

# Neurocognitive Deficits and Cerebral Desaturation During Shoulder Arthroscopy With Patient in Beach-Chair Position: A Review of the Current Literature

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## Abstract

Arthroscopic shoulder surgery with the patient in the beach-chair position (BCP) has been associated with neurocognitive complications caused by cerebral ischemia.

We reviewed the current literature for the incidence of postoperative neurocognitive deficits, number of reported neurocognitive complications, and incidence of intraoperative cerebral desaturation events in patients who underwent arthroscopic shoulder surgery in the BCP.

Among 10 studies with a composite enrollment of 24,701 patients, there was only 1 case of a postoperative neurocognitive

deficit (overall incidence, 0.004%). Four case reports (not included in the 10 studies) described 6 patients with a catastrophic neurocognitive complication after shoulder surgery in the BCP. Incidence of reported intraoperative cerebral desaturation events varied significantly (0%-100%; mean, 41.1%).

Neurocognitive complications have been reported in patients who had arthroscopic shoulder surgery in the BCP. Intraoperative monitoring of cerebral perfusion, alternatives to general anesthesia, and prudent use of intraoperative blood pressure control may improve patient safety.

The beach-chair position (BCP) is commonly used for both arthroscopic and open shoulder surgery. This technique positions the shoulder in an anatomical upright position, facilitating shoulder access and visualization.<sup>1</sup> Compared with the lateral decubitus position, the BCP also improves airway access, reduces bleeding, and lessens the risk for brachial plexus injury.<sup>2</sup>

Despite the advantages of using the BCP, there have been multiple reports of catastrophic neurologic complications, including severe brain damage and death, in relatively healthy patients without any known risk factors.<sup>3-6</sup> The definitive etiology of these complications remains unclear, but it has been hypothesized that BCP use may be an independent risk factor for cerebrovascular ischemia,<sup>1,5-16</sup> as the upright position can cause

hypotension leading to increased risk for cerebral hypoperfusion.<sup>7-11,17</sup> Reducing cerebral perfusion pressure below critical thresholds may result in permanent neurologic injury.<sup>4-6,14</sup> Therefore, monitoring of cerebral perfusion and optimization of intraoperative cerebral oxygenation have been recommended to help avoid potential neurologic complications. However, a direct relationship between intraoperative cerebral desaturation events (CDEs) and postoperative neurocognitive deficits has not been definitively established.<sup>1,9-12</sup>

To put into perspective the importance of detecting and preventing CDEs and neurologic complications, we can consider the incidence of fatal pulmonary embolism associated with total joint arthroplasty. Although the incidence is very low, about 0.1% to 2.0%, some form of venous

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thromboembolism prophylaxis is the standard of care for helping prevent this serious complication. Similarly, catastrophic neurologic complications of upright shoulder arthroscopy are very rare, but it is still important to consider measures that help minimize them.

We reviewed the literature for the incidence of postoperative neurocognitive deficits, number of reported neurocognitive complications, and incidence of intraoperative CDEs in patients who underwent arthroscopic shoulder surgery in the BCP.

## Methods

Dr. Salazar and Dr. Hazel independently searched the Medline, Cochrane, and Embase databases for case series, prospective studies, and cohort studies that reported neurocognitive complications associated with the BCP and the incidence of intraoperative CDEs. The authors used *beach chair*, *desaturation*, *near infrared spectroscopy*, and *shoulder* as medical subject headings (MeSH). In addition, bibliographies of retrieved articles were checked for studies that the search terms may have missed. Eighty-one publications were identified and reviewed for possible inclusion.

Next, the same 2 authors reviewed the titles and abstracts for relevance and determined which articles had potential to contribute to the study. Only English-language publications were considered for inclusion. To review the incidence of postoperative

neurocognitive deficits, we included only those studies with more than 25 patients, documentation of postoperative complications, and arthroscopic shoulder surgery performed with the patient in the seated, semi-upright, or BCP. Only studies with at least 25 patients were used in order to increase the power and improve the level of evidence. To review reported cases of neurocognitive complications, we included all relevant case reports and case series. To review the incidence of intraoperative CDEs and investigate their relationship with postoperative neurocognitive deficits, we included studies that reported on use of intraoperative cerebral perfusion monitoring. Modalities used in these studies included near infrared spectroscopy, electroencephalography, and invasive blood pressure monitoring calculated at the brain level. Studies were excluded if they did not involve arthroscopic shoulder surgery or were not conducted with human subjects.

