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The Validity of Transcutaneous PO_2 Monitoring during Anesthesia

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Abstract The validity of the commercially available electrode for measurement of transcutaneous oxygen partial pressure ($tcPO_2$), Clark type electrode with polyethylene membrane (Oxygen Monitor 632), during anesthesia was examined. Firstly, the interference of anesthetics with this $tcPO_2$ electrode was examined in vitro, and no interference of nitrous oxide (N_2O), halothane and enflurane was found at clinically used concentrations. Then, the correlation between $tcPO_2$ and PaO_2 was examined in 31 adult patients during anesthesia (in vivo study). There was a good correlation between $tcPO_2$ and PaO_2 with correlation coefficient of 0.91, 0.79 and 0.94 in the halothane+N_2O, neuroleptanalgesia+N_2O and enflurane+N_2O anesthesia group, respectively, and the regression equation was $PaO_2=1.37tcPO_2-21.7$, $PaO_2=1.39tcPO_2-25.3$ and $PaO_2=1.23tcPO_2+10.2$, respectively. It is concluded that the $tcPO_2$ electrode tested in the present study is useful in adults during anesthesia.

Key words: transcutaneous PO_2, monitoring, anesthesia

Introduction

Although measurement of transcutaneous oxygen partial pressure ($tcPO_2$) has become valid as a monitoring technique in neonatal intensive care unit[1], its usefulness in adults, especially during anesthesia, has been questioned, since it had been reported by some that the electrode was interfered by halothane and N_2O[2-4]. However, the other reports demonstrated its usefulness during anesthetic circumstances other than halothane[5-7]. For example, Samra[5] reported a good correlation between $tcPO_2$ and PaO_2 during enflurane+N_2O or fentanyl+N_2O anesthesia. Rafferty et al[7] reported the $tcPO_2$ was an accurate and clinically useful trend-indicator of PaO_2 during fentanyl+N_2O or enflurane+N_2O anesthesia. Thus, they suggested the necessity of development of a halothane-resistant electrode for more widespread application of $tcPO_2$ monitoring during anesthesia. Eberhard and Mindt[3] showed that the interference depended upon a variety of electrode sizes, membrane materials and levels of polarization voltage. In the present study, to determine the validity of commercially available $tcPO_2$ electrode (Oxygen Monitor 632, Kontron, Switzerland), we examined the correlation between $tcPo_2$ and PaO_2 in adults during anesthesia with three different anesthetic circumstances as well as *in vitro* test.

Materials and Methods

$TcPO_2$ monitoring system, Oxygen Monitor 632 (Kontron, Switzerland) examined in the present study consists of a Clark type electrode which has a large size cathode (2.5 mm in diameter), covered by a 25-μ thick polyethylene membrane. The electrode is polarized at −600 mV. The calibration was performed in the ambient air as recommended by the manufacturer. Electrode temperature was maintained at 44°C.

1) *In vitro* study

The interference of N_2O, halothane and enflurane in clinically used concentration on $tcPO_2$ electrode was tested. After the stabilization of electrode reading for 15–20 min in air, $tcPO_2$ electrode was placed in the plastic chamber where five different anesthetic gas mixtures were insufflated, i.e. 66% N_2O, 66% N_2+1% halothane, 66% N_2O+1% halothane, 66% N_2+2% enflurane and 66% N_2O+2% enflurane in oxygen. Oxygen concentration in the plastic chamber was monitored continuously with Oxygen Monitor (A-100T, Yamato Sanki Co, Tokyo). $TcPO_2$ reading was recorded continuously and when reading became stable, oxygen tension of the gas in the plastic chamber was measured by PO_2 electrode (ABL3, Radiometer).

