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Research Article

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Changes in Cerebral Oxygenation Assessed by Near-infrared Spectroscopy during Shoulder Arthroscopy in the Beach Chair Position after Brachial Plexus Block

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Abstract

Background: It is well known that patients undergoing shoulder surgery in the Beach Chair Position (BCP) have a potential risk for cerebral ischemia. Using Near-Infrared Spectroscopy (NIRS), this study aimed to test whether cerebral oxygenation in these patients was impaired by brachial plexus block accompanied with general anesthesia.

Methods: Ultrasound-guided interscalene brachial plexus block was performed in 26 patients undergoing elective arthroscopic shoulder surgery under general anesthesia. In all subjects, cerebral oxygenation during anesthesia was evaluated by measuring the Tissue Oxygenation Index (TOI) with NIRS.

Results: No differences were seen in TOI values between Pre-BCP and Post-BCP periods in both block and non-block sides, despite a decrease in mean blood pressure ($P<0.05$, repeated measures one-way ANOVA by the Bonferroni post hoc test). Additionally, no differences were seen in TOI values between block and non-block sides at any time point.

Conclusion: Changing from the supine position to the BCP did not appear to impair cerebral oxygenation, regardless of brachial plexus block, in patients undergoing shoulder arthroscopy under general anesthesia.

Keywords: Cerebral oxygenation; Brachial plexus block; Near-infrared spectroscopy; Beach chair position; General anesthesia; Shoulder arthroscopy

Introduction

As a result of advanced surgical techniques, shoulder surgery and arthroscopy have become increasingly common orthopedic procedures in recent years. After several reports of injuries to the brachial plexus and forearm nerves associated with the traditional lateral decubitus position, the Beach Chair Position (BCP) has become standard for shoulder surgery since the mid-to-late 1980s. Although the BCP provides several benefits for the surgeon, including lower risk of neurovascular trauma, ease of switch to an open approach, and good intra-articular visualization the sitting position introduces several challenges for the anesthesiologist and potential risks to the subject. For example, possible cerebral hypoperfusion related to this position has been suggested by the poor neurological outcomes even in patients without a high preoperative risk for cerebrovascular events [1-3]. In particular, baroreceptor responses after a change in position are blunted under general anesthesia, resulting in attenuation of the increase in systemic vascular resistance, a decrease in mean arterial pressure, and a greater reduction in cardiac output compared with the awake state [4].

Near-Infrared Spectroscopy (NIRS) is a noninvasive and continuous technique that offers the potential for cerebral perfusion monitoring, in which cerebral oxygenation, reflecting the balance between cerebral metabolic supply and demand, can be assessed. Indeed, recent studies have demonstrated that NIRS is capable of providing similar accuracy as transcranial Doppler sonography or stump pressure measurements for the detection of cerebral ischemia during carotid surgery [5]. Moreover, past studies suggested that NIRS is suitable to directly compare cerebral oxygenation between cerebral hemispheres after nerve blocks [6,7]. Among the cerebral NIRS parameters, Tissue Oxygen Index (TOI) appears to be reliable because it is not influenced by tissue hemoglobin concentration, skull thickness, or the area of the cerebrospinal fluid layer.

Interscalene block of the brachial plexus is a common technique for analgesia after total shoulder arthroplasty because it provides good postoperative analgesia. However, it is well known that the resultant block of the cardiothoracic sympathetic chain and/or Stellate Ganglion Block (SGB) is a relatively common nuisance side effect associated with brachial plexus block suggesting that brachial plexus block can affect cerebral blood flow, which in turn can alter cerebral oxygenation [8]. Indeed, a previous report showed that procaine block of the superior cervical ganglion caused cerebral vasodilation [9]. A more recent study showed that SGB resulted in increased Regional Cerebral Oxygenation (rSO_2) on the block side but decreased rSO_2 on the non-block side in awake patients [7]. Cerebral blood flow, measured by spectral Doppler ultrasound, was maintained even in the BCP after brachial plexus block, regardless of the presence or absence of accompanying general anesthesia [10]. However, to our knowledge, few studies

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have investigated the balance between cerebral metabolic supply and demand in patients undergoing shoulder arthroscopy in the BCP under general anesthesia accompanied by brachial plexus block. Using NIRS, this study aimed to test whether cerebral oxygenation was impaired in patients undergoing shoulder arthroscopy in the BCP under general anesthesia with brachial plexus block.