Information recorded for each study included general information such as author and publication year, type of study, number of patients enrolled, type of intraoperative monitoring, anesthesia protocol, number of patients with CDEs, and number of patients with neurocognitive complications after surgery.

## Results

Our search identified 81 publications for potential inclusion. Our first aim was to identify the overall incidence of reported neurocognitive deficits after arthroscopic shoulder surgery with the patient in the BCP. We identified 10 studies (**Table 1**) that met the inclusion criteria. Among the 24,701 patients in these 10 studies, there was only 1 reported case of neurocognitive deficit after surgery, in a mixed prospective-retrospective study of 15,014 cases by Rohrbaugh and colleagues.<sup>18</sup> The deficit they reported was an ischemic cerebral vascular accident. The 0.0067% incidence in their study demonstrates how rare the complication is. Two large retrospective studies (Ns = 4169 and 5177 patients) found no postoperative neurocognitive complications.<sup>19,20</sup> Only 3 studies performed formal postoperative cognitive testing. Salazar and colleagues<sup>21</sup> used the Repeatable Battery for the Assessment of Neuropsychological Status before and after surgery, and Gillespie and colleagues<sup>8</sup> and Lee and colleagues<sup>10</sup> used the Mini-Mental State Examination before and after surgery. Total incidence of reported neurocognitive deficits from our review was 0.004% (1/24,701).

Our second aim was to review all reported

**Table 1. Shoulder Surgeries Performed With Patient in Beach-Chair Position**

Study	Year	Patients, n
Koh et al <sup>30</sup>	2013	60
Salazar et al <sup>21</sup>	2013	50
Murphy et al <sup>12</sup>	2010	61
Tange et al <sup>1</sup>	2010	30
Lee et al <sup>10</sup>	2011	28
Jeong et al <sup>9</sup>	2012	56
Gillespie et al <sup>8</sup>	2012	56
Yadeau et al <sup>20</sup>	2011	4169
Rohrbaugh et al <sup>18a</sup>	2013	15,014
Pin-on et al <sup>19</sup>	2013	5177

<sup>a</sup>Only study that reported a postoperative neurocognitive deficit (in this case, ischemic stroke; incidence, 0.0067%).

cases of neurocognitive complications after arthroscopic shoulder surgery with the patient in the BCP. We identified 4 publications that fit our inclusion criteria (Table 2). Pohl and Cullen<sup>6</sup> described 4 cases of ischemic brain injury after arthroscopic shoulder surgery with the patient in the BCP. Age range was 47 to 57 years. Specific intraoperative cerebral monitoring was not used. However, these patients had several episodes of intraoperative hypotension (systolic blood pressures, 80-90 mm Hg), measured with a traditional blood pressure cuff on the arm. In general, these patients had minimal cerebrovascular risk factors and no known preexisting cerebrovascular disease. Drummond and colleagues<sup>22</sup> described an ischemic stroke in a 50-year-old man after arthroscopic subacromial decompression and open rotator cuff repair that resulted in unresolved right hemiplegia. Subsequent diagnostic investigation revealed an asymmetry of the circle of Willis resulting in limited flow to the left anterior and middle cerebral artery distributions. Bhatti and Enneking<sup>3</sup> reported the case of a 64-year-old man who lost vision in the right eye immediately after arthroscopic rotator cuff repair. His vision improved spontaneously the next morning and continued to improve over the next 6 months—he regained 20/20 vision with some residual optic neuropathy.

Our third aim was to determine the incidence of intraoperative CDEs during arthroscopic shoulder surgery with the patient in the BCP. Incidence of CDEs varied widely among the 7 studies reviewed (Table 3). Minimum incidence of intraopera-

tive CDE was 0% in a cohort of 30 patients,<sup>1</sup> and maximum incidence was 80% in a study of 61 patients,<sup>12</sup> all of whom underwent elective arthroscopic shoulder surgery in the BCP. Although there was wide variability in CDE incidence, the studies were consistent with respect to their definition of a CDE. Most authors used a decrease in regional cerebral tissue oxygen saturation of 20% or more from baseline, or an absolute value up to 55%, to define a CDE. None of the 7 studies reviewed reported a clinically significant adverse neurocognitive event.

