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## SCIENTIFIC ARTICLE

### Patient state index and cerebral blood flow changes during shoulder arthroscopy in beach chair position



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#### KEYWORDS

Patient state index;  
Cerebral;  
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#### Abstract

**Background and objectives:** The aim of the study were to demonstrate the possible hemodynamic changes and cerebral blood flow alterations in patients who were positioned from supine to beach chair position; and to detect if the position change causes any cortical activity alteration as measured by the 4-channeled electroencephalography monitor.

**Methods:** 35 patients were included. Before the induction, mean arterial pressure and patient state index values were recorded (T0). After the intubation, doppler-ultrasonography of the patients' internal carotid and vertebral arteries were evaluated to acquire cerebral blood flow values from the formula. In supine position, mean arterial pressure, patient state index and cerebral blood flow values were recorded (T1) and the patient was positioned to beach chair position. After 5 min all measurements were repeated (T2). Measurements of patient state index and mean arterial pressure were repeated after 20 (T3), and 40 (T4) min.

**Results:** There was a significant decrease between T0 and T1 in heart rate ( $80.5 \pm 11.6$  vs.  $75.9 \pm 14.4$  beats/min), MAP ( $105.8 \pm 21.9$  vs.  $78.9 \pm 18.4$  mmHg) and PSI ( $88.5 \pm 8.3$  vs.  $30.3 \pm 9.7$ ) (all  $p < 0.05$ ). Mean arterial pressure decreased significantly after position change, and remained decreased, compared to T1. The overall analysis of patient state index values (T1–T4) showed no significant change; however, comparing only T1 and T2 resulted in a statistically significant decrease in patient state index. There was a significant decrease in cerebral blood flow after beach chair position.

**Conclusion:** Beach chair position was associated with a decrease in cerebral blood flow and patient state index values. Patient state index was affected by the gravitational change of the cerebral blood flow; however, both factors were not directly correlated to each other. Moreover, the decrease in patient state index value was transient and returned to normal values within 20 min.

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**PALAVRAS-CHAVE**

*Patient State Index*;  
Cerebral;  
Fluxo sanguíneo  
cerebral;  
Posição de cadeira  
de praia

### ***Patient State Index* e alterações do fluxo sanguíneo cerebral durante artroscopia do ombro em posição de cadeira de praia**

**Resumo**

**Justificativa e objetivos:** O objetivo do estudo foi demonstrar as possíveis alterações hemodinâmicas e do fluxo sanguíneo cerebral (FSC) em pacientes que foram posicionados de supinação para cadeira de praia (CP) e detectar se a mudança de posição causa alguma alteração na atividade cortical como mensurado pelo monitor de EEG com 4 canais.

**Métodos:** No total, 35 pacientes foram incluídos. Antes da indução, os valores da PAM e do IEP foram registrados (T0). Após a intubação, ultrassonografias com Doppler da carótida interna e artérias vertebrais dos pacientes foram avaliadas para adquirir os valores do FSC a partir da fórmula. Em supinação, os valores da PAM, IEP e FSC foram registrados (T1) e o paciente foi posicionado em CP. Após 5 minutos, todas as mensurações foram repetidas (T2). As mensurações do IEP e PAM foram repetidas após 20 (T3) e 40 minutos (T4).

**Resultados:** Houve uma diminuição significativa entre T0 e T1 na FC ( $80,5 \pm 11,6$  vs.  $75,9 \pm 14,4$  bpm), PAM ( $105,8 \pm 21,9$  vs.  $78,9 \pm 18,4$  mmHg) e IEP ( $88,5 \pm 8,3$  vs.  $30,3 \pm 9,7$ ) ( $p < 0,05$  para todos). A PAM diminuiu significativamente após a mudança de posição e permaneceu diminuída em relação a T1. A análise global dos valores do IEP (T1-T4) não mostrou nenhuma mudança significativa, mas a comparação de apenas T1 e T2 resultou em redução estatisticamente significativa do IEP. Houve redução significativa do FSC após o posicionado em CP.

**Conclusão:** O posicionado em CP foi associado à diminuição do FSC e dos valores do IEP. O IEP foi afetado pela mudança gravitacional do FSC; no entanto, ambos os fatores não estavam diretamente correlacionados entre si. Além disso, a diminuição do valor do IEP foi transitória e voltou aos valores normais dentro de 20 minutos.

