Effects of Moderate Hyperventilation on Jugular Bulb Gases under Propofol or Isoflurane Anesthesia during Supratentorial Craniotomy

Lan Meng¹, Shu-Qin Li², Nan Ji¹, Fang Luo¹

¹Department of Anesthesiology and Pain Management, Beijing Tiantan Hospital, Capital Medical University, Beijing 100050, China
²Department of Neurosurgery, Beijing Tiantan Hospital, Capital Medical University, Beijing 100050, China

Abstract

Background: The optimal ventilated status under total intravenous or inhalation anesthesia in neurosurgical patients with a supratentorial tumor has not been ascertained. The purpose of this study was to intraoperatively compare the effects of moderate hyperventilation on the jugular bulb oxygen saturation (SjO₂), cerebral oxygen extraction ratio (O₂ER), mean arterial blood pressure (MAP), and heart rate (HR) in patients with a supratentorial tumor under different anesthetic regimens.

Methods: Twenty adult patients suffered from supratentorial tumors were randomly assigned to receive a propofol infusion followed by isoflurane anesthesia after a 30-min stabilization period or isoflurane followed by propofol. The patients were randomized to one of the following two treatment sequences: hyperventilation followed by normoventilation or normoventilation followed by hyperventilation during isoflurane or propofol anesthesia, respectively. The ventilation and end-tidal CO₂ tension were maintained at a constant level for 20 min. Radial arterial and jugular bulb catheters were inserted for the blood gas sampling. At the end of each study period, we measured the change in the arterial and jugular bulb blood gases.

Results: The mean value of the jugular bulb oxygen saturation (SjO₂) significantly decreased, and the oxygen extraction ratio (O₂ER) significantly increased under propofol anesthesia during hyperventilation compared with those values under isoflurane anesthesia during moderate hyperventilation (SjO₂; t = 2.728, P = 0.011 or t = 3.504, P = 0.001; O₂ER; t = 2.484, P = 0.020 or t = 2.892, P = 0.009). The SjO₂ significantly decreased, and the O₂ER significantly increased under propofol anesthesia compared with those values under isoflurane anesthesia during moderate hyperventilation (SjO₂; t = 2.769, P = 0.012; O₂ER; t = 2.719, P = 0.013). In the study, no significant changes in the SjO₂ and the O₂ER were observed under propofol compared with those values under isoflurane during normoventilation.

Conclusions: Our results suggest that the optimal ventilated status under propofol or isoflurane anesthesia in neurosurgical patients varies. Hyperventilation under propofol anesthesia should be cautiously performed in neurosurgery to maintain an improved balance between the cerebral oxygen supply and demand.

Key words: Hyperventilation; Isoflurane; Neuroanesthesia; Propofol

Introduction

Neurosurgical anesthesia should aim at providing brain relaxation. Mild-to-moderate hyperventilation because of the perceived advantage of brain relaxation and a lack of apparent serious deleterious effects has normally been recommended in neuroanesthetic management.

Gelb et al.¹ recently observed that intraoperative hyperventilation improves the intraoperative status of the brain bulk, which was related to a decrease in intracranial pressure (ICP) in patients with supratentorial brain tumors. They proposed that the effect of hyperventilation on the brain bulk assessment or ICP was independent of the anesthetic used during craniotomy procedures.¹¹ Whether intraoperative hyperventilation influences jugular bulb gases under different anesthetic regimens during craniotomy procedures has not previously been studied.

Isoflurane, as other volatile anesthetics, are strong cerebral vasoconstrictors that increase the cerebral blood flow (CBF) and ICP. In contrast, intravenous anesthetics, such as propofol, are cerebral vasoconstrictors and suppress cerebral metabolism and reduce CBF and ICP. These two commonly used anesthetics were associated with similar operative conditions in patients undergoing a craniotomy.¹² A reduction in the arterial carbon dioxide tension (PaCO₂) leads to a rapid reduction in CBF.¹³ As one of the neuroanesthesia adjunct therapies, hyperventilation is as effective as cerebral fluid drainage.¹⁴ Thus, we considered that the optimal ventilated status under inhalation anesthesia or intravenous anesthesia should be detected.

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Address for correspondence: Prof. Fang Luo, Department of Anesthesiology and Pain Management, Beijing Tiantan Hospital, Capital Medical University, Dongcheng District, Beijing 100050, China
E-Mail: 13611326978@163.com
We conducted a randomized trial to evaluate the efficacy of moderate hyperventilation in patients undergoing craniotomy for excision of supratentorial brain tumors during isoflurane or propofol anesthesia. Our hypothesis was that the optimal ventilated status under total intravenous (propofol) or inhalation (isoflurane) anesthesia in neurosurgical patients with a supratentorial tumor should potentially be different, under propofol anesthesia the PaCO₂ should be adjusted to a relatively higher level than that under isoflurane anesthesia. Thus, we measured the jugular bulb gases during propofol or isoflurane anesthesia in 20 patients undergoing a craniotomy for removal of a brain tumor and clarified the effects of hyperventilation on those variables. The purpose of this study was to intraoperatively compare the effects of moderate hyperventilation on the jugular bulb oxygen saturation (SjO₂), cerebral oxygen extraction ratio (O₂ER), mean arterial blood pressure (MAP), and heart rate (HR) in patients with a supratentorial tumor under different anesthetic regimens.

