J Anesth (1999) 13:136–139

Journal of Anesthesia

Cuffed oropharyngeal airway and capnometry: comparison of end-tidal and arterial carbon dioxide pressures

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Abstract

Purpose. The aim of this study was to investigate the reliability of end-tidal CO_2 tension ($P_{ET}CO_2$) as a predictor of $PaCO_2$ during anesthesia in patients breathing spontaneously via a cuffed oropharyngeal airway (COPA).

Methods. Twenty adult patients scheduled for minor surgery were included in this study. After propofol injection, an appropriate size of COPA was inserted. Anesthesia was maintained with 60% nitrous oxide in oxygen (total flow rate of $5 l \cdot min^{-1}$) supplemented with propofol infusion. The patients were allowed to breathe spontaneously throughout the procedure. $PaCO_2$ and $P_{ET}CO_2$ were simultaneously measured when a steady state of anesthesia was reached.

Results. $PaCO_2$ (48.8 ± 5.4 mmHg, range 36.2–58.0 mmHg) was higher than $P_{ET}CO_2$ (43.1 ± 4.2 mmHg, range 32–51 mmHg) in all patients. The difference between end-tidal and arterial CO_2 tension was 5.7 ± 3.2 mmHg (range 0.5–13.0 mmHg), and was significantly correlated with $PaCO_2$ ($P < 0.01$).

Conclusion. The results of this study suggest that $P_{ET}CO_2$ in anesthetized patients breathing spontaneously through a COPA is sometimes unreliable as an indicator of $PaCO_2$ level, and there is some possibility of unexpected hypercapnia.

Key words: Cuffed oropharyngeal airway, Hypercapnia, Capnometry

Introduction

The cuffed oropharyngeal airway (COPA) invented by Greenberg in 1990 is a new device for airway management during anesthesia. It is a modified Guedel-type oral airway with a large cuff occupying the pharyngeal cavity mounted at the distal end, and a standard 15-mm connector at the proximal end for attachment to the anesthetic breathing system. The COPA has been used in spontaneous ventilation anesthesia, which may be managed using a mask or a laryngeal mask airway (LMA) [1].

End-tidal carbon dioxide pressure ($P_{ET}CO_2$) is a reasonable indicator of arterial carbon dioxide pressure ($PaCO_2$) in adult patients breathing spontaneously via a LMA [2] or a tracheal tube [3]. In those systems, there is an adequate seal between the anesthesia circuit and the trachea even for controlled ventilation [4]. With the use of the COPA, however, positive pressure ventilation is not indicated because the cuff cannot provide an effective seal. If air mixing occurs around the cuff, the reliability of the $P_{ET}CO_2$ must be questioned.

The aim of this study was to investigate the reliability of $P_{ET}CO_2$ as a predictor of $PaCO_2$ during anesthesia in patients breathing spontaneously via a COPA.

Materials and methods

Following the local Ethics Committee approval and obtaining informed consent, 20 ASA physical status I and II adult patients, scheduled for elective minor surgery, were included in this study. Data about the patients and the surgery are shown in Table 1. Patients with abnormal airway anatomy or pulmonary disease were excluded. Midazolam $0.05 mg \cdot kg^{-1}$ and atropine $0.006 mg \cdot kg^{-1}$ were administered intramuscularly 40 min before anesthesia. In the operating room, standard monitors, including an electrocardiograph, pulse oximeter, and automated blood pressure manometer were attached. Some patients received regional anesthesia if necessary. After sufficient preoxygenation, anesthesia was induced with propofol $1.5–2.0 mg \cdot kg^{-1}$

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Received for publication on August 31, 1998; accepted on February 9, 1999

Table 1. Demographic and surgical details

Males/females	13/7
Age (years)	55.4 ± 15.7
Height (cm)	162.1 ± 10.4
Weight (kg)	61.5 ± 9.4
Surgical time (min)	42.3 ± 23.2
Surgical procedure	
Genitourinary	12
Gynecological	4
Orthopedic	4

Data are expressed as mean ± SD.