### Discussion

Of concern, there have been several surveys, case reports, and small case series of previously healthy patients who had no known risk factors, underwent arthroscopic shoulder surgery in the BCP, and developed unanticipated postoperative neurologic complications.<sup>4,6,14</sup> Beach-chair positioning during surgical procedures has been

**Table 2. Reported Neurocognitive Complications After Shoulder Surgery With Patient in Beach-Chair Position**

Study	Year	Patients, n	Neurocognitive Complication
Bhatti & Enneking <sup>3</sup>	2003	1	Ophthalmoplegia
Pohl & Cullen <sup>6</sup>	2005	4	Cerebral infarct
Drummond et al <sup>22</sup>	2012	1	Cerebral infarct
Rohrbaugh et al <sup>18</sup>	2013	1	Cerebral infarct

**Table 3. Incidence of Intraoperative Cerebral Desaturation Events During Shoulder Surgery With Patient in Beach-Chair Position**

Study	Year	Patients, n		Incidence, %	Cognitive Test	Definition of CDE
		All	With CDE			
Koh et al <sup>30</sup>	2013	60	25	41.6	NA	SctO <sub>2</sub> ≥20% from baseline or absolute value ≤55%
Salazar et al <sup>21</sup>	2013	50	9	18	RBANS	rSO <sub>2</sub> decrease of 20%
Murphy et al <sup>12</sup>	2010	61	49	80.3	NA	SctO <sub>2</sub> ≥20% from baseline or absolute value ≤55% for >15 s
Tange et al <sup>1</sup>	2010	30	0	0	NA	SctO <sub>2</sub> ≥20% from baseline for >15 s
Lee et al <sup>10</sup>	2011	28	2	7.1	MMSE	Reduction in rSO <sub>2</sub> to <80% of baseline for ≥15 s
Jeong et al <sup>9</sup>	2012	56	23	41	NA	SctO <sub>2</sub> ≥20% from baseline for >15 s
Dippmann et al <sup>7</sup>	2010	2	2	100	NA	Frontal lobe oxygenation 46% and 56%

Abbreviations: CDE, cerebral desaturation event; MMSE, Mini-Mental State Examination; NA, no formal neurocognitive testing was performed; RBANS, Repeatable Battery for the Assessment of Neuropsychological Status; rSO<sub>2</sub> and SctO<sub>2</sub> (terms used interchangeably in various studies), regional cerebral tissue oxygen saturation as measured by near infrared spectroscopy.

implicated as a contributing factor leading to cerebral hypoperfusion with potential for cerebral ischemia.<sup>1,12,23</sup> These changes in cerebral perfusion pressure are thought to be the major determinant of poor neurologic outcomes. Such reports have exposed the potential need for heightened vigilance, alternative anesthesia techniques, and improved monitoring, though the exact etiology of the central nervous system injuries in this patient population is incompletely understood and is likely multifactorial. Therefore, in this study we wanted to determine the incidence of postoperative neurocognitive deficits and review all reported cases of neurocognitive complications in patients who have undergone arthroscopic shoulder surgery in the BCP. In addition, we wanted to define the incidence of intraoperative CDEs and investigate their relationship with postoperative neurocognitive complications.

According to our review, the incidence of postoperative neurocognitive complications after surgery in the BCP is 0.004% (1/24,701). However, this finding is based only on what has been reported; the true incidence is not known. It is also important to note that the incidence of neurocognitive deficits after many other types of surgery is not known and that surgery itself may be a risk factor for postoperative neurocognitive deficits.<sup>24</sup> In their retrospective review of 15,014 patients who underwent arthroscopic shoulder surgery in the BCP at a single institution over an 11-year period, Rohrbaugh and colleagues<sup>18</sup> found an overall postoperative complication rate of 0.37% and a 0.0067% incidence of neurocognitive deficits. One patient in the series was given a diagnosis of ischemic stroke on the basis of neurologic deficits that occurred 24 hours after surgery. Yadeau and colleagues<sup>20</sup> found no postoperative neurocognitive complications in a mixed prospective-retrospective study of 4169 patients—3000 identified retrospectively, 1169 prospectively—who underwent arthroscopic shoulder surgery in the BCP at an ambulatory surgery center. Pin-on and colleagues<sup>19</sup> reported on a series of 5177 orthopedic and neurosurgical patients who underwent surgery in the BCP. In those who had arthroscopic shoulder surgery, intraoperative systolic blood pressures obtained from an arterial line referenced to heart level decreased a mean (SD) of 14.4% (12.7%), whereas in those whose pressures were obtained from a noninvasive blood pressure cuff referenced to heart level decreased 19.3% (12.6%). However, the authors reported no incidence of postoperative

stroke or neurologic deficits.

