Anesthetic Considerations for Patients Undergoing Surgery in Beach Chair Position

Nicholas Simpson, SAA | Ramakrishna Gumidyala, MD | Karen Turner, CAA

University of Colorado – Denver | Anschutz Medical Campus
Department of Anesthesiology

University of Colorado
Anschutz Medical Campus

Introduction

Arthroscopic shoulder surgery is one of the most performed procedures in the US today. Approximately 2/3 of shoulder surgeries are conducted in beach chair position.[3,9] Because of the benefits provided by beach chair position from a surgical standpoint, the popularity of this position has risen sharply among orthopedic surgeons. However, beach chair positioning does not come without drawbacks. These drawbacks include reductions in blood pressure and cardiac output, and cerebral perfusion. Severe neurological events have been reported in patients undergoing shoulder surgery in beach chair position. They are presumed to be caused by hypotension and subsequent cerebral hypoperfusion leading to neurological injuries; however, the exact etiology of these adverse events is uncertain. Studies have been conducted to demonstrate the relationship between patient positioning and blood pressure, cerebral perfusion, and neurological outcomes.

Near-infrared spectroscopy is a useful tool to assess regional brain oxygenation for these studies; however, it does have many limitations shown in Table 1. There are also studies that looked at treatment strategies anesthetists can use to maintain cerebral perfusion in the beach chair position, which may impact outcomes.

Table 1: Limitations of All Tools used to Collect Data in these Studies

Near-Infrared Spectroscopy[10]
This method measures only a small area of cerebral tissue underlying the elliptical path of near-infrared spectroscopy light transmission (typical adult measurements are 3 cm deep and 6 cm horizontally between sensors).
Extracranial contamination of the near-infrared spectroscopy signal can alter the properties of cerebral to extracranial hemoglobin and thus impact regional cerebral oxygen measurements to a variable degree. Alterations in position from supine to beach chair position, changes in ventilation, and medications used to treat hypotension can potentially influence the degree of extracranial blood flow and affect regional cerebral oxygen values.
Near-infrared spectroscopy devices measure hemoglobin oxygen saturation in venous, capillary and arterial blood within the sampling volume. In calculating regional cerebral oxygen, these devices assume a fixed ratio of 70%-75% venous blood and 25%-25% arterial blood. However, there can be considerable variability in individual arterial-to-venous ratios between patients. Furthermore, it is possible that changes in hemodynamics affect this ratio in a given patient.
The near-infrared spectroscopy signal can be contaminated by nonlinear tissue chromophores such as bilirubin, which has been demonstrated to dampen regional cerebral oxygen measurements.
The various near-infrared spectroscopy devices use proprietary algorithms to calculate regional cerebral oxygen values, resulting in different measurement of brain oxygenation in the same patient.
There is no universally accepted threshold for brain oxygenation which represents a critical desaturation value has not been clearly determined in clinical investigations.
The sensitivity and specificity of near-infrared spectroscopy in detecting ischemia in the awake patient undergoing carotid endarterectomy the sensitivity and specificity of near-infrared spectroscopy in detecting ischemia in the awake patient undergoing carotid endarterectomy are reported to be 53% and 82%, respectively[11]
Jugular Venous Oxygen Saturation[12]
Is a technically demanding invasive procedure for placement, with risks including vascular injury, nerve injury, and thrombosis
Significant discrepancies can exist between measurements of jugular venous oxygen saturation of the right and left jugular veins.
A possibility of extracranial contamination exists. As cerebral blood flow decreases, the relative contribution of extracranial contamination of the jugular venous oxygen saturation increases.
Catheter migration is possible with head movement.
Jugular venous oxygen saturation is a measure of global oxygenation and is not sensitive to smaller areas of focal ischemia.
The sensitivity and specificity of jugular venous oxygen saturation in detecting ischemia in the awake patient undergoing carotid endarterectomy are reported to be 75% and 83%, respectively[11]
Transcranial Doppler Ultrasound[13]
Transcranial Doppler ultrasound measurements are highly operator dependent. 3-dimensional knowledge of cerebrovascular anatomy is required.
Transcranial Doppler ultrasound measurements utilize blood flow velocity as a surrogate for cerebral blood flow. Velocity is only proportional to blood flow if the diameter of the insonated artery remains constant. This assumption is not always true.
In 20%-25% of cases, adequate acoustic windows cannot be obtained.
Transcranial Doppler ultrasound measurements are limited to large basal arteries. Specific cortical regional changes may not be detected.
Placement and maintenance of proper positioning of transcranial Doppler ultrasound probes may be difficult in the beach chair position.
The sensitivity and specificity of transcranial Doppler ultrasound in detecting ischemia in the awake patient undergoing carotid endarterectomy are reported to be 67% and 83%, respectively[11]
Electroencephalography[14]
Electroencephalography is not sensitive to impaired blood flow in deep brain structures.
Electroencephalography is not sensitive to hypoxia. To detect hypoxic alteration of neurelectrophysiology data, a trained neurophysiologist is required to continuously assess the electroencephalography.
A high number of channels need to be monitored to increase the sensitivity and specificity for detection of cerebral ischemia.
The electroencephalography is sensitive to the effects of anesthetic drugs, electrolyte imbalances, hypothermia, and elevated ICP.
The sensitivity and specificity of electroencephalography in detecting ischemia in the awake patient undergoing carotid endarterectomy are reported to be 73% and 96%, respectively[11]

