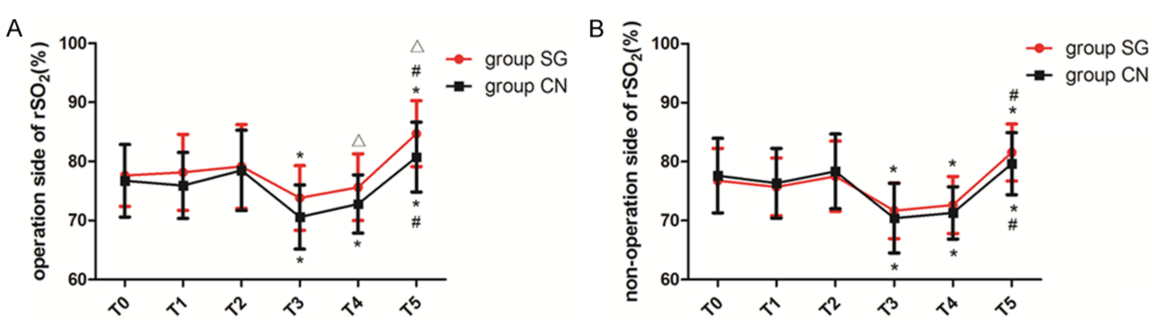

Figure 1. Comparison of rSO_2 changes of patients in both groups at different time point. Note: Compared with T0, $^{*}P<0.05$; compared with T4, $^{\#}P<0.05$; compared with CN group, $^{\Delta}P<0.05$; SG group: stellate ganglion block group; CN group: control group; t denotes for the result of t test; T0: 10 min after patients were placed in supine position in the operation room; T1: 10 min after SGB; T2: 10 min after anesthesia induction in supine position; T3: 10 min after anesthesia induction in beach chair position; T4: 30 min after $P_{ET}CO_2$ was stabilized at 35-40 mmHg, and T5: 30 min after $P_{ET}CO_2$ was stabilized at 45-50 mmHg.

Table 3. Comparison of cerebral oxygen metabolic measures of patients in the two groups ($\overline{x}$ ± sd)

Indicators	Cases	T0	T1	T2	T3	T4	T5
$SjvO_2$ (%)							
SG group	43	64.37±8.61	64.56±8.92	65.64±8.11	66.67±8.23	67.57±8.93	75.83±8.21$^{\#}$
CN group	43	63.58±8.16	64.15±8.44	64.01±8.53	65.12±8.69	66.11±8.56	74.11±7.35$^{\#}$
Da-jvO_2 (mmol/L)							
SG group	43	54.12±5.34	53.46±5.46	54.94±5.04	55.33±4.98	53.62±6.46	47.62±5.23$^{\#}$
CN group	43	55.41±4.92	54.53±5.22	53.83±5.71	56.19±5.35	54.84±4.99	48.53±4.81$^{\#}$
$CERO_2$ (%)							
SG group	43	43.32±4.93	44.60±4.86	45.25±4.87	44.65±5.11	43.52±4.96	35.92±4.07$^{\#}$
CN group	43	43.97±4.86	44.04±5.03	45.67±5.31	46.01±4.88	45.61±5.18	37.21±5.23$^{\#}$

Note: $^{\#}$P<0.05 as compared with that at T4; $SjvO_2$: saturation of jugular bulb venous oxygen; $DajvO_2$: difference in artery-jugular venous oxygen content; $CERO_2$: cerebral oxygen extraction rate; SG group: Stellate ganglion block group; CN group: control group; T0: 10 min in supine position in the operation room; T1: 10 min after SGB; T2: 10 min in supine position after anesthesia induction; T3: 10 min in BCP after anesthesia induction; T4: $PETCO_2$ was stabilized at 35-40 mmHg for 30 min; T5: $PETCO_2$ was stabilized at 45-50 mmHg for 30 min.