Although uncommon, perioperative cerebral ischemic accidents are potentially devastating for patients, their families, and the health care professionals involved. These events have tremendous economic, social, professional, and medicolegal implications, with perioperative stroke being particularly morbid. Perioperative stroke has a mortality rate of 60%, versus 15% to 46% for stroke in general.<sup>25,26</sup> In 2005, Pohl and Cullen<sup>6</sup> published a landmark article on a series of 4 relatively healthy middle-aged patients who were at low risk for stroke but had catastrophic neurocognitive complications (including 1 death) after arthroscopic shoulder surgery in the BCP. Bhatti and Enneking<sup>3</sup> described a case of acute postoperative vision loss and ophthalmoplegia attributed to intraoperative hypotension leading to ischemia in a patient who underwent an elective shoulder arthroscopic procedure in the BCP. These reports prompted multiple investigations into the physiologic hemodynamic changes associated with surgery in the BCP and the treatment strategies used to improve patient safety.

In the normal physiologic state, the sympathetic nervous system is activated when a person assumes the seated position. The result is increased systemic vascular resistance and heart rate alterations to maintain cardiac output and mean arterial pressure. In anesthetized patients, this response is blunted by the vasodilatory effects of intravenous and volatile anesthetics. Multiple studies have demonstrated substantial hemodynamic changes in both awake and anesthetized patients during the maneuver from the supine position to the seated position<sup>1,27,28</sup>; these changes include diminished cardiac index, stroke volume, and arterial pressure.<sup>17</sup> The data underscore the need for attentiveness and accurate monitoring of cerebral perfusion when the transition is made from the supine position to the BCP, particularly in the early phase of surgery and in high-risk patients.

Knowledge of these hemodynamic changes has led several authors to recommend additional intraoperative monitoring of cerebral perfusion. Monitoring techniques have included use of invasive blood pressure monitoring adjusted to brain level, cerebral oximetry using near infrared spectroscopy, and electroencephalography. However, the clinical relevance of intraoperative CDEs in isolation is not well understood.<sup>1,6,7,23</sup> In addition, cost and availability of additional advanced monitoring likely factor into why it is not more commonly used. For

this patient population, the severity, frequency, and duration of desaturation that causes cerebral ischemia and the relationship with postoperative neurocognitive deficits remain undefined.

The incidence of CDEs in patients being monitored with near infrared spectroscopy while undergoing elective arthroscopic shoulder surgery in the BCP varies widely, from 0% to 80% (mean, 41%).<sup>1,4,7,10,12,21</sup> Magnitude and duration of cerebral ischemia required to produce neurocognitive dysfunction in this patient population remain unidentified as well. In conscious patients, a 20% reduction in frontal lobe oxygenation is associated with clinical manifestations of cerebral hypoperfusion, such as syncope.<sup>15,29</sup> As none of the patients in the studies we reviewed experienced any sort of deficit, we cannot definitively state there is a correlation between CDE occurrence and neurocognitive deficit.

One limitation of our investigation is that it was a systemic review, and thus there was substantial heterogeneity in the methods and designs of the studies included in the analysis. Among the different series, there was variability in multiple aspects of the study design, including type of anesthetic, patient inclusion criteria, type of surgery, type of intraoperative cerebral perfusion monitoring, and type of neurocognitive testing. As a result, comparing the groups was difficult, and the generalizability of our findings may be limited. In addition, it is difficult to accurately establish incidence and comprehensively review these events because of the paucity of literature.

## Conclusion

Neurocognitive complications after shoulder arthroscopy with the patient in the BCP are extremely rare but potentially devastating events that can affect healthy patients with no preexisting cerebrovascular risk factors. Our review indicated the incidence of permanent neurologic deficit after arthroscopy in the BCP may be as low as 0.004%. The exact etiology of such complications is not clear. Basic science research and large prospective studies are needed to identify the clinically relevant thresholds of magnitude, duration, and frequency of intraoperative CDEs in order to establish their relationship with postoperative neurocognitive complications. Such large studies may also elucidate modifiable patient-specific risk factors and establish the most sensitive, safe, and cost-effective intraoperative monitoring tools. Current literature suggests that accurate intraoperative monitoring of

cerebral perfusion, alternatives to general anesthesia, and prudent use of intraoperative blood pressure control may improve patient safety.

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