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ORIGINAL ARTICLE

Duration of cerebral desaturation time during single-lung ventilation correlates with mini mental state examination score

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Abstract

Purpose Single-lung ventilation (SLV) is thought to reduce regional cerebral oxygen saturation (rSO_2). In this study, we evaluated changes in rSO_2 during SLV and their correlation with perioperative changes in cognitive function.

Methods Sixty-nine patients participated in this study, each of whom received combined thoracic epidural and general anesthesia. rSO_2 was measured using INVOS 5100 (Somanetics, Troy, MI, USA) before anesthesia (baseline value) and until SLV was completed. Patient cognitive function was assessed using the mini mental state examination (MMSE) on the day before surgery (baseline) and then repeated 4 days after surgery. The patients were classified into two groups: with (desaturation group, group D) and without (nondesaturation group, group N) cerebral desaturation during SLV. Cerebral desaturation was defined as a reduction of rSO_2 during SLV less than 80% of the baseline value. An intergroup comparison was made between perioperative cognitive function findings (MMSE score change between baseline and 4th day after surgery). We also examined the correlation between the duration of desaturation during SLV and perioperative MMSE score changes in group D patients.

Results Seventeen patients were included in group D. The MMSE score decrease was significantly higher in group D as compared to that in group N ($P < 0.05$). The duration of desaturation time was significantly negatively correlated with MMSE score change ($r^2 = 0.444$, $P < 0.05$).

Conclusion Duration of cerebral desaturation time during SLV correlates with MMSE score. Additional studies are needed to determine whether intervention against cerebral desaturation during SLV can prevent postoperative cognitive dysfunction.

Keywords Cerebral desaturation · Single lung ventilation · Cognitive dysfunction

Introduction

Although single-lung ventilation (SLV) is necessary in a variety of thoracic surgical procedures, it can cause various physiological changes, including hypoxic pulmonary vasoconstriction (HPV) in the nonventilated lung, decreased partial oxygen pressure, inflammatory responses, and changes in cardiac output [1]. Near-infrared spectroscopy (NIRS), a technique developed in the 1970s [2], has been used as a method for noninvasive and continuous monitoring of the balance between cerebral oxygen delivery and consumption [3]. However, regional cerebral oxygen saturation (rSO_2) monitoring is now used during cardiac surgery [4–6], abdominal surgery [7, 8], vascular surgery [9], carotid endarterectomy [10–12], and neurosurgery [13] procedures, because decreases in rSO_2 are significantly correlated with prolonged hospital stay [14] and perioperative cerebrovascular accidents [6]. In addition, Hemmerling et al. [15] reported a significant decrease in rSO_2 during SLV, though the correlation between this decrease and perioperative complications has not been evaluated. In the present study, we evaluated changes in rSO_2 during SLV

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and their correlation with perioperative changes in cognitive function.

Methods

This study was approved by the Clinical Research Ethics Committee of our hospital, and written informed consent was obtained from all patients before surgery. The patients were scheduled for a pulmonary lobectomy under thoracoscopy requiring SLV for at least 1 h under combined epidural/general anesthesia during August–November 2009. Exclusion criteria included risk of coexisting peripheral/cerebral vascular disease, hepatic/renal/cardiac dysfunction, a baseline mini mental state examination (MMSE) test <23, and severe obesity as shown by a body mass index ≥35. A total of 82 patients were screened for the study. Three patients did not give their informed consent, and 10 patients were excluded to the exclusion criteria.

Before general anesthesia, each patient was placed in a lateral decubitus position, and an epidural catheter was inserted at T6–T7 or T7–T8. After changing position, continuous monitoring of rSO_2 was started using an INVOS 5100 (Somanetics, Troy, MI, USA), with the value obtained at this time used as the baseline. Other monitoring included noninvasive arterial pressure, invasive arterial pressure, electrocardiogram, percutaneous oxygen saturation (SpO_2), and end-tidal CO_2.