Table 4. Comparison of hemodynamics between the two groups

Group	T0	T1	T2	T3	T4	T5
SG group (n=43)						
$PaCO_2$ (mmHg)	46.21±2.34	47.03±2.42	48.25±3.11	47.52±2.91	45.23±2.11	52.46±2.43*
MAP (mmHg)	91.23±7.62	90.54 ±6.83	92.61±7.07	93.32±6.27	94.45±7.03	93.61±6.88
HR (beats/min)	77.82±10.23	75.62±9.86	73.74±8.57	75.83±9.56	76.23±9.28	77.67±8.45
SpO_2 (%)	97.76±1.47	98.51±1.61	97.89±1.83	98.12±1.03	97.65±2.11	98.03±1.22
CN group (n=43)						
$PaCO_2$ (mmHg)	46.07±2.31	46.84±2.28	47.11±2.84	46.67±2.18	45.21±2.07	53.17±3.29*
MAP (mmHg)	90.23±8.90	91.22±8.97	92.73±9.04	91.48±8.92	92.37±9.44	93.25±9.26
HR (betas/min)	76.23±11.09	74.85±10.47	73.23±8.91	76.33±10.94	77.38±9.67	78.42±9.30
SpO_2 (%)	96.96±1.24	97.67±1.85	98.31±1.21	97.97±2.01	97.89±1.98	98.02±1.79

Note: As compared with T4, *P<0.05; $PaCO_2$: arterial carbon dioxide partial pressure; MAP: mean arterial pressure; HR: heart rate; SpO_2: Saturation of Pulse Oxygen; SG group: Stellate ganglion block group; CN group: control group; T0: 10 min in supine position in the operation room; T1: 10 min after SGB; T2: 10 min in supine position after anesthesia induction; T3: 10 min in BCP after anesthesia induction; T4: $P_{ET}CO_2$ was stabilized at 35-40 mmHg for 30 min; T5: $P_{ET}CO_2$ was stabilized at 45-50 mmHg for 30 min.

between the two groups (P>0.05); there was no significant difference in the intra-group comparison of MAP, HR, and SpO_2 from T0-T5 (P>0.05), while $PaCO_2$ was markedly higher at T5 than at T4 (P<0.05). See **Table 4**.

Comparison of MMSE scores, postoperative complications, CDE occurrence and the use of vasoactive drugs of patients in the two groups

There was no significant difference in the comparison of MMSE scores 1 day before and after surgery, occurrence of postoperative complications (nausea and vomiting), or incidence of CDE at day 1 after surgery between the two groups (P>0.05, **Table 5**).

Discussion

Shoulder arthroscopy in BCP has a clear surgical field, with patients close to an upright position, which is a normally applied position for patients who undergo shoulder surgery. However, patients in BCP under general anesthesia may have aggravated hypotension [9], which, together with the need for controlled hypotension during surgery, will further reduce cerebral perfusion and affect the oxygen supply and demand balance in the brain [10]. It has been reported that such shoulder surgery has a high incidence of POCD, and even stroke [11]. The changes in cerebral blood flow can be reflected indirectly through monitoring the levels of rSO_2

Table 5. Comparison of MMSE scores, postoperative nausea and vomiting of patients in the two groups

	SG group (n=43)	CN group (n=43)	t/χ^2	*P* value
MMSE scores (score, $\bar{x}$ ± sd)				
One day before surgery	27.32±2.15	27.14±2.31	0.374	0.709
One day after surgery	28.11±3.19	27.84±2.86	0.413	0.68
Postoperative nausea (n, %)	14 (32.56)	16 (37.21)	0.205	0.651
Postoperative vomiting (n, %)	8 (18.60)	11 (25.58)	0.608	0.436
CDE (n, %)	5 (11.62)	6 (13.95)	0.104	0.747
The use of vasoactive drugs (n, %)	21 (48.84)	23 (53.49)	0.186	0.667

Note: MMSE: mini-Mental State Examination; CDE: Cerebral desaturation events; SG group: stellate ganglion block group; CN group: Control group; χ^2 denotes for the result of chi-square test and t for t test.