Methods

Patients and anesthesia

After obtaining approval from the local ethics committee (approval No. 216) and written informed consent, 26 consecutive patients scheduled to undergo elective arthroscopic shoulder surgery under general anesthesia accompanied by brachial plexus block in the beach chair position, were enrolled in this prospective observational study. Intraoperative monitoring consisted of the following: electrocardiography, automatic arterial blood pressure assessment using a cuff placed on the nonoperative upper extremity, pulse oximetry, capnography, and measurement of core temperature via a bladder or tympanic membrane probe. The optodes of the NIRS device (NIRO-200, Hamamatsu Photonics, Hamamatsu, Japan) were placed on the right and left sides of the forehead, with the caudal border about 1 cm above the eyebrow and the medial edge at the midline. The Tissue Oxygenation Index (TOI) was used as a marker of cerebral oxygenation. TOI values were automatically calculated and stored every second. An average of TOI values during a 60 second period were calculated offline and used as a TOI value for each period. In principle, TOI values sampled just after an intervention were used for an average. However, we waited for a short time until TOI values were stabilized in some cases. We decided not to use simultaneous BIS monitoring during our study because it would have been impossible to correctly place sensors for both NIRS and BIS monitoring due to the limited amount of space on the forehead.

After measurement of control values (HR, MBP, SpO_2 and TOI), anesthesia was induced with propofol (2.0-2.5 mg/kg IV) followed by rocuronium (0.8 mg/kg IV). Tracheal intubation was preceded by bag-mask ventilation with a facemask, using 3% sevoflurane in 100% oxygen at a fresh gas flow of 6 l/min for 3 minutes. After intubation, mechanical ventilation was started using a 40% oxygen-air mixture (tidal volume 7 ml/kg, respiratory rate 12 bpm, inspiratory-to-expiratory time 1:2, with a 10% inspiratory pause). Mechanical ventilation was adjusted to maintain an $ETCO_2$ partial pressure ranging between 32 and 36 mmHg. General anesthesia was maintained with 1.5% sevoflurane and 0.05-0.2 μg/kg/ml remifentanyl. After anesthetic induction, an ultrasound-guided interscalene-brachial plexus nerve block was performed. We opined that performing the nerve blocks in anesthetized patients was associated with greater safety, due to the minimal risk of sudden patient movement that could result in the block needle impaling vital structures. As a result, none of our patients experienced adverse postoperative symptoms that were attributable to brachial plexus block. However, it might be better to perform nerve blocks before the induction of general anesthesia, because the advisory panel of the American Society of Regional Anesthesia and Pain Medicine (ASRA) recommends that interscalene blocks should not be performed in anesthetized or heavily sedated patients [11]. For the ultrasonography, an S-Nerve® or M-Turbo® (Sono Site Japan Inc., Tokyo, Japan) ultrasound machine was equipped with a 38 mm high-frequency (13 MHz) linear array transducer. The superior, middle and inferior trunks of the brachial plexus were identified approximately 2 cm above the clavicle. A 50-mm 18-gauge needle (Contiplex®, B. Braun Aesculap Japan Co. Ltd., Tokyo, Japan) was introduced percutaneously using an out-of-plane technique. A total of 20 ml of 0.375% ropivacaine was injected. The effectiveness of the block was evaluated postoperatively by confirming the absence of pain during an interview with the patient in the recovery room. In addition, the presence of new major neurologic deficits was checked for through both an interview in the recovery room and by reviewing each patient`s medical chart during hospitalization.

