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Original contribution

Nitrogen accumulation during closed circuit anesthesia depends on the type of surgery☆

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Abstract
Study Objective: The aim of this study is to test the hypothesis that the amount of nitrogen that accumulates within the closed breathing system would be greater during open abdominal surgery than during superficial surgery with small wounds.
Design: Prospective, comparative study.
Setting: Operating rooms of a university hospital.
Patients: Fourteen American Society of Anesthesiologists physical status I and II adult patients scheduled for abdominal surgery (n = 7) or tympanoplasty (n = 7).
Interventions: After induction of anesthesia and endotracheal intubation, the patients were denitrogenated for 30 minutes using 100% oxygen at a fresh gas flow of 10 L/min. The breathing system was then closed and patients were anesthetized using 60% xenon in oxygen, supplemented with epidural anesthesia in the abdominal surgery group and sevoflurane in the tympanoplasty group.
Measurements: Nitrogen concentration in the breathing system was determined by gas chromatography immediately before and 2 hours after the breathing system was closed.
Main Results: The median (range) increase in nitrogen concentration during the 2-hour period of closed circuit anesthesia was greater in the abdominal surgery patients than in the tympanoplasty patients (6.5% [4.0%-10.2%] vs 2.5% [1.4%-8.4%], $P = 0.035$, Mann-Whitney U test).

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Conclusions: The amount of nitrogen accumulation during closed circuit anesthesia is greater during open abdominal surgery than in superficial surgery such as tympanoplasty. We postulate that during open abdominal surgery, nitrogen in the ambient air enters the body across the peritoneum and then diffuses into the alveoli to be exhaled.

1. Introduction

During closed circuit anesthesia, nitrogen accumulates within the closed breathing system because it is released from the body tissues that had been equilibrated with the ambient air [1]. This is of particular concern when anesthetics with high minimum alveolar concentrations (MACs) such as nitrous oxide (MAC = 104% [2]) and xenon (MAC = 71% [3]) are used because nitrogen could dilute the anesthetics and oxygen in the inspired gas to unacceptably low concentrations.

Although the amount of nitrogen that accumulates within the closed breathing system was quantified previously [1,4], it remains unknown whether it is influenced by the type of surgery. We hypothesized that open abdominal surgery would be associated with a larger amount of nitrogen accumulation than superficial surgery with its small surgical wounds, because during open abdominal surgery, nitrogen in the ambient air would enter the body through the thin peritoneum and then diffuse out into the exhaled breaths. In fact, the peritoneum represents a relatively ineffective barrier against diffusion of various gases [5]. To test this hypothesis, we compared the amount of nitrogen within the closed breathing system during open abdominal surgery with that during middle ear surgery.

2. Materials and methods

2.1. Patients

The Institutional Human Studies Committee of Teikyo University approved this study. After obtaining their informed consent, we investigated 14 adult American Society of Anesthesiologists (ASA) physical status I and II patients, aged 42 to 72 years, who were scheduled for open abdominal surgery (n = 7; gastrectomy, hemicolectomy, sigmoidectomy, anterior resection of the rectum) or tympanoplasty (n = 7) lasting more than 3 hours.

2.2. Anesthesia apparatus

The breathing system of the VIP 100 anesthesia machine (IMI, Saitama, Japan) has a gas space of approximately 5 L when our standard breathing circuit made of polyethylene is attached and a CO_2 canister is 80% filled with soda lime. We confirmed that the leak from the system was less than 30 mL/min at a static pressure of 20 cm H_2O before induction of anesthesia in each patient. The end-tidal concentrations of CO_2 and sevoflurane were measured by a Dräger PM8050 anesthesia monitor (Dräger, Lübeck, Germany), and the concentration of xenon was measured by a xenon analyzer (Anzai Medical, Tokyo, Japan). All the gases sampled by these analyzers were returned to the system. The xenon analyzer introduces no foreign gases into the system. The Dräger PM8050 anesthesia monitor introduces approximately 100 mL of the ambient air during calibration, which automatically occurs approximately every 15 minutes if the monitor is used continuously. To avoid this situation, the monitor was maintained in the stand-by state once the breathing system was closed and then turned on only intermittently.

2.3. Anesthesia protocol

No premedication was given. Before induction of anesthesia, the patients were preoxygenated using oxygen at 10 L/min via a face mask for 3 minutes. Anesthesia was induced using propofol 2.5 mg/kg and vecuronium 10 mg administered intravenously, and the trachea was intubated with a cuffed endotracheal tube. Using a stethoscope on the neck, we confirmed that there was no audible air leak around the cuff when the airway pressure was kept at 20 cm H_2O for 3 seconds. The patients' lungs were ventilated for 30 more minutes using a 10-L/min flow of oxygen for thorough denitrogenation. Anesthesia during this period was maintained using either propofol infusion (abdominal surgery group) or sevoflurane (tympanoplasty group). Surgery was started 5 to 10 minutes before the end of this 30-minute denitrogenation period. Then, the breathing system was closed and anesthesia was maintained using 60% xenon in oxygen. The volume of the breathing system was kept constant by adjusting the fresh gas flows of xenon and oxygen so that the top of the upright ventilator bellows came back to a constant position below the ceiling of the bellows case at each end expiration. A positive end-expiratory pressure of 3 cm H_2O was continuously applied to minimize the possible leak-in of ambient air.

The tympanoplasty patients received morphine 10 mg IV before skin incision, and the planned site for skin incision was infiltrated with 1% lidocaine. Supplemental sevoflurane was also administered in these patients. In the abdominal surgery patients, general anesthesia was maintained only with xenon and was supplemented by 1% to 2% mepivacaine administered via an epidural catheter that had been placed before induction of anesthesia. The doses of sevoflurane and epidural mepivacaine were adjusted to maintain blood pressure and heart rate within 20% of preoperative values.