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Original Contribution

The beach chair position for shoulder surgery in intravenous general anesthesia and controlled hypotension: Impact on cerebral oxygenation, cerebral blood flow and neurobehavioral outcome

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ABSTRACT

Study objectives: The aim of this study was to assess the impact of intravenous general anesthesia and controlled hypotension on cerebral saturation ($rScO_2$), cerebral blood flow measured as middle cerebral artery blood flow velocity (Vmax MCA) and neurobehavioral outcome in patients scheduled for shoulder surgery in beach chair position.
Design: Prospective, assessor-blinded observational study.
Setting: University hospital, shoulder surgery operating room.
Patients: Forty ASA I-II patients scheduled for shoulder surgery in beach chair position and controlled hypotension.
Interventions: Neurological and neurobehavioral tests were performed prior and the day after surgery. The baseline data for near-infrared spectroscopy, bispectral index, cerebral blood flow, $PaCO_2$ and invasive blood pressure (radial artery) were taken prior anesthesia and after anesthesia induction, after beach chair positioning and all 20 min after surgery start until discharge of the patient.
Measurements: Neurological and neurobehavioral tests, cerebral saturation ($rScO_2$) using near-infrared spectroscopy, BIS, cerebral blood flow using Doppler of the middle cerebral artery (Vmax MCA), $PaCO_2$ and invasive blood pressure assessed at heart and at the external acoustic meatus level.
Main results: The incidence of cerebral desaturation events (CDEs) was 25%. The blood pressure drop 5 min after beach chair position measured at the acoustic meatus level in the CDE group was higher compared to patients without CDEs ($p = 0.009$) as was the $rScO_2$ ($p = 0.039$) and the Vmax MCA ($p = 0.002$). There were no neurological deficits but patients with CDEs showed a greater negative impact on neurobehavioral tests 24 h after surgery compared to patients without CDEs ($p = 0.001$).
Conclusions: In ASA I-II patients intravenous general anesthesia and controlled hypotension in the beach chair position affects cerebral blood flow and cerebral oxygenation with impact on the neurobehavioral outcome.

1. Introduction

The beach chair position (BCP) is commonly used for arthroscopic and open shoulder procedures and offers different advantages compared to the lateral decubitus position (LDP) [1,2]. However, cerebral ischemic events have been observed after surgery in BCP [3,4] identifying the upright position as an independent risk factor for cerebral ischemia during the perioperative period [5–8]. The change from supine to the beach chair position after anesthesia leads to a decrease in blood pressure, with possible impairment of cerebral blood flow and increasing the risk of ischemic brain injury [9,10]. The use of non-invasive blood pressure monitoring using brachial cuff has been shown to underestimate the blood pressure at the brain level by up to 40 mm Hg due to hydrostatic pressure differences between the arm and head in the beach chair position [11–14]. Triplet et al. have recently described a ratio between the blood pressure measured at brain level and the blood

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pressure value at heart level (eTMAP-to-NIBP ratio). They showed a decrease of this ratio when an anesthetized patient was placed into the beach chair position [13]. Therefore, for high risk patients an invasive blood pressure measurement at the level of the acoustic meatus should be considered [9,15].

Near-infrared spectroscopy technique (NIRS) has successfully been established as a real-time measurement method to assess cerebral oxygenation ($rScO_2$), estimate cerebral perfusion and to allow an early detection of cerebral desaturation events (CDEs) [16,17]. However, the correlation between desaturation events, cerebral blood flow and the impact on cognitive function remains unknown for intravenous general anesthesia [18,19].

The aim of this prospective, observational, assessor-blinded study was to evaluate the prevalence of regional cerebral oxygen desaturation in ASA I-II patients undergoing shoulder surgery in the beach chair position receiving intravenous general anesthesia following a controlled hypotension protocol (systolic blood pressure ≤ 100 mm Hg at heart level) and the correlation of CDEs to cerebral blood flow and neurobehavioral outcome.

We hypothesize that the incidence of CDEs with general anesthesia in beach chair position would be first in the range of 20–80%, as previously determined and second, that CDEs would correlate with cerebral blood flow impairment and neurobehavioral decline.

Our primary outcome was the incidence of cerebral desaturation events (expressed as a drop of absolute $rScO_2$ to a value < 55% for > 15 s of baseline and in relative terms as a decrease in $rScO_2$ ≥ 20% compared to the baseline value) [20] during intravenous general anesthesia using a controlled hypotension protocol. Our secondary outcomes were the correlations of the CDEs on the cerebral blood flow (CBF) expressed as Vmax MCA (maximal blood flow (mean) of the middle cerebral artery), on the neurological and neurobehavioral outcome and the effects of blood pressure (measured at heart level and at the level of the acoustic meatus) on $rScO_2$.

2. Materials and methods

Our study was approved by the local Ethics Committee (Kantonale Ethikkommission Zürich, KEK-Zh) and written informed consent was obtained from each patient. Forty ASA I-II adult patients scheduled for elective, unilateral shoulder surgery were included in this prospective, assessor-blinded, mono-center observational study.

The exclusion criteria were: pregnancy, a history of central neurological diagnosis (transient ischemic attack, stroke, bleeding, syncope, chronic headache, cervical disk herniation, spinal cord injury, recent vision impairment/loss, cerebral tumor or metastasis, orthostatic hypotension), allergies to any drug used for anesthesia, known neurobehavioral disorders or baseline Mini Mental State Examination (MMSE) < 24 and cardiovascular contraindications for controlled hypotension like recent myocardial infarction (< 6 months) or symptomatic coronary heart disease, known relevant carotid stenosis (> 40%) or known flow disturbance of vertebral arteries.