To avoid excessive hypotension (systolic blood pressure below 80 mmHg), 4-8 mg ephedrine was administered intravenously, if required. We mainly used ephedrine as vasopressor agent, because ephedrine does not change cerebral oxygenation assessed by NIRS in anesthetized patients [12,13]. However, phenylephrine (0.05-0.1 mg IV) was administered only in the cases hypotension was not improved by administration of ephedrine (4 cases out of 25 patients) (Table 1).

Statistics

Sample size was calculated to detect an 8% difference in TOI values with an 80% power between block and non-block sides. Based on a previous study, we assumed a TOI Standard Deviation (SD) value of 4% [14]. As a result of sample size calculation, we aimed to recruit more than 20 patients. Discrete data were compared using the Fisher exact test. Ordinal data that were not normally distributed were compared between groups using the Mann-Whitney U test. Normally distributed continuous data are presented as mean and SD. The criterion for rejection of the null hypothesis established a priori was a 2-tailed $P<0.05$.

Results

Surgery was performed uneventfully in all the study patients, and no severe intraoperative complications occurred. The demographic data of the study patients are presented in Table 1. As a result of brachial plexus block, none of the patients complained of shoulder pain during their 30-60-min stay in the recovery room, even without

	All patients (n=26)
Male/Female	22/4
Age (Years)	56 ± 18
Height (cm)	165 ± 10
Weight (Kg)	64 ± 10
Hemoglobin (g/dl)	14 ± 2
Underlying diseases, n (%)	
Hypertension	9 (35%)
Diabetes melitus	2 (8%)
Preoperative medication, n (%)	
α-blockers	3 (12%)
β-blockers	2 (8%)
calcium-channel blockers	7 (27%)
angiotensin II antagonist	4 (15%)
Smoking history, n (%)	4 (15%)
Vasopressor administered, n (%)	
Ephedrine	25 (96%)
Total ephedrine dose per patient(mg)	20 ± 10
Phenylephrine	4 (15%)
Total phenylephrine dose per patient(mg)	0.2 ± 0.2
Duration of surgery (min)	179 ± 86
Duration of BCP (min)	221 ± 69
Duration of anesthesia (min)	278 ± 79
Fluid administered (ml)	1307 ± 464

Data are mean ± standard deviation or numbers (%)

Table 1: Demographical and intraoperative variables in patients undergoing surgery in the beach chair position under general anesthesia.

administration of analgesic drugs, such as fentanyl, before extubation. A relatively low dose 0.05-0.2 µg/kg/ml of remifentanyl was enough to block sympathetic responses during the surgery. This suggests that the brachial plexus block was successful in most patients. However, it is difficult to state that brachial plexus block was completely effective in all the patients.

Figure 1 shows the hemodynamic data. HR decreased between the Post-Intub and Pre-BCP periods ($P<0.0001$, repeated measures one-way ANOVA by the Bonferroni post hoc test). MBP decreased between the Control and Pre-Intub ($P<0.05$) and between the Pre-BCP and Post-BCP periods ($P<0.05$). SpO_2 increased between Control and Pre-Intub ($P<0.0001$), and decreased between Post-Intub and Pre-BCP periods ($P<0.01$). The changes in TOI values in the study patients are shown in Figure 2. TOI values recorded on the side of the block were increased in the Pre-Intub period as compared to control levels ($P=0.014$, repeated measures two-way ANOVA by the Bonferroni post hoc test) and decreased between Post-Intub and Pre-BCP periods ($P=0.007$). Similarly, TOI values recorded on the non-block side were increased in the Pre-Intub period compared to control levels ($P=0.037$, repeated measures two-way ANOVA by the Bonferroni post hoc test) and decreased between Post-Intub and Pre-BCP periods ($P=0.005$). However, no difference was found in Pre-BCP and Post-BCP TOI values on the block and non-block sides, and no differences were seen in TOI values between the block and non-block sides at any time point.

