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Association between temporal mean arterial pressure and brachial noninvasive blood pressure during shoulder surgery in the beach chair position during general anesthesia

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Background: Estimation of cerebral perfusion pressure during elective shoulder surgery in the beach chair position is regularly performed by noninvasive brachial blood pressure (NIBP) measurements. The relationship between brachial mean arterial pressure and estimated temporal mean arterial pressure (eTMAP) is not well established and may vary with patient positioning. Establishing a ratio between eTMAP and NIBP at varying positions may provide a more accurate estimation of cerebral perfusion using noninvasive measurements.

Methods: This prospective study included 57 patients undergoing elective shoulder surgery in the beach chair position. All patients received an interscalene block and general anesthesia. After the induction of general anesthesia, values for eTMAP and NIBP were recorded at 0°, 30°, and 70° of incline.

Results: A statistically significant, strong, and direct correlation between NIBP and eTMAP was found at 0° ($r = 0.909$, $P \leq .001$), 30° ($r = 0.874$, $P < .001$), and 70° ($r = 0.819$, $P < .001$) of incline. The mean ratios of eTMAP to NIBP at 0°, 30°, and 70° of incline were 0.939 (95% confidence interval [CI], 0.915-0.964), 0.738 (95% CI, 0.704-0.771), and 0.629 (95% CI, 0.584-0.673), respectively. There was a statistically significant decrease in the eTMAP/NIBP ratio as patient incline increased from 0° to 30° ($P < .001$) and from 30° to 70° ($P < .001$).

Conclusion: The eTMAP-to-NIBP ratio decreases as an anesthetized patient is placed into the beach chair position. Awareness of this phenomenon is important to ensure adequate cerebral perfusion and prevent hypoxic-related injuries.

Level of evidence: Basic Science, Physiology.

Keywords: Mean arterial pressure; beach chair position; shoulder surgery; cerebral perfusion pressure; noninvasive blood pressure; cerebral hypoxic injury

This study was approved by the Western Institutional Review Board (Study No. 1132925).

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The beach chair, or seated, position is the most commonly used position for patients undergoing arthroscopic and open shoulder procedures in the United States,[8] and its safety has been well established.[28,41] Although extremely rare, cerebral ischemic events have been observed after surgery in the beach chair position.[8] These reports have identified upright positioning as an independent risk factor for cerebral ischemia during surgery.[14,17,25,34] Ischemic brain and spinal cord injuries have been described,[4,25] resulting in blindness,[3] pituitary apoplexy,[11] and death.[4] In a survey of the American Shoulder and Elbow Surgeons Society, the reported incidence of intraoperative cerebrovascular events during beach chair positioning was 0.00291% (8 of 274,225).[8] It is believed that transitioning from supine to the beach chair position, in an anesthetized patient, results in a decrease in blood pressure, increasing the risk for cerebral hypoperfusion and ischemic brain injury.[24,25] Significant decreases in cardiac output, mean arterial pressure (MAP), and cerebral perfusion pressure (CPP) have been observed with this position change.[5,29] Nonanesthetized patients are able to compensate for this decrease in blood pressure by increasing systemic vascular resistance to maintain MAP and cardiac output, a response that is blocked in anesthetized patients due to vasodilating intravenous and volatile anesthetics.[7,11,19,30,39]

Historically, it was believed that cerebral autoregulation was able to preserve constant cerebral blood flow when MAP was maintained between 50 and 150 mm Hg.[4,10] However, the lower limit of autoregulation (LLA) has recently been challenged.[1,6,18] Many believe that higher values, up to 80 ± 8 mm Hg, for the LLA are necessary to prevent potential hypoxic ischemic encephalopathy.[6,10,15,21-23,27,32,33,40] Koh et al[12] have stated that cerebral blood flow may be underestimated by as much as 40 mm Hg with the use of brachial cuff readings due to hydrostatic pressure differences between the arm and head in the beach chair position. Numerous other studies have also shown the beach chair position results in a decrease in blood pressure.[4,12,25,35,42]

These recent findings suggest that brachial measurements may not accurately represent cerebral arterial pressures. However, no study, to our knowledge, has determined the ratio between these 2 variables at varying positions in an anesthetized patient. The purpose of this study is to determine if a direct correlation exists between brachial and temporal arterial pressures and to calculate the ratio of the estimated temporal MAP (eTMAP) to the noninvasive brachial mean arterial blood pressure (NIBP) at 0°, 30°, and 70° of inclination. Establishing these ratios may provide a more accurate assessment of cerebral blood pressure during procedures performed in the beach chair position without the need for invasive monitoring. We hypothesize that there is a strong direct correlation between eTMAP and NIBP and that a ratio between these 2 variables exists, regardless of position.

Materials and methods

This was a prospective cohort study of 57 patients (32 men, 25 women) undergoing elective shoulder surgery (56 shoulder arthroplasty and 1 humeral fracture fixation), from July 2012 to July 2013, using noninvasive arterial monitoring of blood pressure in the beach chair position. Patients were included if they were having an elective open shoulder procedure and were at least 18 years old. Excluded were minors, pregnant patients, prisoners, and patients with impaired decision-making abilities.

American Society of Anesthesiologists Physical Status Classification scores of 1, 2, and 3 were assigned to 1, 35, and 21 patients, respectively. The patients were an average age of 71 years (range, 32-87 years). All patients had a preoperative interscalene block and peripheral arterial catheterization. Anesthesia was induced with propofol and maintained with inhaled sevoflurane.

An arterial transducer was leveled at the temporal artery to represent the arterial pressure at the level of the brain. The eTMAP was recorded from the reading of this transducer. The NIBP was measured from an automated sphygmomanometer placed on the upper arm. Baseline values for eTMAP and NIBP were recorded with the patient supine after the induction of general anesthesia. Values were again recorded in the beach chair position at 30° and 70° of inclination. Any postoperative neurologic sequelae were reported.

Statistical analysis

Data were checked for normality, and descriptive statistics were calculated for each of the examined variables. Repeated-measures analysis of variance with least significant difference pairwise comparisons were conducted to assess differences in NIBP, eTMAP, and the eTMAP/NIBP ratio at 0°, 30°, and 70° of incline. The relation between NIBP and eTMAP at the 3 different positions (0°, 30°, and 70° of incline) was assessed using Pearson correlation coefficients (r). Data were analyzed using PASW Statistics 18.0 software (SPSS Inc, Chicago, IL, USA). A P value of $<.05$ was considered statistically significant.

Results

Our results demonstrate a statistically significant effect of inclination on NIBP ($P < .001$) and eTMAP ($P < .001$). Mean NIPB was highest at 0° of incline (110 ± 24 mm Hg), with statistically significant decreases seen at inclines of 30° (94 ± 20 mm Hg) and at 70° (81 ± 19 mm Hg; $P < .001$ for all pairwise comparisons). Increasing the degree of inclination also elicited significant reductions in eTMAP. The highest mean values of eTMAP were recorded at 0° of incline (104 ± 24 mm Hg), with statistically significant decreases in eTMAP occurring at inclinations of 30° (71 ± 22 mm Hg) and 70° (52 ± 21 mm Hg; $P < .001$ for all pairwise comparisons; Table I). Statistically significant, strong, and direct correlations between eTMAP and