Table 2. Anesthetic details

Anesthesia time (min)	72.4 ± 24.6 (mean ± SD)
Anesthetic procedure	
N_2O–O_2–Propofol	6
N_2O–O_2–Propofol + regional block	14
COPA size	
10	16
11	4

Table 3. The values of $P_{ET}CO_2$, arteria*l blood gases, and respiratory parameters

	Mean ± SD	Range
$P_{ET}CO_2$ (mmHg)	43.1 ± 4.2	32–51
$PaCO_2$ (mmHg)	48.8 ± 5.4	36.2–58.0
$Pa{-}_{ET}CO_2$ (mmHg)	5.7 ± 3.2	0.5–13.0
PaO_2 (mmHg)	171.0 ± 46.3	96.8–235.4
pH	7.36 ± 0.03	7.30–3.42
RR (min^{-1})	19.3 ± 3.1	15–28
V_t (ml)	182.8 ± 43.6	105–270

i.v. After loss of lid reflex, the correct size of COPA was inserted using the reverse Guedel technique. The cuff was inflated with 30–40 ml air to obtain an effective airway. If necessary, some additional supportive measures, such as turning the head to one side, increasing head tilt and gentle chin lift, were provided to ensure airway patency and to obtain hands-free performance. All patients were allowed to breathe spontaneously throughout the procedure. A fresh gas flow of $5 l \cdot min^{-1}$ was provided from a semiclosed circle system. Anesthesia was maintained with 60% nitrous oxide in oxygen supplemented with propofol infusion. The infusion rate of propofol was appropriately adjusted by the anesthetist in charge as clinically indicated.

Expired gas tension and fraction were measured with a sidestream anesthetic gas monitor (Ohmeda 5250 RGM, Louisville, CO, USA). Gas samples were drawn from the sampling port of the elbow connector between the proximal end of the COPA and the breathing circuit through a sampling catheter at a rate of $200 ml \cdot min^{-1}$. The capnometer was calibrated before each study with a dry gas containing a known concentration of CO_2. Its stated accuracy is ±2.28 mmHg. Tidal volume (V_t) and respiratory rate (RR) were also measured with the 5250 RGM. The flow sensor for measuring V_t was mounted between the exhalation check valve and the expiratory limb of the breathing circuit.

When a reasonably steady state of anesthesia was reached after the start of the operation, an arterial blood sample was obtained from the radial artery and was immediately analyzed utilizing a blood gas analyzer (ABL 505, Radiometer, Copenhagen, Denmark). The accuracy of the analyzer was maintained by automatic two-point calibration using machine-created standards. Blood gas analysis was performed at 37°C with conventional electrodes. $P_{ET}CO_2$, V_t, and RR were measured simultaneously with each blood sampling. Body temperature, measured with a rectal thermistor probe, and noninvasive systolic blood pressure were noted at the same time.

Data were expressed as mean ± standard deviation. Statistical analysis was performed using Student's *t*-test or Mann–Whitney's *U*-test, and $P < 0.05$ was considered statistically significant. Correlation was evaluated using Pearson's correlation coefficient and Fisher's *R–Z* statistic.

Results

Anesthetic details are shown in Table 2. Although the above-mentioned additional supportive measures were needed for airway patency, "hands-free" anesthesia was obtained in all cases before the start of the operation.

The values of $P_{ET}CO_2$, arterial blood gases, and respiratory parameters are shown in Table 3. $P_{ET}CO_2$ was lower than $PaCO_2$ in all patients, but the correlation between them was significant (Fig. 1; $P < 0.0001$). The difference between $PaCO_2$ and $P_{ET}CO_2$ ($Pa{-}_{ET}CO_2$) was 5.7 ± 3.2 mmHg, and was significantly correlated with $PaCO_2$ ($r = 0.629$; $P < 0.01$). The pH values were below 7.35 in seven patients because of hypercapnea. $Pa{-}_{ET}CO_2$ was not significantly correlated with RR, V_t, $P_{ET}CO_2$, and blood pressure. The size of the COPA or the presence of a regional block did not influence the values of $PaCO_2$, $P_{ET}CO_2$, and $Pa{-}_{ET}CO_2$. There were no episodes of oxygen desaturation due to placement of the COPA.

