New equipment to prevent carbon dioxide rebreathing during eye surgery under retrobulbar anaesthesia

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Abstract

Background—Carbon dioxide concentration under ophthalmic drapes increases during eye surgery under local anaesthesia. A new prototype has been designed which combines continuous suction of carbon dioxide enriched air and continuous oxygen insufflation under ophthalmic drapes to prevent carbon dioxide accumulation in spontaneously breathing patients undergoing cataract surgery.

Methods—In a prospective randomised single blind study the effectiveness of this new prototype was examined in 50 unpremedicated elderly patients. In 25 patients suction was applied under ophthalmic drapes, whereas in the other 25 patients no suction was used. In all cases oxygen was insufflated under the drapes at a constant flow of 2 l/min. Carbon dioxide concentration in the ambient air surrounding the patient's head under ophthalmic drapes, transcutaneous partial pressure of carbon dioxide, respiratory rate, and oxygen saturation were measured.

Results—Carbon dioxide concentration under the drapes, transcutaneous partial pressure of carbon dioxide, and respiratory rate remained unchanged in the suction group, whereas in the non-suction group these values increased significantly. Oxygen saturation rose significantly in both groups without differences between the groups.

Conclusion—Application of this new prototype for continuous aspiration of carbon dioxide enriched air prevents carbon dioxide rebreathing and subsequent hypercapnia associated with an elevated respiratory rate. This new equipment may therefore be useful in patients undergoing ophthalmic surgery under retrobulbar anaesthesia.

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An intraoperative increase in arterial partial pressure of carbon dioxide due to rebreathing of exhaled carbon dioxide under ophthalmic drapes has been reported in patients undergoing ophthalmic surgery under retrobulbar anaesthesia.^{1,2} Carbon dioxide exhaled by the patient escapes only partially through ophthalmic drapes and hence results in an increase in carbon dioxide in the ambient air around the patient's head.²⁻⁶ High oxygen flows with and without suction have been described for reducing the carbon dioxide concentration under the

drapes using hoops and suction with particularly high fresh gas flows of 5-10 l/min.^{4,6} Technical problems found when using similar previously designed equipment^{4,6} (for example, difficult placement of the surgical microscope) prompted us to design a new prototype combining both suction and oxygen insufflation.

The aim of the present study was to examine the effectiveness of this new prototype in spontaneously breathing geriatric patients undergoing cataract surgery.

Materials and methods

The university ethics committee approved the study protocol. After receiving written informed consent, 50 unpremedicated patients (ASA 1-3) scheduled for cataract surgery under retrobulbar anaesthesia were examined in a randomised, single blind manner.

Patients with pre-existing pulmonary disease, neurological or psychiatric disorders, and severe cardiovascular, renal, or hepatic dysfunction, or patients needing intraoperative sedation or additional opiate analgesia were excluded from the study.

EQUIPMENT FOR SUCTION AND OXYGEN INSUFFLATION

The design of the new equipment and its position during surgery are shown in Figure 1. One end of a flexible 750 mm long plastic tube (12 mm inner diameter) consisting of 36 ball and socket elements (Lock Line, Lock Wood Productions, Lake Oswego, OR, USA) is attached to a metal connecting tube rigidly fixed to a rod clamped to a bar along the operating table. Inserted in the other end of the tube is a Y connector, and its two free ends each hold a transparent 120 mm long curved suction tube (12 mm ID) (Fig 1, B). The underside of each of these transparent tubes has a row of three apertures, 6 mm in diameter and 25 mm apart, and the end of each tube is closed with a plug. As shown in Figure 1, this part of the equipment is placed over the chin of the patient. Suction is performed at 800 mbars using a conventional suction device for anaesthetic gas. A small flexible plastic tube (4 mm ID) taped along the ball and socket elements provides oxygen supply (Fig 1, C). The tip of a sampling tube fixed to the underside of the Y piece is used to measure the concentration of carbon dioxide and oxygen under the drapes (Fig 1, A).

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Figure 1 Design and position of the prototype during surgery: probe for measuring carbon dioxide and oxygen concentration under the drapes (A), suction tubes (B), and oxygen probe (C) in a model without drapes.

STUDY DESIGN

Patients were randomly allocated to one of two study groups comprising 25 people each. While in one group patients were provided with suction and oxygen supply (2 l/min), the other group received only oxygen insufflation with 2 l/min. Heart rate (HR), peripheral oxygen saturation (SpO_2) and non-invasive mean arterial blood pressure (MAP) were continuously measured using a standardised monitor (Cardiocard, Datex, Helsinki, Finland).

After the ophthalmic surgeon induced retrobulbar anaesthesia, the study equipment was placed over the chin of the patient as shown in Figure 1. A large drape was placed over each patient, fully covering him except for the head. The patient's head was covered with a sterile cotton drape having a central, circular aperture (80 mm in diameter) over the eye to be operated. An ophthalmic drape (Steri Drape 1024, 3M) measuring 460 × 390 mm was placed over the cotton drape. Immediately after draping the patient's head oxygen 2 l/min was continuously insufflated through the oxygen tube in each group. In the suction group the ambient air was also suctioned off during the entire course of the operation.