Anesthesia was induced with propofol 2 mg/kg, fentanyl 2 μg/kg, and vecuronium 0.1 mg/kg. For airway management, a left-sided double-lumen tube (Broncho-cath; Tyco Healthcare, Argyle, Mansfield, MA, USA) was utilized. After securing the airway, an arterial pressure line was inserted and patient position was changed to lateral decubitus. Anesthesia was commenced with 1.0–1.5% sevoflurane, with the anesthetic depth maintained at 35–50 using a BIS monitor (v4.0; Aspect Medical System, Natick, MA, USA). The intraoperative inspired O_2 concentration (FiO_2) was 100%. SLV was started with a ventilatory volume of 8 ml/kg, positive end-expiratory pressure (PEEP) of 5 cmH_2O, and a ventilation rate of 12 breaths/min, which was adjusted based on intraoperative arterial blood gas (ABG) results.

We measured rSO_2 from before anesthesia induction until completion of SLV. In addition, ABG levels were measured every 30 min. For intraoperative hemodynamic and respiratory managements, systolic BP was maintained at ≥80 mmHg and $PaCO_2$ was maintained at 35–45 mmHg and PaO_2 at ≥100 mmHg. If systolic blood pressure was lower than 90 mmHg (not 80 mmHg), vasopressor agents were administered. For epidural analgesia, 0.05 ml/kg 0.75% ropivacaine was given, followed by a maintenance infusion of 0.2% ropivacaine at 2 ml/h. For additional anesthetic drugs, fentanyl 1 μg/kg by IV administration, 0.75% ropivacaine by epidural administration, and/or additional vecuronium 0.02 mg/kg were given as needed.

In cases of blood loss exceeding 20% of the whole circulating volume, the actual hemoglobin concentration was measured and homologous blood transfused if the hemoglobin concentration was <8 g/dl. After discontinuation of sevoflurane at the end of the procedure, the patient was confirmed to have recovered spontaneous ventilation and be able to open the eyes on verbal command and squeeze the observer's hand. At that time, extubation was performed and the patient transferred to a general surgical ward.

Postoperative analgesia consisted of 0.2% ropivacaine 2 ml/h by epidural administration, with additional diclofenac sodium suppositories of 50 mg each given as needed. The patients were followed daily after surgery until hospital discharge by the surgeons and ward nurses, who were blinded to the intraoperative management procedures and patient grouping.

Patient cognitive function was assessed using the MMSE on the day before surgery (baseline) and then repeated 4 days after surgery. The patients were classified into two groups; with (desaturation group, group D) and without (nondesaturation group, group N) cerebral desaturation during SLV. Cerebral desaturation was defined as a reduction of rSO_2 during SLV of less than 80% of the baseline value. An intergroup comparison was made between perioperative cognitive function findings (MMSE score change between baseline and 4th day after surgery). We also examined the correlation between the duration of desaturation during SLV and perioperative MMSE score changes in the group D patients. Statistical analyses were conducted using Student's *t* test, a chi-square test, and Pearson's correlation coefficient, with differences of $P < 0.05$ regarded as statistically significant.

Results

Of the 69 patients enrolled in the study, 17 had cerebral desaturation during SLV and were included in group D; the remaining 52 patients without cerebral desaturation during SLV were included in group N. In all cases, intraoperative systolic blood pressure was maintained at ≥80 mmHg. BIS scores were kept at 35–50, and there were no cases with desaturation ($SpO_2 < 98\%$, $PaO_2 < 100$ mmHg) during SLV. There were no significant differences in regard to perioperative data between the groups (Table 1). No patients in either group received an intraoperative blood transfusion.