Discussion

The results of this study indicate that hypercapnia may be underestimated when $P_{ET}CO_2$ is substituted for

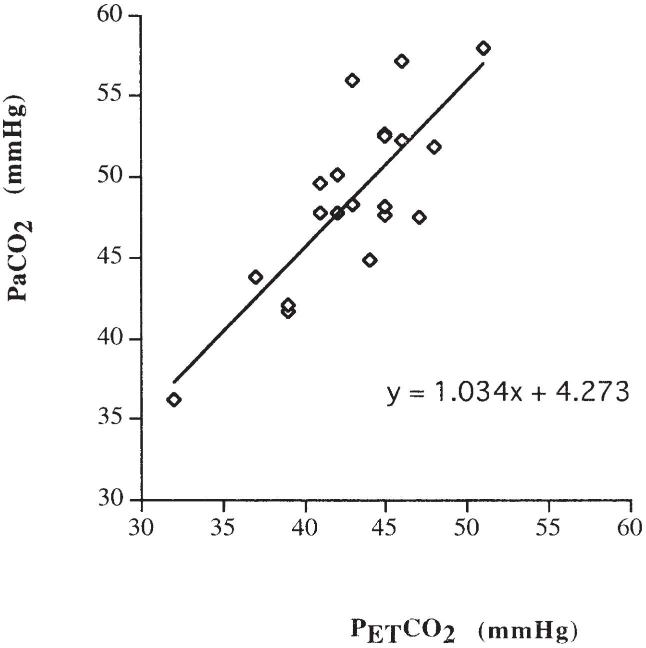
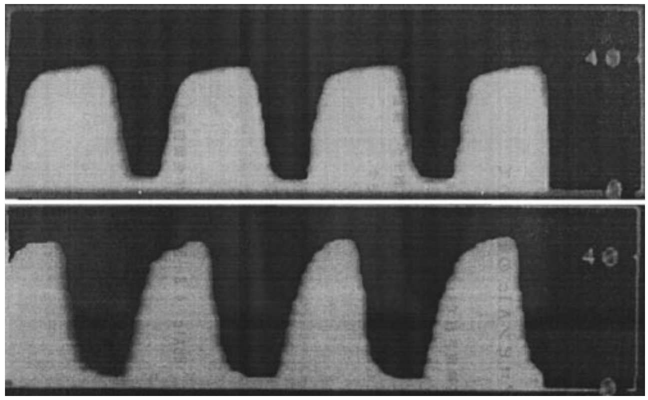


Fig. 1. Relationship between $P_{ET}CO_2$ and $PaCO_2$. There is a significant correlation (r^2 = 0.65, $P < 0.0001$)



a

b

Fig. 2. The shapes of a capnogram during airway maintenance with a COPA. **a** Capnogram with a sufficient plateau (phase III). **b** Capnogram with a sloping phase III seen in a patient with mild airway obstruction

$PaCO_2$ in patients breathing spontaneously via a COPA. This conclusion is based on the following results. First, although $P_{ET}CO_2$ measured at the proximal end of the COPA was well correlated with $PaCO_2$, it was less than $PaCO_2$ in all patients. Furthermore, Pa–$_{ET}CO_2$ was significantly correlated with $PaCO_2$.

Generally, a COPA has been used in patients undergoing minor surgery requiring mask anesthesia. Besides hands-free performance, the advantage of the COPA compared to the mask is the fact that it allows the use of a capnometer, which has been standardized as an essential monitor during general anesthesia. In patients without lung disease, ventilated either mechanically or spontaneously via a tracheal tube, the Pa–$_{ET}CO_2$ was 0.8–3.5 mmHg [5,6]. Hicks et al. [2] reported that $P_{ET}CO_2$ correlated well with $PaCO_2$, and the Pa–$_{ET}CO_2$ was 3.9 mmHg in patients breathing spontaneously via a laryngeal mask airway. Consequently, $P_{ET}CO_2$ is a good index of $PaCO_2$ in these patients. In this study, however, the mean Pa–$_{ET}CO_2$ had to be relatively large to allow $P_{ET}CO_2$ to be recognized as a predictor of $PaCO_2$. In two patients, moreover, Pa–$_{ET}CO_2$ was 11.1 and 13.0 mmHg when $P_{ET}CO_2$ was 46 and 43 mmHg, respectively.