**Methods**

This study was approved by the Medical Ethics Committee of Beijing Tiantan Hospital affiliated to Capital Medical University (No. kylw-2012-001-02), and informed consent was obtained from the patients or their families.

**Inclusion criteria**

Aged 18–70 years, American Society of Anaesthesiologists I or II patients (both genders), body mass index of 20–24 kg/m² suffered from supratentorial tumors undergoing an elective craniotomy. Without comorbidities such as heart, lung, hepatic or renal disease, or acute inflammatory/infectious processes.

**Exclusion criteria**

Patients with abnormal results of blood routine test, hepatorenal function, blood coagulation function, electrocardiogram, or chest X-ray examination were excluded from this study.

The patients were fasted about 8 h, and the operations were performed under general anesthesia. Anesthesia was induced with 2 mg/kg of propofol and 4 μg/kg of fentanyl, and tracheal intubation was performed, facilitated with vecuronium at 100 μg/kg intravenously. Surgery was begun after insertion of a 22-gauze catheter in the radial arterial and a 16-gauze single lumen catheter (ES-04301, Arrow International, Inc., Germany) in the internal jugular venous (IJV) bulb. Before retrograde IJV cannulation, the length from the puncture point to the mastoid process was identified as the landmark for removal of a brain tumor and clarified the effects of hyperventilation on those variables. The purpose of this study was to intraoperatively compare the effects of moderate hyperventilation on the jugular bulb oxygen saturation (SjO₂), cerebral oxygen extraction ratio (O₂ER), mean arterial blood pressure (MAP), and heart rate (HR) in patients with a supratentorial tumor under different anesthetic regimens.

**Results**

Twenty patients (12 male, 8 female; age range 21–59 years; weight range 53–87 kg) were included in this study. All the
Table 1 shows the effects of moderate hyperventilation on the jugular bulb and arterial gases parameters during propofol or isoflurane anesthesia in patients undergoing a selective craniotomy for a supratentorial tumor. The mean PaCO$_2$ levels during hyperventilation under isoflurane or propofol anesthesia were 27.5 ± 2.3 mmHg and 26.9 ± 1.7 mmHg, respectively. The mean value of the SjO$_2$ significantly decreased, and the O$_2$ER significantly increased under isoflurane or propofol anesthesia during hyperventilation compared with those during normoventilation (SjO$_2$: t = –2.728, P = 0.011 or t = –3.504, P = 0.001; O$_2$ER: t = 2.484, P = 0.020 or t = 2.892, P = 0.009). The SjO$_2$ significantly decreased, and the O$_2$ER significantly increased under propofol anesthesia compared with those under isoflurane anesthesia during moderate hyperventilation (SjO$_2$: t = –2.769, P = 0.012; O$_2$ER: t = 2.719, P = 0.013). No significant changes in the SjO$_2$ and the O$_2$ER were observed under propofol anesthesia compared with the changes under isoflurane during normoventilation in the study.

Blood pressure showed a tendency of decrease from propofol anesthesia to isoflurane anesthesia, without significance. No significant HR changes were found in our study.

### Discussion

Hyperventilation has been an integral part of neuroanesthesia for 50 years. Although more recent guidelines discourage the use of long-term hyperventilation in severe head injury patients, hyperventilation to some degree is typically used to facilitate intracranial surgery.$^{[8]}$ No previous study has included a formal evaluation of whether the optimal ventilated status is identical during volatile anesthesia or intravenous anesthesia in craniotomy. For a better understanding of ventilation management in neurosurgical anesthesia, the jugular bulb gases were measured under isoflurane anesthesia in comparison with the total intravenous anesthesia (TIVA) using propofol, during which patients were ventilated to maintain moderate hyperventilation followed by normoventilation or normoventilation followed by hyperventilation. Our null hypothesis was that because hyperventilation, which has been recommended for anesthetic management during craniotomy, decreases the CBF, the cerebral oxygen balance could deteriorate under propofol anesthesia, a cerebral vasoconstrictor, compared with that under isoflurane anesthesia, a cerebral vasodilator, during hyperventilation in neurosurgery.

As one of the indexes of ischemia, the SjO$_2$ monitors the adequacy of cerebral perfusion, reflecting the ratio between the CBF and cerebral metabolism.$^{[9]}$ The balance between the cerebral oxygen supply and demand is a significant problem requiring unique attention. First, our results found that no significant changes in the SjO$_2$ and O$_2$ER were observed under propofol anesthesia compared with isoflurane during normoventilation in the study. Sato et al.$^{[9]}$ reported that little difference in cerebral metabolic rate of oxygen (CMRO$_2$) is hypothesized to exist between anesthesia by 0.9% isoflurane and by 8 mg·kg$^{-1}$·h$^{-1}$ propofol. Because the anesthetics used in our study was delivered at the above doses, CMRO$_2$ is hypothesized to be approximately identical in anesthesia by isoflurane or propofol in our study, and the results suggested that the balance between isoflurane and propofol under normoventilation showed no significant difference.

