The effect of heat-moisture exchanger and closed-circuit technique on airway climate during desflurane anesthesia

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Abstract

Purpose. We assessed whether closed-circuit anesthesia (CCA) could provide a more favorable airway climate than semiclosed anesthesia (SCA), and we also determined the beneficial effect of heat moisture exchangers (HMEs) on the preservation of airway climate during desflurane anesthesia.

Methods. Forty patients scheduled for colorectal surgery \((n = 10\) for each group) were randomized to receive a fresh gas flow of 250 or 3000 ml·min\(^{-1}\) with or without HMEs. Anesthesia was maintained by adjusting the inspired concentration of 6% desflurane. Absolute moisture and temperature of inspired gases were measured as the baseline value first at 5 min after tracheal intubation, and then at 10, 20, 45, 60, 90, and 120 min after the induction of anesthesia.

Results. At 120 min, the inspiratory humidity and temperature were higher in CCA than in SCA. The HME led to major improvements of the humidity (from 22.1 to 35.7 mg H\(_2\)O·l\(^{-1}\)) and temperature (from 23.6°C to 31.5°C) of anesthetic gases in the CCA group.

Conclusion. CCA was much more advantageous than SCA for maintaining the patient’s airway climate during the 2-h study. The beneficial effect of HME on the airway climate should be emphasized, especially in patients undergoing general anesthesia.

Key words Closed-circuit anesthesia · Semi-closed anesthesia · Airway humidity and temperature · Heat moisture exchangers (HMEs)

Introduction

Inadequate humidification of inspired gases occurs most obviously when a patient is ventilated with dry, compressed gases without additional humidification via an endotracheal tube [1]. A previous study indicated that lower fresh-gas flow (1000 ml·min\(^{-1}\)) provided better preservation of airway humidity than higher fresh-gas flow (6000 ml·min\(^{-1}\)) in intubated patients [2]. To the best of our knowledge, the higher gas flow leads to considerable loss of water and heat from the respiratory tract as a result of vaporization of water [3–5]. Conversely, the lower gas flow leads to less loss of water and heat. According to Bengtson et al. [6], the use of a circle system with a fresh-gas flow of 500 ml·min\(^{-1}\) resulted in higher inspiratory gas temperature and humidity than a nonrebreathing system.

In the history of clinical anesthesia, closed-circuit anesthesia (CCA) has been practiced in the clinical arena for decades [7–10]. Compared to conventional higher fresh-gas flow anesthesia, the use of a closed-circuit or minimal low flow (flow rate, \(\leq 500\) ml·min\(^{-1}\)) technique has become increasingly popular in anesthesia practice because of several advantages, such as lower consumption of inhalational anesthetics, better hemodynamic stability, favorable skin blood flow improving postoperative recovery, and less environmental contamination with inhalational anesthetics [7–9, 11–13]. In considering the integrity of mucociliary function, recent studies have begun to elucidate the potential benefit of minimal low-flow anesthesia on a patient’s airway climate. However little work has been done to evaluate the efficacy of CCA in preventing loss of airway temperature and moisture during general anesthesia [14,15]. The popular use of heat and moisture exchangers (HMEs) has been proven to improve airway climate. However, it is still controversial whether an HME in combination with CCA can possibly demonstrate added or synergistic effects on the preservation of airway heat and moisture during desflurane anesthesia.

The above consideration prompted us to investigate the different levels of airway humidity and temperature in patients who received either CCA or semiclosed anesthesia (SCA) for a 2-h period of study. We also evaluated the effectiveness of heat and moisture exchangers (HMEs) in improving airway temperature...
and humidity of respiratory gas in the presence of CCA or SCA during the first 2 h of CCA or SCA.