Abbreviations: CBF, cerebral blood flow; ICP, intracranial pressure

Review of Literature

Effect of Beach Chair Position on Regional Brain Oxygenation - Many clinical trials have assessed changes in regional brain oxygenation values during beach chair position and the results are compiled in Table 2. Some studies have documented that the threshold value for detection of pathological brain oxygenation, or a cerebral desaturation event, is a decrease in regional brain oxygenation values of 15%–20%. These percentages are associated with a relatively high sensitivity (80%-100%) and specificity (82%–96%) in detecting cerebral ischemia.[2-4] Some studies showed a clear relationship between regional brain oxygenation and beach chair position. For example, Songy et all found a linear decline in regional brain oxygenation as beach chair position was changed from 0º to 80º.[5] The risk of neurologic injury is related not only to the severity of cerebral hypoperfusion, but also to the duration of these events.[6] Other studies,[7, 8, 9, 10] did not find a significant relationship between regional brain oxygenation and beach chair position.

Relationship between Hypotension, CBF, Jugular Venous Oxygenation, and Cerebral Autoregulation in Beach Chair Position - Jugular venous oxygen is a surrogate for balance between cerebral blood flow and cerebral oxygen consumption. Saturation values < 50% are indicative of hypoperfusion and saturation values < 40% are indicative of ischemia. Type of anesthetic may affect jugular venous oxygen saturation in beach chair position. Jeong et al.[11] found that a decrease in jugular venous bulb oxygen saturation was greater with a TIVA anesthetic (23% decrease) versus an inhalational anesthetic (11% decrease) which suggests a greater margin of safety with inhalational agents against impaired cerebral oxygenation. When it comes to BP, Hypotension (below a MAP of 60) is below the brain's autoregulation curve and it can no longer dilate any further to improve blood flow. Some studies have found significant associations between hypotension and cerebral desaturation events. For example, Kocaoglu et al. found a correlation between hypotension and cerebral desaturation events in their study.[13] There have also been studies that assess the relationship between CBF and patient positioning; the results support a correlation between CBF and positioning. More specifically, McCulloch et al. determined that changing from supine position to sitting position resulted in a decrease in MAP of 47% (measured at the level of the brain) and a reduction in middle cerebral artery blood velocity of 22%.[14] Studies using transcranial Doppler documented a consistent reduction in MCA blood velocity after beach chair position was assumed. Buget et al. calculated CBF with transcranial Doppler of ICA and vertebral arteries. After sitting position, CBF (mL/min) decreased from 756 to 586.[15] Prolonged reductions in CBF in beach chair position may induce brain ischemia and neurologic injury.[16] Additionally, moving from supine position to beach chair position under GA may result in impairment of cerebral autoregulation further causing ischemia and neurologic injury.[16].