with a near-infrared spectrometer [12]. It has been shown that there is a good correlation between invasive monitoring of oxygen saturation in the jugular sinus and rSO_2 [13]. So, the balance between supply and demand of cerebral oxygen was assessed with rSO_2 levels. However, some factors, such as anesthetic drugs, anesthesia depth, oxygen concentration, $PaCO_2$ and blood pressure control, might affect the accuracy of rSO_2 levels [14, 15]. In this study, patients in the both groups were anesthetized intravenously, with no difference in the amount of anesthesia drugs used. The hemodynamic was stabilized as much as possible under strict conditions, and patients in both groups were anesthetized to similar depth. The BIS value was maintained at 40 to 60 and oxygen concentrations inhaled at 60%. The rSO_2 levels of patients in the two groups were significantly different 10 min after switching from supine position to BCP after anesthesia induction, probably because venous blood return was reduced, leading to a decrease in cardiac output, MAP, and cerebral perfusion pressure, which lasted for 30 min after patients were placed in a BCP [16, 17]. In addition, the blood pressure in the radial or brachial arteries was not the same as that in the brain, so the zero point of blood pressure of patients in BCP was set to the level of external auditory canal [18]. MAP is the main factor that affects cerebral perfusion pressure and cerebral oxygen [19, 20], so a decrease in MAP is closely associated with the decrease of rSO_2 [18]. However, MAP value was set to fluctuate not over 20% of baseline to reduce its influences on the research results. Approaches to improve cerebral perfusion include increasing ABP, increasing inspired oxygen concentration, increasing $P_{ET}CO_2$ [22] and dilating regional cerebral vessels. However, increased ABP leads to blood oozing from the surgical field, making the surgery harder. Additionally, inspiring too much oxygen might result in damage to other organs such as the lung and brain. In clinical practice, in addition to increasing blood pressure, most of the time, surgeons would regulate $P_{ET}CO_2$ and dilate regional cerebral blood vessels to increase blood flow, thereby increasing cerebral oxygen supply [23]. PHC is a lung-protective ventilation strategy performed by adjusting the ventilator to increase the $PaCO_2$ within a certain range. Under normal physiological conditions, mild hypercapnia has little effect on cardiac function, but when $PaCO_2$ reaches 6.67-8.66 kPa, it can stimulate sympathetic nerves, activate the locus coeruleus-sympathetic-adrenomedullary system and hypothalamic-pituitary-adrenocortical system, cause increased secretion of blood catecholamines and glucocorticoids, enhance the body's stress response, increase blood pressure and heart rate [24]. This study showed that $PaCO_2$ of patients was significantly higher at T0-T4 than at T5 in the two groups, but there was no significant change in MAP, HR, and SpO_2, indicating that mild hypercapnia had little effect on circulatory function. $PaCO_2$ is well correlated with $P_{ET}CO_2$, so $PaCO_2$ was assessed with $P_{ET}CO_2$ levels [25]. According to previous studies, the $P_{ET}CO_2$ level was maintained at 45-50 mmHg for permissive hypercapnia [13]. When patients received shoulder arthroscopy in BCP, the decrease in rSO_2 levels due to the change of position was also associated with arterial blood pressure and $P_{ET}CO_2$ [26, 27]. Increasing $P_{ET}CO_2$ through adjusting the ventilators' parameters is a relatively simple approach, which could increase cerebral blood flow unconsciously [28, 29]. When the partial pressure of carbon dioxide in arterial blood fluctuates between a normal range from 25 to 75 mmHg, there is a linear relationship between the partial pressure and cerebral blood flow [30, 31]. It was suggested in the study that the $SjvO_2$ values at T5 in the two groups were markedly increased as compared with those at T4, while the Da-jvO_2 and $CERO_2$ values decreased. However, all values were within normal scope, indicating PHC would not result in over-perfusion in the brain and could still maintain a balanced supply and demand of cerebral oxygen. PHC can not only increase cerebral blood flow, improve oxygenation capacity, improve cerebral oxygen metabolism, but also reduce the inflammatory response [32], reduce ischemia-reperfusion injury, and reduce the incidence of postoperative cognitive dysfunction (POCD). However, the risk of over-perfusion needs attention because the CO_2 pneumoperitoneum time of the aged patients and patients complicated with chronic cardio-cerebrovascular disease is relatively long, which might lead to cerebral anoxia resulting from cellular insufficient oxygenation in brain tissues.