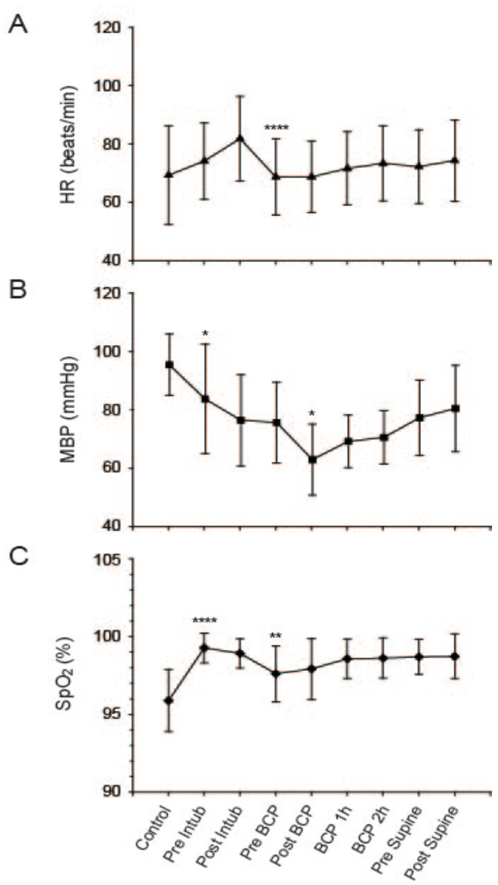

Figure 1: Hemodynamic data.

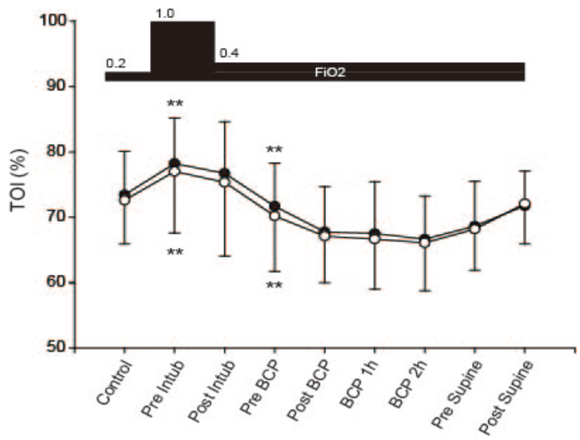

Figure 2: TOI values.

Discussion

Our data shows that cerebral oxygenation is not impaired by a change in body position from the supine to beach chair position in spite of an apparent reduction in systemic blood pressure. All the patients enrolled in this study received general anesthesia and brachial plexus block. Taken together, these results suggest that brachial plexus block does not impair cerebral oxygenation during arthroscopic shoulder surgery under general anesthesia.

In awake patients, adoption of the sitting position stimulates the sympathetic nervous system, resulting in an elevation in blood pressure (10-15%) along with increased systemic vascular resistance (30-40%) and declined cardiac output (15-20%) [15]. Similar hemodynamic changes occur with surgery in the BCP. Under general anesthesia in the BCP, on the other hand, as much as 1500 ml of blood may be sequestered in the venous system of the lower limbs, due to the effect of gravity and increased diffusion through the capillary walls and venous dilation associated with the use of anesthetic agents [16]. Indeed, general anesthesia blunts the baroreceptor response, resulting in a decrease in mean arterial pressure in conjunction with a less prominent increase in systemic vascular resistance and a greater decrease in cardiac output [4]. These facts reflect a recent study demonstrating the advantage of regional anesthesia over general anesthesia during shoulder surgery in BCP in neurobehavioral outcome [17]. Consistent with most previous reports the current study demonstrated that systemic arterial blood pressure decreased immediately after changing from the supine position to the BCP (Figure 1) [10,18-22].