Use of Regional Anesthesia with Sedation and Neurocognitive Outcomes After Surgery in Beach Chair Position - Aguirre et al. compared neurological assessments of patients who underwent GA vs. regional anesthesia and found patients in the general anesthesia group had impaired neurocognitive scores. Also, an association between cerebral desaturation events and worsened scores was noted.[17] They also found no decreases in intraoperative regional brain oxygenation or postop neural scores in patients who underwent shoulder surgery with regional anesthesia. Higher $ETCO_2$ levels occur in the sedated patient compared to a patient under GA who is typically hyperventilated which potentially results in increased CBF and regional oxygen values.[6] However, another study found no association between intraoperative desaturations and postoperative neuro assessments.[18] When it comes to the cardiovascular system, cardiovascular consequences of placing a patient in beach chair position are attenuated by regional anesthesia.[6] Ozzeybek et al. found that MAP decreased significantly in those given a combined anesthetic (interscalene block plus sedation), whereas no change in blood pressure was noted in those with an interscalene plexus block alone.[12] In another study by Koh et al. that examined hemodynamic parameters and regional brain oxygenation, both MAP and regional brain oxygenation values were higher and incidence of desaturation events were lower in the regional cohort.[22]

Treatment Strategies to Maintain Cerebral Perfusion in Beach Chair Position - Preventing hyperventilation has been proven beneficial for CPP in several studies. This is because CBF is proportional to PCO_2. Murphy et al. found that an $ETCO_2$ between 40-42 mmHg improved brain oxygenation compared to an $ETCO_2$ between 30-32 mmHg.[6] Cerebral desaturations were also lower in the 40-42 mmHg cohort. However, it should be noted that hypoventilation strategies can decrease blood flow in the setting of focal cerebral ischemia via intracerebral steal phenomenon.[19] Reduction of BP and CO in patients undergoing shoulder surgery is thought to partly be caused by pooling of blood in the lower extremities so the application of intermittent compression devices can help correct this problem.[6] Saline infusion prior to entering beach chair position has been found to be less effective than phenylephrine at preventing hypotension in beach chair position; however, regional brain oxygenation was 18% lower after assuming position in patients who received phenylephrine vs. 11% in patients who received NS.[20] Phenylephrine and vasopressin attenuate hypotension by maintaining preload and increasing SVR, but may decrease CO and reduce regional brain oxygenation.[15] However, MCA blood velocity was increased by 20% in beach chair position after pretreatment with phenylephrine compared to a decrease of 15% without pretreatment.[15] Ephedrine, which maintains BP primarily via increased CO, effectively manages hypotension in beach chair position and maintains regional oxygenation values.[21]

Table 2: Study Results Assessing Changes in Regional Brain Oxygenation vs. Beach Chair Position