Second, our results demonstrated that the SjO$_2$ mean value significantly decreased and the O$_2$ER significantly increased during hyperventilation compared with those during normoventilation, regardless of whether isoflurane or propofol anesthesia was administered. Although hyperventilation might improve the operating condition, concern remains that hyperventilation might exacerbate a preexisting impairment of CBF and metabolism and lead to deterioration from cerebral ischemia in traumatic brain injury patients.$^{[8]}$ Chan et al.$^{[8]}$ reported that SjO$_2$ values of 40–45% were related to cerebral metabolic failure and secondary brain damage in patients suffering from brain injury. Coles et al.$^{[8]}$ suggested that a brief hyperventilation,
which decreases CBF, quickly increased the volume of severely hyperperfused cerebral tissue within the injured brain. The risk of intraoperative hyperventilation during a craniotomy has not been fully determined. Previous studies in neurosurgical patients have proposed that the SjO₂ decreased after hyperventilation and during mild hypothermia with up to 50% of patients having a SjO₂ <50%.[11] In our study, the patients underwent moderate hyperventilation, and the mean values of SjO₂ were 70.1% ± 7.7% and 58.9% ± 12.7% in the isoflurane and propofol groups, respectively. Because the oxygen consumption of the brain was constant, the decrease of the SjO₂ demonstrated the decrease of CBF globally from normal ventilation to hyperventilation.

Third, the SjO₂ significantly decreased, and the O₂ER significantly increased under propofol anesthesia compared with those levels under isoflurane anesthesia in cases in which the patients were hyperventilated. The results of our study suggested that the balance of the cerebral supply and demand under anesthesia by 0.9% isoflurane inhalation was better than that under anesthesia by 8 mg·kg⁻¹·h⁻¹ propofol administration under moderate hyperventilation. Recent evidence suggested that compared with inhalational anesthetics, propofol could deteriorate the cerebral oxygen balance which is more frequently related to lactic acidosis and hypertension in intracranial surgery.[12,13] Because propofol is hypothesized to suppress the cerebral metabolism and cause a decrease in the CBF if accompanied with hyperventilation, which decreases the CBF, the potential for causing the SjO₂ to fall below the critical threshold is greater than that for inhalational anesthetics. Although we did not find propofol-induced metabolic disturbances, our results suggested that the isoflurane group maintained a better balance of cerebral oxygen than that of the propofol group in the cases in which hyperventilation was performed. Although clinical and basic studies found that propofol was better than isoflurane in many respects,[14,15] concerns remain regarding the propofol-based regimen in neuroanesthesia.

Our results suggested that propofol, compared with isoflurane, could decrease the SjO₂ and increase the O₂ER only under hyperventilation, whereas under normoventilation, propofol could not further deteriorate the cerebral oxygen balance. The results are in agreement with a recent study, which found that hypocapnia caused by moderate hyperventilation in patients undergoing intravenous anesthesia significantly reduced SjO₂.[16]

Because propofol contracts and isoflurane dilates the cerebral vessels, the degree of hyperventilation in craniotomy should consider the anesthetic regimen. The SjO₂ under propofol anesthesia decreased 21%–58.9% ± 12.7%, whereas under isoflurane anesthesia, the SjO₂ decreased 10%–70.1% ± 7.7% from normoventilation to hyperventilation. According to our results, in the neurosurgery cases in which hyperventilation is performed under TIVA such as propofol, the SjO₂ should be adjusted to a relatively higher level than that under inhalation anesthesia to maintain an improved balance between the cerebral oxygen supply and demand. Although the outcome was not assessed in this article, the results of this study indicate that it is possible that hyperventilation under propofol anesthesia should be cautiously performed to maintain an improved balance between the cerebral oxygen supply and demand.

Based on this study, we suggest that the optimal ventilated status under total intravenous or inhalation anesthesia in neurosurgical patients should vary. Neurosurgery is typically performed under balanced anesthesia using volatile anesthetics and intravenous analgesics. Until now, the optimal PaCO₂ level administered in neurosurgery patients under isoflurane, propofol anesthesia or balance anesthesia has not been fully and clearly determined or standardized. Although an overall CBF decrease under propofol anesthesia with moderate hyperventilation was suggested by the decrease in the SjO₂, whether the blood flow might decrease in some areas is not clear. To verify these preliminary results, substantially more data are required. There were several other limitations, for example, we did not observe the clinical prognostic data in this study. Further research should be performed to investigate the effect of different degree of hyperventilation under propofol or isoflurane anesthesia on patients’ prognostic situations in the future.

In conclusion, the optimal ventilated status under propofol or isoflurane anesthesia in neurosurgical patients varies. Hyperventilation under propofol anesthesia should be cautiously performed in neurosurgery to maintain an improved balance between the cerebral oxygen supply and demand.

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