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**Introduction**

In shoulder arthroscopy surgeries beach chair position (BCP) is often used due to certain advantages<sup>1</sup>: combined with "controlled hypotension", it provides easier anatomic orientation and set-up, better visualization of subacromial space and glenohumeral structures, and it is a better choice than lateral decubitus position for open surgeries. It also provides optimal upper extremity rotation control,<sup>2</sup> and under normal circumstances many patients are operated in the BCP without any serious adverse events;<sup>3</sup> however, when the patients are positioned from supine to BCP under general anesthesia, a marked reduction in cardiac output, mean arterial pressure (MAP) and cerebral perfusion pressure (CPP) can be encountered.<sup>1,2,4</sup>

Following its relative recent introduction into the anesthesia practice, "Monitoring the depth of anesthesia" (DoA) is now becoming an important part of routine anesthesia monitoring. The Sedline electroencephalograph based monitor is one such DoA monitoring options, and is used to monitor the state of the brain by real-time data by processing a 4-channel EEG signals and providing numerical value termed the Patient State Index (PSI). PSI is processed quantitative EEG index to evaluate the degree of consciousness during both general anesthesia and conscious sedation.<sup>5</sup> The sensitivity of the PSI index depends on the neurometrics technology it is using, and it can evaluate both the background EEG and the brain's response to anesthetic agents.<sup>6-8</sup> Some clinical results suggest that there are differences between DoA monitoring devices

(including PSI) in evaluation of neurological data.<sup>6,9</sup> Several studies have shown that changes in both hemodynamic status and cerebral perfusion can affect the accuracy of DoA measurements.<sup>10-12</sup> In a recent study, effects of BCP on the bispectral index have been investigated;<sup>13</sup> however, the relation of BCP and cerebral blood flow (CBF) and their effects on PSI have not been investigated before.

The hypothesis of this prospective study was that BCP with controlled hypotension would cause a parallel decrease both in CBF and the PSI-value. The aims of the study were to demonstrate the possible hemodynamic changes and CBF alterations in patients who were positioned from supine to beach chair position (primary outcome); and to detect if the change from supine to beach chair position (BCP) causes any cortical activity alteration as measured by the 4 channelled sedation monitor (Sedline™) (secondary outcome). As a tertiary outcome we have investigated the time course of PSI and blood pressure.

**Methods**

Ethical committee approval was taken from İstanbul University ethical committee number 2012/1370-1195 and dated 31/08/2012. Sample size was calculated according to the pilot study (including 10 patients) which based the PSI values before and after beach chair position by G Power version 3.1.7. In this pilot study, we have found mean PSI values as  $30\% \pm 6\%$  and  $26.8\% \pm 7\%$  for before and after position respectively. Accordingly the power analysis suggested that at least 30 patients were necessary for 80% power to detect

differences among the means with a 0.05 significance level (two-tailed).

Informed consent was taken from 35 patients who had arthroscopic shoulder surgery and agreed to join our study. Patients between age of 18–80 without any carotid stenosis or orthostatic hypotension were included. Patients with an ASA status 3, 4 or 5 and patients with cerebrovascular diseases were excluded.

All patients were pre-hydrated prior to their arrival into the operating room with 1000 cc saline and pre-medicated with 2 mg of midazolam. For postoperative analgesia all patients had a single shot interscalene block under USG guidance. Standard monitoring included ECG, SpO<sub>2</sub>, arterial pressure, capnography (Draeger Infinity XL, Draeger Medical Inc., 3135 Quarry Road, Telford, PA 18969, USA) and four channeled EEG to evaluate the brain function (Sedline with PSI Masimo Corporation, Irvine, USA). Invasive arterial pressure monitoring was performed via a 20G arterial cannula inserted radial artery on the non-operated extremity. The transducer of the invasive arterial monitor was kept at the level of heart. Before the induction, MAP and PSI values were recorded (T0).

For all the patients anesthesia was induced with fentanyl 1.5 µg/kg; propofol 2 mg/kg; rocuronium 0.6 mg/kg; and all patients had tracheal intubation. In all patients, anesthesia was maintained with remifentanyl infusion, 50% O<sub>2</sub>/N<sub>2</sub>O mixture and desflurane to keep end tidal desflurane level was kept as 6%.