Intraoperative rSO_2 data and MMSE scores are summarized in Table 2. Although baseline rSO_2 was not

Table 1 Perioperative data in both groups

Variable	N group ($n = 52$)	D group ($n = 17$)	P value
Gender (male/female)	38/14	10/7	0.268
Age (years)	66.3 ± 12.1	67.6 ± 7.60	0.615
Height (cm)	159 ± 8.25	160 ± 10.1	0.804
Weight (kg)	57.0 ± 9.89	59.7 ± 13.8	0.460
Hugh–Jones classification			
I, II (cases)	52	17	
III, IV (cases)	0	0	1.0
ASA class			
I, II (cases)	46	15	
III (cases)	6	2	0.980
Respiratory function			
$FEV_{1.0}$ (%)	77.5 ± 12.0	82.5 ± 14.7	0.222
%VC (%)	96.6 ± 19.1	106 ± 17.1	0.065
Operation time (min)	154 ± 61.4	187 ± 75.4	0.118
Anesthetic time (min)	204 ± 56.1	234 ± 75.1	0.110
Single lung ventilation time (min)	147 ± 59.3	174 ± 67.0	0.115
Infusion (ml)	1120 ± 481	1320 ± 437	0.126
Urine (ml)	165 ± 116	166 ± 134	0.977
Blood loss (ml)	121 ± 131	210 ± 221	0.129
Intraoperative minimum PaO_2 (mmHg)	223 ± 49.4	244 ± 21.8	0.509
Intraoperative minimum systolic blood pressure (mmHg)	87.0 ± 3.67	88.0 ± 4.42	0.601

Data are presented as mean ± SD

%VC percent of predicted volume capacity, *$FEV_{1.0}$* percent of predicted forced expiratory volume in 1 s

Table 2 Cerebral oxygen saturation and mini mental state examination score in both groups

Variable	N group ($n = 52$)	D group ($n = 17$)	P value
Baseline rSO_2 (%)	71.0 ± 7.46 (52 to 87)	70.9 ± 6.31 (58 to 82)	0.969
Minimum rSO_2 (%)	66.1 ± 6.61 (54 to 86)	52.3 ± 5.39 (43 to 60)	<0.05
Desaturation time (min)	0 (0)	105 ± 81.3 (10 to 262)	<0.05
MMSE baseline	28.4 ± 1.07 (26 to 30)	28.5 ± 1.23 (26 to 30)	0.780
MMSE at 4th day	27.6 ± 1.68 (23 to 30)	26.5 ± 2.32 (23 to 30)	0.084
MMSE changes from baseline	−0.808 ± 1.34 (−4 to 0)	−2.0 ± 1.96 (−5 to 0)	<0.05

Data are presented as mean ± SD

rSO_2 cerebral oxygen saturation, *MMSE* mini mental state examination score

significantly different between the groups, minimum rSO_2 was lower in group D. In addition, there were no significant differences between the MMSE score at the baseline and the score 4 days after surgery in each group. However, the MMSE score decrease from the baseline was significantly higher in group D as compared to that in group N ($P < 0.05$).

Results of correlation analysis between the duration of desaturation time and perioperative MMSE score changes in group D are shown in Fig. 1. The duration of desaturation time was significantly negatively correlated with MMSE score change from the baseline ($r^2 = 0.444$, $P < 0.05$).

Discussion

General anesthesia causes cardiovascular depression, which can be augmented, potentially exposing the patient to inadequate brain perfusion [16, 17] that might be related to postoperative cognitive dysfunction. Various studies have reported cases of postoperative cognitive dysfunction following general anesthesia [18]. In addition, Moller et al. [19] reported regarding long-term postoperative cognitive dysfunction in 1,218 surgical patients [International Study of Post-Operative Cognitive Dysfunction (ISPOCD) 1]. They found that postoperative cognitive dysfunction was present in 266 (25.8%) of their patients at 1 week after surgery and in 94 (9.9%) at 3 months after surgery. In a study of cardiac surgery cases, Newman et al. [20] found long-term postoperative cognitive dysfunction in 216 patients who underwent coronary artery bypass grafting (CABG). Among those, the incidence of cognitive decline was 53% at discharge, 36% at 6 weeks after surgery, 24% at 6 months after surgery, and 42% at 5 years after surgery.