2) In vivo study

Thirty-one adult patients without circulatory and respiratory abnormalities (physical status 1–2, Classification of patient's status by American Society of Anesthesiologists) were studied. Patients were divided randomly into three different anesthesia groups, i.e. group 1; halothane+N_2O (12 patients), group 2; neuroleptanalgesia (NLA)+N_2O (9 patients) and group 3; enflurane+N_2O (10 patients). The range of patients' age in group 1, 2 and 3 was 46–71, 28–73 and 50–77 years, respectively, and there were no statistically significant differences in mean age among the groups. Following premedication with diazepam 10mg and atropine 0.5mg intramuscularly or hydroxyzine 25 mg and atropine 0.5mg and pentazocine 15 mg intramuscularly, anesthesia was induced with thiopental 3–5 mg/kg in group 1 and 3. In group 2, droperidol 0.2 mg/kg and fentanyl 5μg/kg were slowly given intravenously and, then a dose of thiopental sufficient to induce unconsciousness was intravenously administered. Either succinylcholine or pancuronium was administered to facilitate endtracheal intubation. After intubation, the ventilation was mechanically controlled to maintain $Paco_2$ at 35.4±0.7 mmHg (mean±SE). The $tcPo_2$ electrode was positioned on anterior chest in 19 cases. In 12 cases, it was placed on antebrachial area or inter-scapular area depending on the patients' positions or operative procedures. Twenty-two gauge indwelling catheter was placed in the left radial artery to obtain arterial blood samples. Fifteen to 20 min were allowed for $tcPo_2$ readings to be stabilized after the placement of electrode on the skin or after changing inspired oxygen concentration (Fio_2). When $tcPo_2$ reading was stable for 10–20 min, arterial blood sample was drawn in a heparinized syringe and Pao_2 was measured by blood gas analyzer (ABL3, Radiometer) at 37°C. Temperature correction for deviation from 37°C was performed. Rectal temperature of the patients ranged 34.0–37.4°C. Measurements were repeated several times during operation with varing Fio_2 from 0.2 to 1.0 in group 1 and 3, and 0.2 to 0.5 in group 2. The minimum number of paired data points per patient was two, the maximum was eight, averaging five. During the measurements, mean arterial blood pressure was maintained at 61–133 mmHg.

3) Statistics

The correlation between Pao_2 and $tcPo_2$ was examined with the regression analysis. Comparisons of correlation coefficient and the $tcPo_2$ to Pao_2 ratio ($tcPo_2/Pao_2$ ratio) between the groups were performed with Student's t-test. $P<0.05$ was considered statistically significant.

Results

1) *In vitro* study

Fig. 1 summarizes the results of *in vitro* study. $TcPO_2$ electrode was not interfered

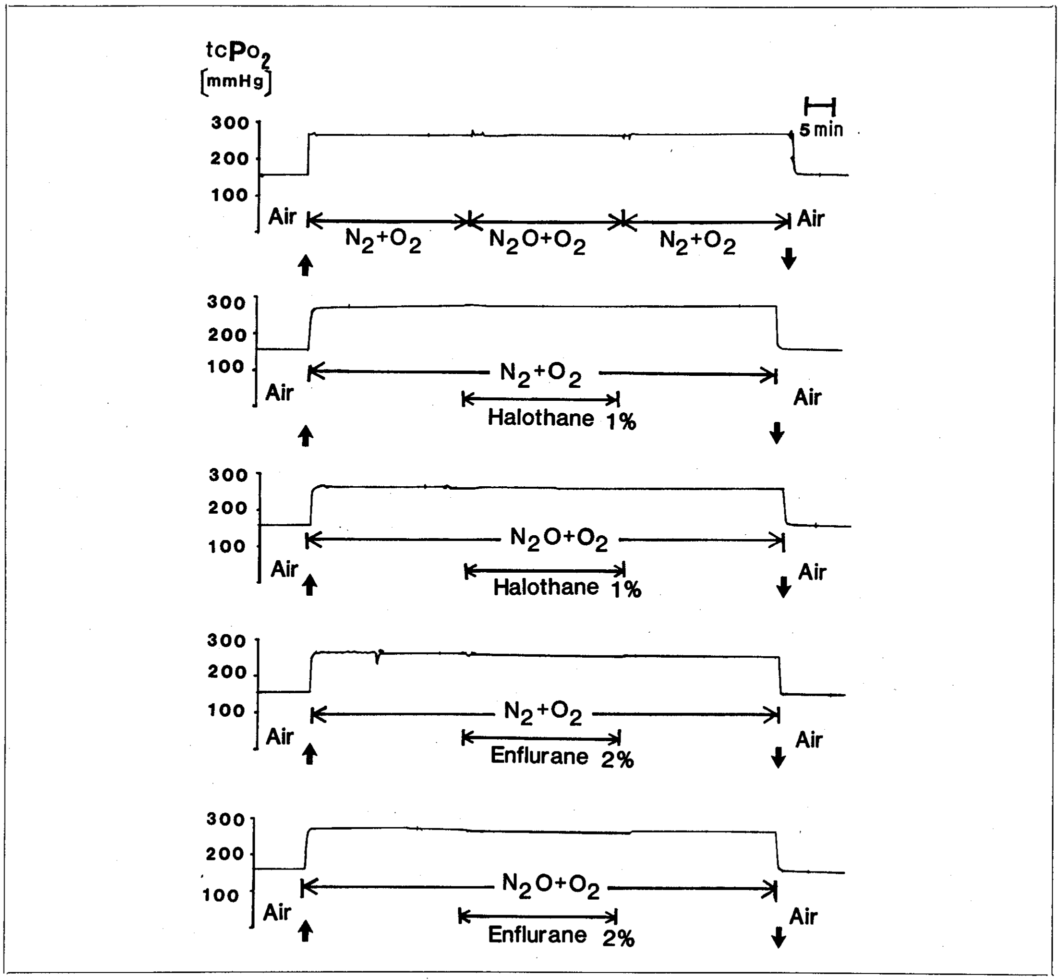

Fig. 1 $TcPO_2$ recordings during insufflation of different inhalational anesthetic gases (in vitro).