After the intubation, Doppler USG of the patients' internal carotid artery (ICA) and vertebral arteries were evaluated. The time averaged mean velocity (VTAM) was measured for the vessels. Vessel diameter was measured on USG and the cross-sectional area of each vessel was determined with the formula  $\pi r^2$ . Flow volume is the product of VTAM and cross-sectional area. The sum of the flow volumes of ICA and vertebral artery was equal to the total CBF.<sup>14</sup>

In supine position, MAP, PSI and CBF values were recorded (T1), and the patient was positioned to BCP. Both in supine and BCP, remifentanyl infusion was started with 0.05 µg/kg/min and was titrated to maintain MAP between 50 and 75 mmHg. After 5 min following positioning to beach-chair, all measurements were repeated (T2). Patients, in whom a 50% or more reduction in CBF was observed, were excluded from the study. The operation started immediately after T2 recordings. Throughout the operation, inspiratory desflurane concentration was adjusted according to the end-tidal concentration (i.e. not to PSI). MAP was kept at the value in T2 via adjustment in the ratio of remifentanyl infusion. If MAP decreased below 50 mmHg, a bolus of 500 mL of colloidal solution and/or 1 mg ephedrine IV was given; if MAP increased above 75 mmHg (with no increase in PSI), the infusion rate of remifentanyl was increased. Violation of MAP above and below the limits (50–75 mmHg) was not an exclusion criterion, unless it was possible to manage it back to the range.

Measurements of PSI and MAP were repeated after 20 (T3), and 40 (T4) min. Because of application difficulties, CBF was not measured during the operation (i.e. T3 and T4). At the end of the operation, patients were positioned back to supine; extubation was performed regarding the PSI value and clinical evaluation. All patients were kept in the PACU

**Table 1** Demographic characteristics of the patients.

Gender (F/M)	24/11 (68.6%/31.4%)
Age	48.4 ± 12
Body weight (kg)	78.3 ± 11.41
Height (cm)	169.71 ± 13.09

for 30 min; after the assessment of modified-Aldrete Score and VAS, the patients were discharged to the ward.

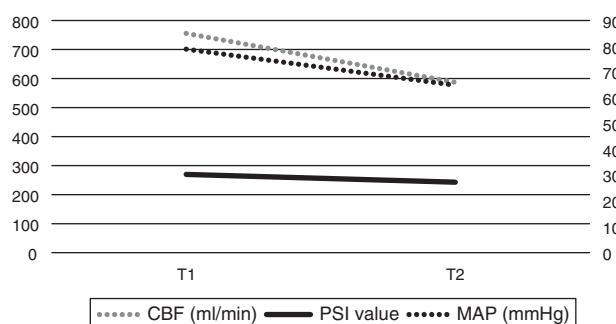
## Statistical analysis

SPSS.20 software was used for the analysis. Paired samples *t*-tests for means were used for the preinduction (T1) and post induction (T1) values of all measurements. To compare data (for mean arterial pressure (MAP), heart rate (HR), and PSI after the induction (T1–T4), repeated measures of ANOVA test were performed with Tukey-test as post hoc; whereas changes in cerebral blood flow (CBF) (T1 vs. T2) were evaluated with paired *t*-test. The *p*-value <0.05 was noted as significant. Correlation between changes in PSI, MAP and CBF after position change (i.e. between T1 and T2) was examined with linear regression tests.

## Results

Thirty-five patients were included in the study. Patient demographics are shown in Table 1. None of the patients was excluded from the study due to any intraoperative exclusion criteria.

There was a significant decrease between T0 and T1 in HR (80.5 ± 11.6 vs. 75.9 ± 14.4 beats/min), MAP (105.8 ± 21.9 vs. 78.9 ± 18.4 mmHg) and PSI (88.5 ± 8.3 vs. 30.3 ± 9.7) (all *p* < 0.05). Results of T1 to T4 can be found in Table 2. Mean arterial pressure decreased significantly after position change to BCP, and remained decreased, compared to T1. The overall analysis of PSI-values (T1–T4) showed no significant change; however, comparing only T1 and T2 (immediate change from supine to BCP) resulted in a statically significant decrease in PSI (*p*-value <0.05). There was a significant decrease in CBF after BCP (Figs. 1 and 2).