Patients, materials, and methods

The study was approved by the institutional review board, and written informed consent was also obtained from each patient. The study population consisted of 40 adult patients, American Society of Anesthesiologists (ASA) physical status 1 and 2, selectively scheduled for elective colorectal surgery with an anticipated anesthesia time of 2 h or longer. Patients with signs and symptoms of pulmonary or cardiovascular disease were excluded from the study. In the practice of SCA, a range of 2000 to 3000 ml·min⁻¹ fresh-gas flow has been applied popularly in clinical anesthesia. Thus, we chose a 3000-ml fresh-gas flow for the SCA group. After induction, 6% desflurane in high O₂ flow (3000 ml·min⁻¹) was given for 10 min to all patients (both groups) initially to wash desflurane in the functional residual capacity of both lungs and the breathing circuit. For the CCA group, O₂ flow was reduced to 250 ml·min⁻¹ after 10 min of high-flow wash-in period, while the vaporizer setting of desflurane was set at 10% for the maintenance of anesthesia [10]. Patients were randomly assigned to receive fresh-gas flows of either 250 ml·min⁻¹ (CCA) or 3000 ml·min⁻¹ (SCA). Twenty patients were allocated to SCA either with HME (n = 10) or without HME (n = 10), and the other 20 were allocated to CCA (fresh-gas flow about 250 ml·min⁻¹) either with HME (n = 10) or without HME (n = 10).

All patients were premedicated with midazolam 2 mg intravenously 10 min prior to their arrival at the operating room. Anesthesia was induced by the administration of 100% oxygen for 3 min, followed by 2 µg·kg⁻¹ of fentanyl and 3–4 mg·kg⁻¹ of thiopental. Then intubation was facilitated by 1.0–1.25 mg·kg⁻¹ of succinylcholine with pancuronium priming (0.015 mg·kg⁻¹), and a maintenance dose, 0.045 mg·kg⁻¹·h⁻¹ pancuronium, was given in the course of 2-h desflurane anesthesia. Ventilation of the lungs was manually assisted with 100% oxygen via a breathing circuit until tracheal intubation was performed. A Datex-Ohmeda anesthetic machine (AS/4; Datex, Helsinki, Finland), used with soda lime as a CO₂ absorber in the anesthesia system, was connected. A Datex-Ohmeda anesthetic machine (AS/4; Datex-Ohmeda, Helsinki, Finland) was set up either at approximately 10% of desflurane in CCA or 6% of desflurane in SCA for the maintenance of anesthesia after 10 min of tracheal intubation. A humidity and temperature sensor system (Gibeck Respiration, Upplands Vaesby, Sweden) was normally placed between the tracheal tube and the Y-piece of the breathing system. Whenever HME (Gibeck Humid-Vent 2S; Gibeck; Upplands Vaesby, Sweden) is applied, the tracheal tube and the system need to be connected. The hemodynamic variables and inspiratory airway humidity and temperature were monitored and recorded at scheduled points of 5, 10, 20, 30, 45, 60, 90, and 120 min after tracheal intubation. The humidity sensor system had a sampling rate of 21 times per second and a sampling time of 17 s. Data were measured every 5–20 min during the anesthesia. The stated system accuracy was ± 2% relative humidity and ±1°C. The response times were 1.4 s for a 90% relative humidity response and less than 150 ms for a 90% temperature response.

During anesthesia, routine monitoring included electrocardiogram, heart rate, and noninvasive mean arterial blood pressure (MABP), and pulse oximetry with a Datex AS/3 anesthesia monitor. The inspired oxygen concentration, end-tidal (ET) CO₂, and inspiratory and expiratory concentrations of desflurane were monitored at 1-min intervals during the first 10 min and thereafter at 5-min intervals throughout the study. Gases were sampled at the Y-piece and analyzed gas was returned to a port fitted into the CO₂ absorber. Prior to anesthetic administration, fresh soda lime (Absorber; Anmedic, Vallentuna, Sweden; 15% water) was used. The lungs were mechanically ventilated to maintain ETCO₂ between 35 and 42 mm Hg. The ventilatory rate was 10 min⁻¹, and ratio of time in each respiratory cycle (inspiratory to expiratory) was 1:2. Additional intravenous fentanyl and ephedrine were indicated if the blood pressure and heart rate fluctuated by more than 20% of baseline values at 5 min after tracheal intubation. A nasopharyngeal thermistor was used to measure body temperature, which was actively maintained at 35.5°C–37.5°C by a warmer during the study.

Data values were expressed as means (SEM). To determine intergroup differences, one way analysis of variance (ANOVA) was used. The Tukey test was used for post-hoc comparisons. Nonparametric values were compared using the χ² test. P values of less than 0.05 were considered statistically significant.

Results

The demographic profiles of the patients in the four groups were similar (Table 1). The baselines values for temperature and the relative humidity were also comparable between the groups. The profiles of inspiratory humidity and temperature for the four groups (CCA,