$TcPO_2$ reading responds almost instantaneously with changing oxygen concentration in the insufflated gas mixture either from 21% (Air) to 33% or from 33% to 21% (Air) as indicated by the arrow (↑, ↓). In all recordings, there were no detectable changes in $tcPO_2$ reading with changing insufflated anesthetic gases.

with anesthetics studied and PO_2 readings were well correlated with the partial pressure of oxygen in the insufflated gas mixture.

2) In vivo study

There was a significant correlation between $TcPO_2$ and PaO_2 with a correlation coefficient of r=0.91, r=0.79, r=0.94 in group 1, 2 and 3, respectively (Fig. 2). The regression equation was $PaO_2=1.37tcPO_2-21.7$, $PaO_2=1.39tcPO_2-25.3$, $PaO_2=1.23tcPO_2+10.2$ in group 1, 2 and 3, respectively. There were no significant differences in correlation coefficient among the groups. The mean $tcPO_2/PaO_2$ ratio was 0.88 ± 0.03

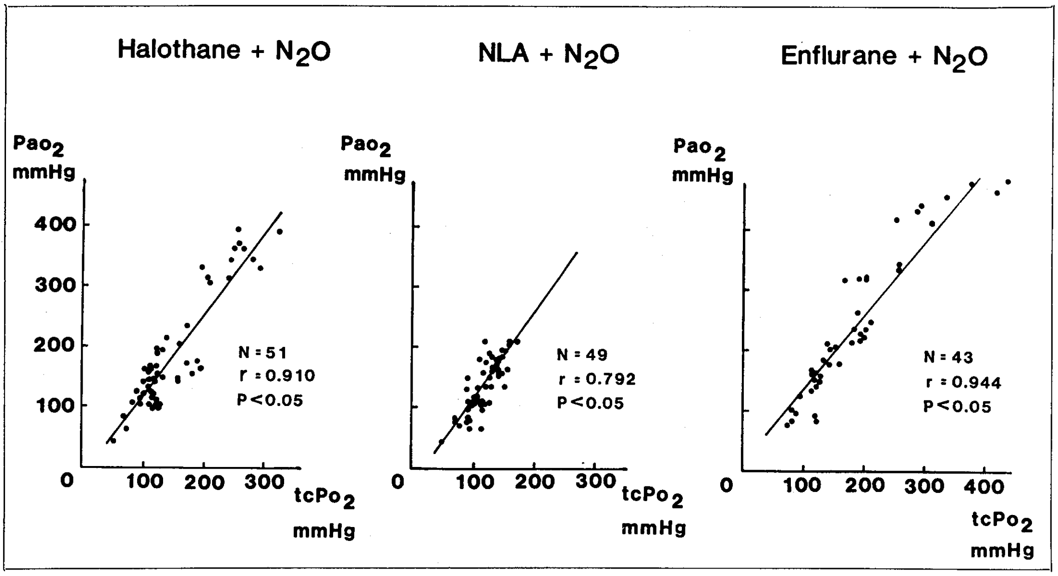

Fig. 2 Correlation between $tcPO_2$ and PaO_2 during halothane $+N_2O$, neuroleptanalgesia (NLA) $+N_2O$ and enflurane$+N_2O$ anesthesia in adults (in vivo). Note statistically significant correlation between $tcPO_2$ and PaO_2 with a regression equation of $PaO_2=1.37tcPO_2-21.7$, $PaO_2=1.39tcPO_2-25.3$ and $PaO_2=1.23tcPO_2+10.2$ in the halothane$+N_2O$, NLA$+N_2O$ and enflurane$+N_2O$ group, respectively.

(mean±SE), 0.90±0.03, and 0.81±0.03, respectively. There were no significant differences in $tcPO_2/PaO_2$ ratio among the groups.