**Figure 1** Immediate changes of MAP (mean arterial pressure), CBF (cerebral blood flow), and PSI values during change from supine to beach-chair position (from T1 to T2). All changes are statistically significant. For MAP: *p* < 0.0001; for CBF: *p* < 0.0001; for PSI: *p* = 0.0142).

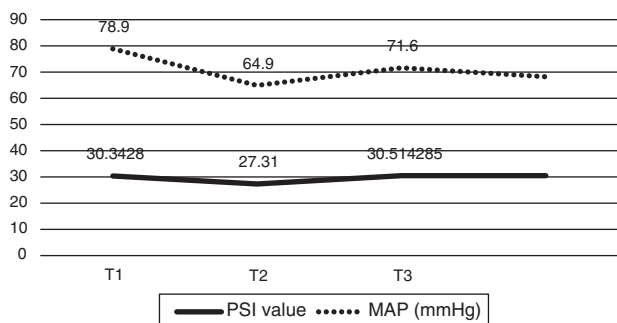
**Table 2** Time course of MAP, CBF and PSI (MAP, mean arterial pressure; CBF, cerebral blood flow). T1, supine; T2, immediate after beach chair position; T3, 20 min after BCP; T4, 40 min after BCP.

	T1 (supine)	T2 (BCP)	T3 (BCP-20 min)	T4 (BCP-40 min)
MAP (mmHg) <sup>a</sup>	78.9 ± 18.4	64.9 ± 12.1	71.6 ± 8.7	68.2 ± 10.7
CBF (ml/min) <sup>b</sup>	755.59 ± 106.18	586.75 ± 84.79	Not measured	Not measured
PSI (%) <sup>c</sup>	30.3 ± 9.7	27.3 ± 7.2	30.5 ± 9.2	30.5 ± 7.5

<sup>a</sup>  $p > 0.0001$ ; where T1 vs T2:  $p < 0.001$ ; T1 vs T3:  $p < 0.5$ ; T1 vs T4:  $p < 0.01$ .

<sup>b</sup>  $p < 0.001$ .

<sup>c</sup> No significant change with repeated measures of ANOVA;  $p = 0.0142$  when compared only T1 vs T2.



**Figure 2** Time course of PSI-value: T1, supine; T2, beach-chair position (BCP); T3, BCP after 20 min; T4, BCP after 40 min. Note that there is no significant change in PSI values, when all measurements are compared. If only T1 vs. T2 are compared, there is a significant decrease ( $p = 0.0142$ ).

None of the changes in the hemodynamic parameters studied correlated with changes in PSI values. Similarly, the changes in cerebral blood flow did not interact with changes in level of sedation (PSI) (Linear Regressions regarding changes T1–T0: MAP vs. PSI ( $R$ -squared: 0.05); CBF vs. PSI ( $R$ -squared: 0.02); BP vs. CBF ( $R$ -squared: 0.07); for all correlations:  $p > 0.05$ ).

## Discussion

In this study we have shown that changing the position from supine to beach-chair was associated with a decrease in MAP, CBF and also PSI-levels; whereby the decrease in PSI was temporary for only 20 min, the MAP values were decreased throughout the process.

It should be noted that a decrease in MAP is ‘‘warranted’’ to achieve a decrease in bleeding during the operation; therefore it was not a ‘‘variable’’ of the protocol of our study, but it was kept within a fixed margin with remifentanyl infusion. BCP offers further advantages to a ‘‘controlled hypotension’’, such as anatomical positioning, reduced use of arm traction and decreased risk of brachial plexus injury. The majority of the studies investigating the changes in blood pressure have found a decrease associated with position change, probably due to gravitational reasons. The standard practice is to keep the MAP within limits after changing to BCP to achieve the additive advantages of BCP and controlled hypotension. We have shown that after a transient decrease in PSI parallel to MAP, the PSI values returned to initial values.