As soon as the operation was completed, the drapes were removed from the head and the suction equipment withdrawn.

VARIABLES MEASURED

- Carbon dioxide concentration in the ambient air surrounding the patient's head under the drapes (p_{CO_2}): Carbon dioxide was measured with

an anaesthesia monitor (Cardiocard Datex, Helsinki, Finland). To prevent variations in the carbon dioxide curves caused by the patient's breathing, a collection reservoir (150 ml) was placed in the line of the gas sampling tube.

- Transcutaneous partial pressure of carbon dioxide (p_{tCO_2}) measurement: (TCM 3 Monitor, Radiometer, Copenhagen, Denmark). Calibration of the measuring electrode was performed at 43°C using a standardised carbon dioxide/oxygen/nitrogen gas mixture (5% carbon dioxide, 20.9% oxygen, nitrogen balanced). The electrode for p_{tCO_2} measurements was placed on the left lateral thorax at the level of the fourth intercostal space.
- Respiratory rate (RR): Thoracic excursions were counted for a period of 1 minute at each measurement time.
- Heart rate (HR), non-invasive mean arterial blood pressure (MAP), and peripheral oxygen saturation by pulse oxymetry (SpO_2) were measured with an anaesthesia monitor (Cardiocard, Datex, Helsinki, Finland).

Baseline values were obtained immediately before the patient's head was draped. Additional measurements were taken at 3, 6, 9, 12, 15 minutes after draping the head, and then at 5 minute intervals until the end of surgery (drape removed from head) as well as 5 minutes after complete removal of the remaining drapes.

STATISTICAL ANALYSIS

For statistical analysis SPSS 7.5 (SPSS Inc, Chicago, IL, USA) was used. Demographic data were compared by using the unpaired *t* test. Overall effects within and between the groups were evaluated by repeated measurement analysis of variance (ANOVA). In the case of significant differences, further comparisons between groups at individual times were made with the unpaired two tailed *t* test. $p \leq 0.05$ was considered statistically significant. The Bonferroni test was used for correction of multiple comparison. Results are expressed as mean (SD).

Results

Forty eight patients were enrolled in the study. Two patients were excluded from data analysis because one needed additional opiate analgesia and the other developed intraoperative psychic disorders.

Demographic data and baseline measurements were similar in both groups (Table 1). During the investigative period no significant differences in MAP and HR were measured either within or between the groups. Three minutes after starting oxygen insufflation the SpO_2 values rose significantly in both groups without differences between the groups (suction group: 95.6 % (0.9) to 97.9 % (1.1), $p \leq 0.0001$; non-suction group: 95.3 % (0.9) to 97.5 % (0.9), $p = 0.0012$).

Covering the patient's head increased the ambient carbon dioxide concentration (p_{CO_2}) in the non-suction group when compared with the suction group from five-sixfold at 3 minutes to 14-fold at 30 minutes ($p \leq 0.001$),

Table 1 Demographic data and baseline values expressed in numbers and mean (SD). Baseline values were measured before draping

Demographics	S group	NS group	Baseline values	S group	NS group
Sex (F/M)	12/12	13/11	p_{tCO_2} (mm Hg)	43.4 (4.4)	42.5 (4.6)
Age (years)	72.8 (7.1)	73.16 (7.2)	RR (/min)	15.2 (2.1)	14.5 (1.7)
Body weight (kg)	69.14 (11.5)	75.7 (13.3)	SpO_2 (%)	95.6 (0.9)	95.3 (0.9)
Height (cm)	166.6 (7.2)	168.8 (9.3)	MAP (mm Hg)	104.8 (11.1)	105.3 (12.3)
ASA physical status	2.0 (0.3)	2.0 (0.3)	HR (beats/min)	66.2 (12.5)	70.0 (13.2)

S group = continuous suction under the drapes; NS group = no suction under the drapes; p_{tCO_2} = partial pressure of carbon dioxide; RR = respiratory rate; SpO_2 = peripheral oxygen saturation; MAP = mean arterial blood pressure; HR = heart rate.

Figure 2 Delta values (mean (SD)) of carbon dioxide partial pressure (p_{CO_2}) under the drapes during cataract surgery under retrobulbar anaesthesia. Baseline values (BL) were measured before draping. Further values were measured after covering the head. Last measurement (post) was taken 5 minutes after removal of the drapes. * $p < 0.05$, comparing the suction group and the non-suction group (unpaired t test).

Figure 3 Delta values (mean (SD)) of transcutaneous measured pressure of carbon dioxide (p_{tCO_2}) during cataract surgery under retrobulbar anaesthesia. Baseline values (BL) were measured before draping. Further values were measured after covering the head. Last measurement (post) was taken 5 minutes after removal of the drapes. * $p < 0.05$, comparing the suction group and the non-suction group (unpaired t test).