The evening prior to surgery, a standardized neurological control (pupil size and reaction, lateralization tests of both extremities, Glasgow Coma Scale (GCS), MMSE) and neurobehavioral tests (Trail Making A, Trail Making B, Grooved Pegboard) were conducted as baseline measurements. Trail Making A/B are neurobehavioral tests focusing on visual attention and task switching. They consist of two parts in which the patient is instructed to connect a set of 25 dots (numbers in A, alternating numbers and letters in B) as fast as possible. They provide information about visuomotor speed, attention, speed of processing, scanning, mental flexibility, as well as executive functioning. The Grooved Pegboard test assesses fine motor dexterity and speed. Patients have to fit notched pegs into matching holes as quickly as possible. Time taken to fill all holes is recorded. All three tests were suggested by Murkin et al. in a consensus to assess neurobehavioral outcomes after cardiac surgery and have been used in other studies dealing with beach chair [11,14,21]. All the tests were performed by the patients in the pre- and postoperative (24 h after surgery) sessions using always the non-operated arm and monitored by an anesthesia research fellow not further involved in the anesthesia management. Z-scores were calculated from individual test scores by subtracting the study mean, and dividing by the SD. In order to calculate a summary measure across all tests in the battery, the 3 individual raw test scores were standardized to z-scores [mean = 0; standard deviation (SD) = 1] by subtracting the mean test score over all participants, and dividing by the sample SD (internal standardization). Patients were defined as having cognitive dysfunction when two Z-scores in individual tests or the combined Z-score were 1.96 or more, meaning their scores were > 2 SD from the mean [22].

The evening prior to surgery, the carotid arteries of the patients were assessed by ultrasonography to exclude significant obstructions. Cerebral oximetry values are known to be affected by several factors as type of anesthetic used, depth of anesthesia, FiO_2, $PaCO_2$ as well as blood pressure management [23]. Therefore, anesthetic management was standardized for all patients, and the anesthesiologist and the anesthesia nurse in charge of each patient were blinded for the $rScO_2$ value during the whole procedure by covering the NIRS monitor and switching off the CDE alarms. All patients were premedicated with 0.1 mg/kg oral midazolam 1 h before the arrival in the induction room. There, standard monitoring was installed (oxygen saturation, ECG, non-invasive blood pressure measurement and placement of an i.v. line on the non-operated arm). Additionally, all patients got a bispectral index (BISTM, Aspect Medical/Covidien, Mansfield, MA, USA) electrode on the forehead and anesthesia was titrated to a BIS target of 40–60. Moreover, a radial artery line for invasive blood pressure measurement (IBP) on the non-operated arm was placed. Further, two NIRS sensors were applied both sides on the forehead just above the BIS electrode (INVOS® Near-infrared spectroscopy monitoring, Somametics, Covidien, MA, USA) [16]. All patients had a middle cerebral artery flow velocity (Vmax MCA: Maximal blood flow) measurement at the non-surgical site (EZ-Dop, 2 MHz probe for transtemporal measurement, Neurolite, Switzerland). Baseline oxygenation parameters were set and Vmax MCA measurements were performed 5 min after initial monitoring installation. Arterial oxygen saturation (SpO_2) and $rScO_2$ values were measured in patients while breathing a 40% air/oxygen mixture. Blood pressure was invasively recorded at heart and acoustic meatus level. All measurements were recorded at baseline, 5 min after induction of general anesthesia, 5 min after beach chair positioning, at surgery start and then all 20 min until discharge to the post anesthesia care unit (PACU) or ward and at periods of adverse events (systemic deoxygenation, hypoventilation states). BIS and $rScO_2$ values were continuously recorded by the monitor system for evaluation after surgery. Interscalene catheter using neurostimulation was placed in all patients to avoid impairment in the neurobehavioral tests due to opioids for pain treatment after painful shoulder surgery. However, it was not activated until discharge to the PACU to avoid additional hemodynamic alterations to general anesthesia [24] and to avoid possible interactions with cerebral monitoring [25]. General anesthesia was induced with a propofol target-controlled infusion (TCI) using 100–200 μg of fentanyl and 0.6 mg/kg body weight of rocuronium for intubation and propofol/remifentanil TCI for maintenance keeping the loss of consciousness (LOC) effect site concentration at its 1.5 - double value [26]. The inspired oxygen fraction was kept at 40% and the end-tidal CO_2 maintained stable between 4.6 and 5.3 kPa. All interventions were performed in BCP with 65° from horizontal. A controlled hypotension protocol for a systolic blood pressure at heart level (SAP_{heart}) ≤ 100 mm Hg was used according clinical practice [11,15,27]. An intervention protocol for a SAP_{heart} > 100 mm Hg for > 3 min was defined: (1) deepening of anesthesia with propofol/remifentanil according to clinical findings, (2) clonidine 75–150 μg i.v. (3) labetalol 10 mg bolus i.v. The intervention protocol for a SAP_{heart} < 80 mm Hg for > 3 min consisted in: (1) crystalloid bolus of 250 ml, (2) ephedrine i.v. 2.5–5 mg, (3)