Discussion

The present findings indicate that, both *in vitro* and in vivo, halothane, enflurane and N_2O did not cause the interference on the tested $tcPO_2$ electrode with a large size cathode covered by a 25μ-thick polyethylene membrane and polarized at -600mV. $TcPO_2$ electrode's error due to the presence of halothane or N_2O has been reported in vitro[2-4]. No interference of halothane with the electrode used in the present *in vitro* study can be explained mainly by the size of cathode, material of membrane and polarization voltage different from those used by the previous investigators. Eberhard and Mindt[3] studied various factors which cause the interference of anesthetics with $tcPO_2$ electrode. With large size cathode (mm range), covered by a polyethylene membrane, the N_2O interference current was less than 5% of air current when the electrode was polarized at -600mV. The interference current with 2% halothane was smaller than 3% of the air current. On the other hand, with a microcathode (μm range) covered by a teflon, the N_2O interference was 40% of the current in air when the electrode was polarized at -800mV. The interference current with 2% halothane was 30% of the current in air. From these, they concluded that to reduce the interference of anesthetics with $tcPO_2$ electrode it was necessary to use a membrane with low permiability for oxygen and a polarization voltage of approximately -600mV. The electrode examined in the present study seems to fulfill these factors. Samra[2] studied the effect of halothane on electrode covered with a polypropylene membrane *in vitro* and found that halothane caused interference. However, when this electrode was tested in vivo, the interference by halothane was not observed. They suggested that a possible explanation for the lack of interference by halothane in vivo is that the amount of halothane lost through the skin during clinical anesthesia[8] is too small to interfere with electrode signal. This may indicate that some of the $tcPO_2$ electrodes which are interfered by anesthetics *in vitro* can be used clinicaly. Thus, it might be necessary to test the anesthetic interference with $tcPO_2$ electrode not only *in vitro* but also in vivo.

In this study, a good correlation between PaO_2 and $tcPO_2$ readings was found in all groups and there were no significant differences in the $tcPO_2/PaO_2$ ratio among the three different types of anesthesia in adults. In neonates the $tcPO_2/PaO_2$ ratio has been known to be close to identity because of their thin skin. In adults, this ratio is not necessarily identity because of thickness of the skin. Circulatory state of patients is another factor to produce the difference between $tcPO_2$ and PaO_2 For example, in poor circulatory condition, the difference between $tcPO_2$ and PaO_2 was reported to be increased[9-11], hence the $tcPO_2/PaO_2$ ratio was decreased. Nolan et al[12] suggested that this ratio can be used as one of the indices of circulatory state during the perioperative period. Our patients' circulatory state was satisfactory and the lowest mean blood pressure was 61 mmHg and the $tcPO_2/PaO_2$ ratio was above 0.8 in all groups.

We conclude that $tcPO_2$ monitoring with electrode examined in this study is useful in adults, as a noninvasive, continuous monitor during anesthesia.

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References

1) Huch, R., Lubbers, D.W. and Huch, A.: Reliability of transcutaneous monitoring of arterial PO_2 in newborn infants. *Arch. Dis. Child.*, 49: 213-218, 1974.

2) Samra, S.K.: Halothane interference with transcutaneous oxygen monitoring: In vivo and *in vitro*. *Crit. Care Med.*, 11 : 612-615, 1983.

3) Eberhard, P. and Mindt, W.: Interference of anesthetic gases at skin surface sensors for oxygen and carbon dioxide. *Crit. Care Med.*, 9 : 717-720, 1981.

4) Sugioka, K. and Woodley, C.: The use of transcutaneous oxygen electrodes in the presence of anesthetic agents. *Can. Anaesth. Soc. J.*, 28 : 498, 1981.

5) Samra, S.K.: Comparison of Teflon and polypropylene membranes for transcutaneous oxygen monitoring during anesthesia. *Crit. Care Med.*, 11 : 46-49, 1983.

6) Dennhardt, R., Fricke, M., Mahal, S., Huch, A. and Huch, R.: Transcutaneous PO_2 monitoring in anaesthesia. *Eur. J. Intensive Care Med.*, 2 : 29-33, 1976.

7) Rafferty, T.D., Marrero, O., Nardi, D., Schachter, E,N. Mentelos, R. and Ngeow, Y.F.: Transcutaneous PO_2 as a trend indicator of arterial PO_2 in normal anesthetized adults. *Anesth. Analg.*, 61 : 252-255, 1982.

8) Stoelting, R.K. and Eger, E.I, Ⅱ : Percutaneous loss of nitrous oxide, cyclopropane, ether and halothane in man. *Anesthesiology*, 30 : 278-283, 1969.

9) Lollgen, H., Nieding, G.V., Kersting, F. and Just, H.: Transcutaneous measurement of PO_2 in adults: Exercise testing and monitoring in acute myocardial infarction. *Med. Progr. Technol.*, 6 : 43-52, 1979.

10) Eberhard, P., Mindt, W. and Schafer, R.: Cutaneous blood gas monitoring in the adult. *Crit. Care Med.*, 9 : 702-705, 1981.

11) Tremper, K.K., Keenan, B., Applebaum, R. and Shoemaker, W.C.: Clinical and experimental monitoring with transcutaneous PO_2 during hypoxia, shock, cardiac arrest, and CPR. *J. Clin. Engin.*, 6 : 149-155, 1981.

12) Nolan, L.S. and Shoemaker, W.C.: Transcutaneous O_2 and CO_2 monitoring of high risk surgical patients during the perioperative period. *Crit. Care Med.*, 10 : 762-764, 1982.