Figure 4 Delta values (mean (SD)) of respiratory rate (RR) during cataract surgery under retrobulbar anaesthesia. Baseline values (BL) were measured before draping. Further values were measured after covering the head. Last measurement (post) was taken 5 minutes after removal of the drapes. * $p < 0.05$, comparing the suction group and the non-suction group (unpaired t test).

causing a significant increase in RR and p_{tCO_2} in the non-suction group (Fig 2). RR and p_{tCO_2} remained constant in the suction group throughout the investigative period. In the non-suction group p_{tCO_2} values (Fig 3) and RR (Fig 4) increased significantly immediately after covering the patient's head and rose in the further course of the operation. In both groups RR, p_{CO_2} , and p_{tCO_2} values again approximated the baseline values 5 minutes after removal of the drapes.

Discussion

The results of the present study show that our new device, which is easy to handle, prevents rebreathing of carbon dioxide in spontaneously breathing patients undergoing intraocular surgery and the subsequent rise in p_{tCO_2} and respiratory rate owing to the rebreathing of carbon dioxide.

In the clinical use of previously described equipment for continuous suction and oxygen insufflation⁴⁻⁶ we observed several problems. In some cases the surgeons had trouble placing the surgical microscope and in other cases the nursing staff complained about being hindered when passing the surgical instruments to the surgeon. In contrast, the above mentioned problems were not seen when using our prototype. We were able to adapt our device to fit not only the needs of the patient but also the operating conditions. Additionally, our equipment has the advantage of being permanently fixed to the operating table while still swinging aside to let patients take position.

Our results extended previously reported findings in carbon dioxide accumulation under ophthalmic drapes during eye surgery.²⁻⁶ In our non-suction patients, carbon dioxide concentration under the drapes rose immediately after covering the patient's head. Although carbon dioxide rebreathing and hypercapnia led to a compensatory increase in respiratory rate,⁷ the patients were not able to keep their p_{tCO_2} values within the normal range.

Sufficient suction of part of the carbon dioxide enriched air or a high oxygen flow under the drapes has been shown to be of outstanding importance in removing the carbon dioxide enriched air accumulating under sterile ophthalmic drapes.²⁻⁶ Ramanathan *et al*⁴ examined unsedated volunteers using a special hoop for suction and oxygen supply. Without any suction or oxygen insufflation carbon dioxide concentration under the drapes reached 3.5% 15 minutes after covering. Suction and oxygen supply at 10 l/min in their study decreased the carbon dioxide concentration under the drapes to 0.2%.

Zeitlin *et al*⁶ conducted their study in patients and in laboratory experiments. Examining carbon dioxide concentrations under drapes in patients, they found only a small decrease in p_{CO_2} from 10.1 mm Hg without suction to 7.9 mm Hg with suction at a fresh gas flow of 5 l/min. Using 10 l/min fresh gas flow p_{CO_2} decreased to a minimal value of 4.9 mm Hg. Because of these still high p_{CO_2} values, their method does not seem able to reduce carbon dioxide concentration under ophthalmic

drapes sufficiently to prevent carbon dioxide rebreathing in spontaneously breathing patients during eye surgery. In contrast with the work by Zeitlin *et al*⁶ our equipment prevents carbon dioxide accumulation under ophthalmic drapes. Suction and oxygen supply at 2 l/min ensure constant low p_{CO_2} values at 1.35 mm Hg under ophthalmic drapes without an increase in p_{CO_2} or in respiratory rate in our patients. These data led us to assume that no carbon dioxide rebreathing occurred in this study group.

The present study comprised only patients with no known pulmonary disorders and no sedation. Therefore, we cannot make any statements concerning p_{CO_2} values and respiratory rate in patients with impaired pulmonary function or in sedated patients. However, it may be assumed that carbon dioxide retention is more pronounced in patients with pre-existing pulmonary disorders and in patients undergoing surgery under rescue breathing apparatus (RBA) with additional sedation. Higher arterial p_{CO_2} values result in raised choroidal blood flow and intraocular pressure.^{8,9} This in turn may complicate the operation and aggravate outcome.¹⁰

Additionally, we found an oxygen flow of 2 l/min sufficient to keep SpO_2 values within normal ranges. In contrast with previous investigations,^{4,6} no high flow of oxygen was necessary in our study to prevent hypercapnia and hypoxia when combined with suction. Cummings *et al*, who administered air or oxygen at a flow of 5 l/min, questioned the benefit of pure oxygen insufflation during surgery under RBA.¹¹ In contrast, other authors have suggested the use of low flow oxygen supplementation for all patients undergoing ophthalmic surgery under local anaesthesia.^{12,13}

We found our newly designed suction equipment easy to handle and useful in preventing carbon dioxide accumulation, carbon dioxide rebreathing, and unwanted tachypnoea and exhaustion of patients. The addition of a low flow oxygen supply (2 l/min) is a simple means of providing normoxaemia. In conclusion, the equipment presented here is beneficial for practical use in elderly patients undergoing eye surgery under retrobulbar anaesthesia.

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