It has been shown that a decrease in V_t and an increase in RR cause an increase in the physiological deadspace/tidal volume ratio ($V_{D^{phys}}/V_t$) and Pa–$_{ET}CO_2$ [7,8]. In the present study, however, neither V_t nor RR were significantly correlated with Pa–$_{ET}CO_2$. The decrease in V_t would be caused by respiratory depression due to propofol and the obstruction of the upper airway due to misplacement of the COPA. Moreover, expiratory gas leak around the cuff might cause an underestimation of the real V_t. In some patients, increasing the head tilt or chin lift caused an increase in both $P_{ET}CO_2$ and V_t. Such a decrease in V_t may be one of the reasons for the increase in the Pa–$_{ET}CO_2$ in anesthetized patients using a COPA.

The state of airway patency could be judged from the shapes of the capnograms. The steep slope of phase II (the S-shaped upswing) and a sufficient phase III (plateau) on the capnograph are needed for an effective airway. Airway obstruction will induce an extension of phase II and a shortening of phase III. An insufficient period in phase III causes an underestimation of the real $P_{ET}CO_2$ because phase III becomes a slope rather than a plateau [7] (Fig. 2). Therefore, airway obstruction caused by the COPA may increase Pa–$_{ET}CO_2$. It is important to pay attention to the capnogram to estimate the airway patency during anesthesia using a COPA.

Another reason why the measured $P_{ET}CO_2$ underestimated the actual alveolar carbon dioxide tension might be the dilutional effect of the fresh gas flow. A high gas flow may distort the effect of the plateau on the capnograph. In children, this adverse effect is accelerated when the expired volume is small [8]. In anesthetized adult patients breathing spontaneously via the laryngeal mask airway, however, a fresh gas flow rate from 1 to 6 $l \cdot min^{-1}$ did not influence the Pa–$_{ET}CO_2$ [9]. Thirdly, an escape of the expired gas around the cuff might reduce the carbon dioxide tension in the gas. However, it was not clear whether there was a gas leak because the discrepancy between the inspired and expired volumes of the gas was not measured in this study.

In conclusion, when anesthesia is maintained using a COPA, $P_{ET}CO_2$ is sometimes unreliable and attention should be paid to the shape of the capnograph and airway patency to avoid unexpected hypercapnia due to a discrepancy between $P_{ET}CO_2$ and $PaCO_2$.

References

1. Greenberg RS, Brimacombe J, Berry A, Grouze V, Piantadosi S, Dake EM (1998) A randomized controlled trial comparing the cuffed oropharyngeal airway and the laryngeal airway in spontaneously breathing anesthetized adults. Anesthesiology 88:970–977
2. Hicks IR, Soni NC, Shephard JN (1993) Comparison of end-tidal and arterial carbon dioxide measurements during anaesthesia with the laryngeal mask airway. Br J Anaesth 71:734–735
3. Nunn JF, Hill DW (1960) Respiratory dead space and arterial to end-tidal CO_2 tension difference in anesthetized man. J Appl Physiol 15:383–389
4. Devitt JH, Wenstone R, Noel AG, O'Donnell MP (1994) The laryngeal mask airway and positive-pressure ventilation. Anesthesiology 80:550–555
5. Whitesell R, Asiddao C, Gollman D, Jablonsky J (1981) Relationship between arterial and peak expired carbon dioxide pressure during anesthesia and factors influencing the difference. Anesth Analg 60:508–512
6. Takki S, Aromaa U, Kauste A (1972) The validity and usefulness of the end-tidal PCO_2 during anesthesia. Ann Clin Res 4:278–284
7. Fletcher R, Jonson B (1984) Deadspace and the single breath test for carbon dioxide during anaesthesia and artificial ventilation. Effects of tidal volume and frequency of respiration. Br J Anaesth 56:109–119
8. Spahr-Schopfer IA, Bissonnette B, Hartley EJ (1993) Capnometry and the paediatric laryngeal mask airway. Can J Anaesth 40:1038–1043
9. Kobayashi Y, Tsuchida H, Kurihara C, Namiki A (1997) Low flow anesthesia using a laryngeal mask airway. J Clin Anesth (Jpn) 21:1243–1247