Study	Sample Size	Blood Pressure Cuff Placement	Blood Pressure Measurement Site	Incidence of Hypotension	Treatment of Hypotension	Method of Hypotension Treatment	Blood Pressure Changes	Regional Brain Oxygenation Changes	Conclusions
Mirski et al.[2]	2003, 1000 patients	Forearm/contralateral arm	Forearm/contralateral arm	Not stated	Yes	Phenylephrine, ephedrine, fluids	35% MAP	No	Hypotension is a common non-cerebral ischemic event in patients undergoing cardiac surgery. The relationship of regional brain oxygenation to hypotension is complex and the effects of medications compound its complexity. Regional brain oxygenation is a performance and safety measure.
Lynch et al.[3]	2003, 1000 patients	Forearm/contralateral arm	Forearm/contralateral arm	Not stated	Yes	Ephedrine	Not stated	No	Induction of anesthesia is a vulnerable period for cerebral ischemia in cardiac surgery and risk factors associated with a decrease in regional brain oxygenation.
Nelson et al.[4]	2004, 1000 patients	Forearm/contralateral arm	Forearm/contralateral arm	Not stated	Yes	Not stated	Not stated	No	Fluid and wine boosting did not influence the incidence of cerebral desaturation events.
Ali et al.[7]	2004, 20 patients	Forearm/contralateral arm	Forearm/contralateral arm	Not stated	No	Not stated	Not stated	No	Cerebral desaturation significantly more in beach chair position.
Cullen et al.[8]	2004, 100 patients	Forearm/contralateral arm	Forearm/contralateral arm	Not stated	Yes	Not stated	Not stated	No; no difference between beach chair and supine positions	Cerebral oxygenation is impaired, and cerebral oxygenation does not keep pace with changes in MAP in beach chair position compared to supine position in a sedated anesthetized population.
Kim-Hwang et al.[9]	2005, 1000 patients	Forearm/contralateral arm	Forearm/contralateral arm	Not stated	No	Not stated	25–40%	No	Cerebral desaturation events are frequently observed in patients in beach chair position and are not associated with changes in blood pressure.
Pellicer et al.[10]	2006, 30 patients	Ankle/contralateral arm	Forearm/contralateral arm	Not stated	No	Phenylephrine, ephedrine, fluids	40–50%	No	Blood pressure decreased at the cuff and brain but not at the forehead in beach chair position.
Ruhl et al.[11]	2007, 1000 patients	Forearm/contralateral arm	Forearm/contralateral arm	Not stated	Yes	Phenylephrine, ephedrine, fluids	20–40%	Yes; no gross changes in cerebral oxygenation	Temporarily attenuated hypotension is not associated with gross changes in cerebral oxygenation and supports safety of beach chair position.
Pellicer et al.[12]	2007, Not stated	Forearm/contralateral arm	Forearm/contralateral arm	Not stated	Yes	Phenylephrine, ephedrine, fluids	Not stated	No	Decreasing regional oxygenation in beach chair position is associated with hypotension.
Tapia et al.[13]	2007, 1000 patients	Forearm/contralateral arm	Forearm/contralateral arm	Not stated	Yes	Not stated	30–40%	Yes	Hypotension attenuated decreases in cerebral blood velocities and in cerebral oxygenation.
Bigeh et al.[14]	2007, 1000 patients (2 patients with CA)	Forearm/contralateral arm	Forearm/contralateral arm	Not stated	No	Fluid administration	Not stated	No	Beach chair position was associated with a significant decrease in cerebral oxygenation.
Matsuo et al.[15]	2007, 1000 patients	Forearm/contralateral arm	Forearm/contralateral arm	Not stated	Yes	Phenylephrine, ephedrine, fluids	Not stated	Yes; decrease in cerebral oxygenation	Hypotension and cerebral desaturation are frequent events in the beach chair position; cerebral desaturation events were associated with a decrease in cerebral oxygenation.
Ikeda et al.[16]	2007, 1000 patients	Forearm/contralateral arm	Forearm/contralateral arm	Not stated	No	Ephedrine, fluids	Not stated	Yes; decrease in cerebral oxygenation	There was a linear relationship between cerebral oxygenation and blood pressure in beach chair position. Cerebral oxygenation is impaired when autoregulation is exceeded by changes in $ETCO_2$ concentration.
Tiwari et al.[17]	2008, 1000 patients	Forearm/contralateral arm	10%	Yes	Ephedrine, phenylephrine	46–48%	Yes; 1 patient with impaired cerebral oxygenation and cognitive dysfunction	No	Cerebral desaturation events occurred in 1/3 of patients and were associated with cognitive dysfunction.
Lynch et al.[18]	2009, Sample size not stated	Forearm/contralateral arm	Forearm/contralateral arm	Not stated	Yes	Fluid administration, ephedrine	30–40%	Yes; cerebral oxygenation decreased 5–10 %	Cerebral oxygenation changes in cerebral blood flow in a vasoconvex suggestive of cerebral ischemia. Cerebral oxygenation testing was informed.
Ortega et al.[19]	2010, Sample size not stated	Forearm/contralateral arm	Forearm/contralateral arm	Not stated	Yes	Phenylephrine, ephedrine, fluids	20–30	No	The decrease in regional brain oxygenation was not associated with hypotension in the beach chair position; cerebral oxygenation was not affected by changes in blood pressure. Cerebral desaturation events were common, and cerebral oxygenation was frequently measured at the brain.
Hazama et al.[20]	2011, Not stated	Forearm/contralateral arm	Forearm/contralateral arm	Not stated	Yes	Phenylephrine, ephedrine, fluids	30–40%	No; no gross changes in cerebral oxygenation	Hypotension is common in beach chair position; a significant fluid bolus cerebral desaturation events.
Rosada et al.[21]	2011, Not stated	Forearm/contralateral arm	10%	Yes	Ephedrine, fluids	30–35 (2 of 20 patients)	Not stated	No	Hypotension decreased cerebral oxygenation in beach chair position; ephedrine administration increased cerebral oxygenation.
Jeong et al.[11]	2011, Not stated	Forearm/contralateral arm	Forearm/contralateral arm	Not stated	Yes	Ephedrine, fluids	20–40	Yes; decrease in cerebral oxygenation	Hypotension decreased cerebral oxygenation in beach chair position; ephedrine administration increased cerebral oxygenation.
Kocaoglu et al.[13]	2012, 1000 patients	Forearm/contralateral arm	Forearm/contralateral arm	Not stated	Yes	Fluid administration	30–40%	Yes	Hypotension is a common finding; decreased the incidence of hypotension can be a useful measure to prevent cerebral desaturation events.
Lee et al.[22]	2013, 1000 patients (2 patients with CA)	Forearm/contralateral arm	Forearm/contralateral arm	Not stated	Yes	Ephedrine, phenylephrine, fluids	20–30%	Yes; no change in cerebral oxygenation	Hypotension is a common finding; decreased the incidence of hypotension can be a useful measure to prevent cerebral desaturation events.