Casati et al. [7] investigated the correlation between intraoperative cerebral desaturation and postoperative cognitive dysfunction in 122 patients undergoing major abdominal surgery. They found a significant correlation

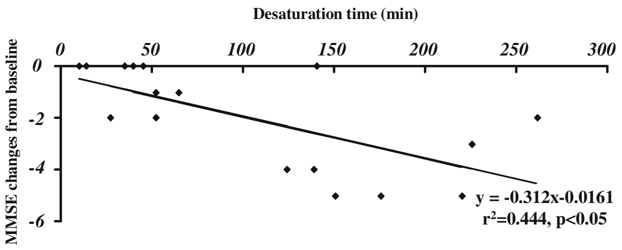

Fig. 1 Correlation analysis between the duration of desaturation time and perioperative mini mental state examination score (MMSE) score changes in group D. The duration of desaturation time was significantly negatively correlated with MMSE score change from baseline ($r^2 = 0.444$, $P < 0.05$)

between the area under the curve for rSO_2 readings less than 75% of the baseline value and postoperative decrease in MMSE score from preoperative values measured in 26 patients who had at least one episode of intraoperative cerebral desaturation ($r^2 = 0.26$, $P = 0.01$). The findings in the present study indicate that cerebral desaturation during SLV is a risk factor for postoperative cognitive dysfunction and are consistent with the results reported by Casati et al. [7].

The cause of the decrease in rSO_2 during SLV is unknown. However, Paquet et al. [21] showed significant correlations between mean rSO_2 and mean pulmonary artery pressure in cardiac surgery patients. Taking this into consideration, it is possible that increased pulmonary artery pressure caused by SLV [22] has effects on decrease of rSO_2. Increase in pulmonary artery pressure causes decrease in cardiac output. Therefore, we suppose that changes in cardiac output during SLV may cause decrease in rSO_2. The changes observed during thoracic surgery do not seem to be influenced by general anesthesia and the lateral position. Hemmerling et al. [15] applied cerebral oximetry in patients undergoing surgery in the lateral position without SLV, and none of the patients showed changes of rSO_2 of more than 10% throughout surgery. Our result showing that cerebral desaturation during SLV causes postoperative cognitive dysfunction suggests that such dysfunction could be prevented by intervention against decreased rSO_2 during SLV.

Slater et al. [23] reported that patients after cardiac surgery with prolonged rSO_2 desaturation had nearly threefold risk of increased length of stay ($P = 0.007$) and a significantly higher risk of early postoperative cognitive decline ($P = 0.024$).

As noted in those reports, postoperative cognitive dysfunction can be prevented by some type of intervention against decreased rSO_2 during SLV. Hong et al. [24] reported postoperative cognitive dysfunction could not be predicted with cerebral oximetry in patients undergoing valvular heart surgery. This finding is not consistent with our results. The present investigation was observational, and additional studies are needed to determine whether intervention against cerebral desaturation during SLV can prevent postoperative cognitive dysfunction and perioperative complications. The MMSE test has a ceiling effect when used for evaluation of cognitive function; as most patients obtain the maximum score, it is not suited to detect subtle cognitive decline [25]. Nevertheless, a reduction in MMSE scores in repeated testing suggests that a decline in cognitive dysfunction is occurring [26, 27]. Future studies that utilize more sensitive psychometric tests would be helpful to investigate the correlation between changes in rSO_2 during SLV and changes in perioperative cognitive function, as well as to establish an absolute safe threshold for rSO_2.

In conclusion, this study showed duration of cerebral desaturation time during SLV correlates with MMSE score. Additional studies are needed to determine whether intervention against cerebral desaturation during SLV can prevent postoperative cognitive dysfunction.

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