The potential consequences of hypotension during shoulder surgery in the BCP include cerebral ischemia. To avoid serious postoperative neurologic injury, continuous monitoring of cerebral oxygenation, including by NIRS, has recently been used. The current study showed that TOI values decreased between Post-Intub and Pre-BCP periods (Figure 2). We decreased FiO_2 at the same time to avoid O_2 toxicity. The decrease in FiO_2 resulted in a decrease in SpO_2 as well (Figure 1). On the other hand, TOI values increased between Control and Pre-Intub periods, accompanied by an increase in both FiO_2 and SpO_2 (Figures 1 and 2). These parallel changes in FiO_2, SpO_2 and TOI suggested that the changes in FiO_2 resulted in the usual changes in TOI and SpO_2. TOI values measured on both the block and non-block sides did not change between Pre-BCP and Post-BCP periods despite the decrease in MBP (Figures 1 and 2). Given that brachial plexus block has a minimal effect on cerebral oxygenation on the non-block side, our results are consistent with previous studies showing that changing from the supine position to the BCP does not affect cerebral oxygenation [14,20]. Although the threshold of cerebral tissue oxygen saturation for cerebral ischemia varied among previous studies, one previous study defined the critical threshold as a ≥ 20% decrease from baseline or an absolute value of ≤ 55% for 15 seconds. In this study, TOI values in one of the patients were below the critical threshold in the Post-BCP period (i.e., TOI value was ≤ 55% on both sides). However, the low TOI value appeared to be independent of changes in body position and regional anesthesia, because the control TOI value was also relatively low on both sides (64% and 65% on the block and non-block sides, respectively). In all patients, including this one, no new major neurologic deficits were observed in the early postoperative period. These results suggest that changing from the supine position to the BCP under general anesthesia does not impair cerebral oxygenation, regardless of brachial plexus block, in most patients. Given that systemic blood pressure decreased after the change in position, cerebral perfusion pressure may also have decreased in our patients. However, the siphon concept, or "closed model", postulates that the BCP may produce equivalent decreases in mean arterial pressure and central venous pressure, resulting in no net change in cerebral perfusion pressure [1]. Our results can be explained by this hypothesis, although its validity is still an issue of debate. A previous study showed that cerebral blood flow, which was measured using the time averaged velocity of the spectral Doppler waveform, remained constant in anesthetized patients who received an interscalene brachial plexus regional block, despite adoption of the BCP and a fall in mean arterial pressure [10]. This evidence also supports our findings. Interestingly, recent studies suggested that jugular venous bulb oxygen saturation reflected cerebral ischemia during arthroscopic surgery in the BCP better than cerebral tissue oxygen saturation measured using NIRS [18,19]. Thus, further studies are needed to clarify whether brachial plexus block affects cerebral oxygenation under general anesthesia.

We used vasopressor agents to treat excessive hypotension (i.e., systolic blood pressure below 80 mmHg) during the surgery. As mentioned above, past reports showed that ephedrine did not change cerebral oxygenation but phenylephrine did in anesthetized patients [11,12]. Given that a measurement of blood pressure and a subsequent administration of vasopressor agent were performed after a measurement of TOI, the effect of vasopressor agents, even phenylephrine, on TOI values would be minimal. We should point out here that the subjects of this study included patients with hypertension, as shown in Table 1. Some of these patients were treated with anti-hypertensive medication preoperatively. It is difficult to exclude the possibility that these medications may have interfered with the results of this study because the vascular response after changes in body position in these patients may be modified. Another limitation of this study is the relatively small size of the subject group, although power analysis indicates the sample size was enough to detect a significant change in TOI values. Therefore, we would still advise physicians to monitor cerebral oxygenation, using devices such as NIRS, during arthroscopic surgery in the BCP. The significance of our study is supported by the fact that it is the first to directly test the effect of brachial plexus block on cerebral oxygenation during arthroscopic surgery in the BCP under general anesthesia.

Conclusion

Changing from the supine position to the BCP did not appear to impair cerebral oxygenation, regardless of brachial plexus block, in patients undergoing shoulder arthroscopy under general anesthesia.

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