Abbreviations: MAP, mean arterial pressure; CA, cardiac arrest; $ETCO_2$, end-tidal carbon dioxide

Conclusions

Despite the availability of trials and studies that have looked at the effects of beach chair positioning on cerebral physiology, more data needs to be collected in order to: 1. determine a standard parameter to define a cerebral desaturation event, 2. adequately demonstrate a correlation between hypotension, cerebral desaturation events, and adverse neurological events in patients undergoing surgery in beach chair position, and 3. determine the optimum method to treat hypotension intraoperatively in patients who are undergoing surgery in the beach chair position.

Although it may seem simple, determining a universal parameter for cerebral desaturation events is complicated by the NIRS technology. There is question as to whether NIRS devices can accurately detect significant reductions in brain oxygenation.[6] Although NIRS suggest a decrease in brain oxygenation in beach chair position, interpretation of the results are hampered by the limitations of the device. Also, there are studies that contradict each other when determining whether there is a correlation between beach chair position and a decrease in brain oxygenation. Furthermore, an association between changes in BP, CO, and brain oxygenation and incidence of adverse neurological events has not been clearly demonstrated. Another reason why more data on this subject is needed is to determine optimum methods to treat intraoperative hypotension in patients undergoing surgery in beach chair positioning. The medications used intraoperatively to treat hypotension have variable effects on regional brain oxygenation values. It seems that using a pressor that maintains cardiac output such as ephedrine or using a combination of NS + phenylephrine infusions as pretreatment for hypotension caused by beach chair positioning is the best approach, but again, more data is needed to confirm this.

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