Stellate ganglion, also known as the cervicothoracic ganglion, mainly innervates the head, face, neck, shoulders, upper limbs and upper chest. SGB could inhibit the excitation of sympathetic nervous system. However, SGB can restore the function of the autonomic nervous system by regulating the hypothalamus and pituitary, so as to achieve homeostasis, and then maintain the normal function of neuroendocrine system of the body. SGB can also increase the blood flow and improve many body functions such as perfusion of various organs by dilating the blood vessels in its dominant areas, thus playing an active role in clinical treatment [33]. Tests on awake volunteers in a supine position have shown that SGB can reduce cerebrovascular tension, increase rSO_2 on the blocked side, and reduce rSO_2 on the unblocked side, and oxygen inhalation can also increase rSO_2 on the unblocked side [34]. Therefore, SGB can possibly be used in the perioperative period for brain protection in many clinical settings, but its influences on rSO_2 remain controversial. In elderly patients undergoing coronary artery bypass grafting, SGB significantly increased rSO_2 on the intraoperative blocked side; while in patients undergoing breast cancer surgery, SGB had no significant effects on rSO_2 during surgery [35, 36]. However, in patients with permissive hypercapnia who underwent shoulder arthroscopy, the effect of SGB on rSO_2 has not been studied. Magnetic resonance imaging, computed tomography, or transcranial Doppler ultrasound have been used to demonstrate cerebrovascular dilatation and increased cerebral blood flow after SGB. Some scholars have used jugular bulbar oxygen saturation monitoring methods to show that SGB can reduce postoperative inflammatory factors and improve cerebral oxygen metabolism in patients. It was found in this research that rSO_2 of patients in both groups was higher at T4 than that at T5, and higher in the operation side than that in the non-operation side of patients in the SG group, indicating the cerebral blood vessels of patients with permissive hypercapnia in the SG group have more intense reaction to carbon dioxide. Therefore, SGB can be a good choice for patients with inadequate cerebral perfusion and less cerebral oxygen.

In this research, 5 patients in the SG group and 6 in the CN group had cerebral desaturation events (CDE). In a prospective cohort study investigating risks of CDE in patients undergoing shoulder arthroscopy in a beach chair position, the increase of BMI was statistically associated with the occurrence of CDE during surgery. The cut-off was 34 or higher, with 78% of patients above the cut-off and 21% below the cut-off having CDE [37]. In 2016, Kim reported that diabetes reduced the reaction of rSO_2 to $PETCO_2$ [38]. In 2019, Gilotra stratified 100 patients undergoing shoulder arthroscopy in a beach chair position in terms of the CDE risks according to Framingham stroke standards, and found that patients with Framingham scores no less than 10 or with BMI no less than 35 kg/m^2, and who were also fully anesthetized, had increased risks of CDE. Diabetes, smoking, cardiovascular diseases or left ventricular hypertrophy won't result in CDE [39]. Also, the cognitive function of patients in the two groups was not significantly affected, so we assumed that it might be associated with the fact that we had excluded the elderly who have high risks of cognitive dysfunction, thus the occurrence of this abnormality in patients in the two groups was decreased. However, our results have some limitations because the sample size is small. Only rSO_2 was analyzed in the research, and other lab indicators at corresponding periods were not investigated to support the results. In future research, we would draw blood from patients during the period when the changes in cerebral oxygen are significant and include relevant lab indicators to further prove clinical significance of our results.

In summary, the decrease in rSO_2 of patients who had shoulder arthroscopy in beach chair position can be effectively improved with ventilator-assisted permissive hypercapnia, which is enhanced by SGB performed on the operated side, achieving a well-balanced supply and demand of cerebral oxygen.

Disclosure of conflict of interest

None.

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