Cerebral blood flow can affect the PSI value both directly or indirectly over MAP. Studies regarding the CBF alterations

have reported contradictory results. McCulloch et al.<sup>15</sup> found that BCP was associated with a decrease in CBF, whilst Soeding et al.<sup>14</sup> did not observe any change. One of the primary aims of this study was to demonstrate the possible hemodynamic changes and cerebral blood flow alterations in patients who were positioned from supine to beach chair position; we have shown that both blood pressure and CBF decreased significantly after position change. Our results are similar to the results from the McCulloch study, at least for the initial period of BCP.<sup>15</sup>

In a recent study, Lee et al.<sup>13</sup> have examined the relationship between bispectral index, another DoA monitor (BIS), with BCP. They found a decrease in BIS after changing the position to BCP. However, in that study the change in CBF was not investigated; moreover, the results were limited to 15 min after BCP. In our study, we could show that the decrease in PSI was parallel to decreases in MAP and also CBF. In addition, this decrease was transient for 20 min, although the decrease in MAP persisted.

Several studies have shown the reliability of different DoA monitors.<sup>16–19</sup> Obviously, there are some factors affecting the sensitivity and specificity of these monitors. Kawanishi et al. have shown that BCP can have some impact on Bispectral Index, i.e. BCP can cause a decrease in BIS values.<sup>20</sup> Kawanishi compared patients in supine position and BCP, and interestingly, the difference in BIS values were observed only as a succession of the position, whereas end-tidal anesthetic gas concentration and mean blood pressure did not significantly differ between the groups consistently. It can be assumed that the decrease in CBF as a result of gravitational change would also cause a change in cortical activities of the patient. Our study confirms the information of the decrease in DoA monitoring value also for the Sedline monitor, and adds some important information to this issue.

First, although both the BCP and the controlled hypotension have continued during the operation, PSI value has a trend toward the values in supine position and has reached them within approximately 20 min. This can be explained by ‘‘auto regulation’’ of the cerebral perfusion. Indeed, there was also a decrease in CBF immediately after the position change. Unfortunately, it was not possible to measure the CBF during the operation. It can be assumed that the cerebral blood flow increased to initial values again, although the blood pressure remained low.

Second, although there were decreases in all MAP, CBF and PSI, there was no correlation between MAP and PSI, or between CBF and PSI. The study was not powered to examine this correlation; however, this finding may be explained the fact that cerebral perfusion is only one of the affecters of PSI

(i.e. cortical activities). This result concludes that although PSI can be affected by the position change to beach-chair; clearly, it is still a DoA monitor and is not suggested to be a monitor of perfusion.

Some case reports have shown complications of BCP regarding cerebral ischemia. Pohl and Cullen reported four cases of ischemic brain and spinal cord injury, and Bhatti reported visual loss, and external ophthalmoplegia after shoulder surgeries.<sup>21,22</sup> The authors of those studies assumed that these complications were associated mostly with postural hypotension and cerebral hypoperfusion. Fortunately, the frequency of these complications is rather low in the literature; even lower in patients who had no previous findings that could affect the cerebral perfusion (e.g. carotid stenosis, atherosclerosis, etc.). As a matter of fact, in our study, only patients without any previous findings affecting the CBF were included. It can be speculated that the increase of PSI within 20 min after BCF is, (in some specific range) an indicator of the auto regulation of CBF. In patients with higher risk of cerebral hypoperfusion, the effects of CBF plus controlled hypotension can vary.

The most important limitation of the study is that the CBF could not be measured during the operation; this was not possible because of the close proximity of the operation area; and even if a measurement were possible, its reliability would be questionable. However, the time course of the CBF was not the hypothesis of the study, nor was it the secondary outcome.

Similarly, cerebral oximetry has not been performed, because the deal of the study was regarding the perfusion and not the oxygenation of the cortex. Patients with a possible impairment of cerebral perfusion and perhaps also of cerebral auto regulation have been excluded from the study. Therefore, the findings and also the time course in this group of patients should be examined in further studies.

In conclusion, it has been shown that beach chair position was associated with a decrease in both cerebral blood flow and PSI value. PSI (i.e. cortical electroencephalic activities) was affected by the gravitational change of the CBF; however, both factors are not directly correlated to each other. Moreover, the decrease in PSI value was transient and returned to normal values within 20 min.

## Conflicts of interest

The authors declare no conflicts of interest.

## Acknowledgements

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