COMPARISON OF THREE OXYGEN MONITORS IN DETECTING ENDOBRONCHIAL INTUBATION

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ABSTRACT. Rapid and reliable detection of inadvertent endobronchial intubation is an essential function of oxygen monitoring. We have studied the detection of this event by using three oxygen monitoring techniques: pulse oximetry, transcutaneous measurement of oxygen tension, and intraarterial fiberoptic measurement of oxygen tension. Four dogs were anesthetized, intubated, and monitored with these three techniques and with arterial and central venous cannulas. Endotracheal tubes were moved from the trachea into the right mainstem bronchi at several inspired oxygen fraction (FI O₂) values for each dog, and the responses of the oxygen monitors were recorded for 20 minutes thereafter.

The pulse oximeter showed little change in oxygen saturation (Sp O₂) during endobronchial intubation at FI O₂ values above 0.3. Sp O₂ decreased by an average of 1.3 ± 2.1% at an FI O₂ of 1.0 and by 4.0 ± 4.1% at an FI O₂ of 0.5. Simultaneously measured transcutaneous oxygen tensions decreased by 42 to 64% and the optode reading decreased by 64 to 79%. At lower FI O₂ values, the changes in Sp O₂ were more significant: a decrease of 6.0 ± 6.3% at an FI O₂ of 0.3 and of 9.8 ± 6.1% at an FI O₂ of 0.2. The transcutaneous oxygen and optode readings decreased by 31 to 45% under these conditions.

Endobronchial intubations at FI O₂ values greater than 0.3 may not yield immediate decreases in arterial saturation and hence may go undetected by pulse oximetry. Transcutaneous oxygen tension decreases significantly with endobronchial intubation at any FI O₂. The experimental intraarterial optode consistently yielded the greatest changes with the fastest time response.


Continuous monitors of patient oxygenation during anesthesia have come into widespread use in the past five years. In particular, noninvasive oxygen monitoring by pulse oximetry is becoming an anesthetic standard of practice. Pulse oximeters are so easy to use that we tend to rely on them to detect any potentially hypoxic events that may occur during anesthesia. One event that we must detect rapidly and reliably is inadvertent endobronchial intubation. Although there have been previous studies of noninvasive oxygen monitors during one-lung ventilation, none have addressed the response of these monitors to sudden onset of one-lung ventilation at various inspired oxygen fraction (FI O₂) values. In one study of 19 patients undergoing one-lung ventilation at an FI O₂ of 1.0, only 5 patients had a pulse oximeter saturation (Sp O₂) of less than 90% at any time during one-lung ventilation [1]. In another study of Sp O₂ versus arterial oxygen tension (Pa O₂) in 10 thoracotomy patients at an FI O₂ of 0.5, the Pa O₂ was greater than 100
mm Hg (that is, arterial saturation above 97%) in 42 of 63 data points [2]. On the other hand, studies of transcutaneous oxygen tension (PtcO₂) in thoracotomy patients at several FIO₂ values have shown significant decreases in PtcO₂ with the onset of one-lung ventilation [3-5].

Hence, it is not clear whether either pulse oximetry or transcutaneous measurement of oxygen will give an early and reliable warning of endobronchial intubation at any FIO₂ value. In this study we used an animal model to compare these two noninvasive techniques and one invasive method: use of the intratracheal fiberoptic fluorescence quenching probe, or "optode." Data from all three continuous monitors were also compared with intermittently sampled arterial blood gas data.

### MATERIALS AND METHODS

Four mongrel dogs weighing 15 to 25 kg were anesthetized with intravenous pentobarbital 20 mg/kg and intubated. Arterial and central venous cannulas were inserted through a femoral incision. Two PtcO₂ sensors (Novametrix model 805) were applied to shaved skin on the chest and heated to 44°C. Two pulse oximeter probes (Nellcor N-100 and Novametrix 500) were attached to the tongue and the shaved forefoot. In addition, a fiberoptic (optode) continuous PO₂ probe was inserted through the arterial cannula to protrude 3 mm into the femoral artery. This experimental probe, developed by American Bentley, Inc, uses the phenomenon of fluorescence quenching to determine the PO₂ at the tip of a 0.5-mm-diameter optical fiber [6,7]. The accuracy and reliability of this particular optode have been studied in both animals and humans [8,9]. Arterial blood samples were drawn intermittently during the experiment for blood gas analysis (Radiometer ABL-2 and Instrumentation Laboratories IL-282).

A flexible bronchoscope was used to determine the distance from the teeth to the carina in each dog. Endobronchial intubation was achieved by guiding the endotracheal tube into the left mainstem bronchus under direct visualization with the bronchoscope. The left mainstem bronchus was chosen because in dogs the right upper lobe bronchus often leaves the trachea above the carina. Equivalent results were also obtained by using a 37-F left-sided double-lumen endotracheal tube (Bronchocath) to produce one-lung ventilation. After establishing steady baseline values of all variables during two-lung ventilation, endobronchial intubation was performed and data were recorded at regular intervals. In addition, PtcO₂ and optode arterial oxygen tension (OpPo₂) were recorded continuously on a strip chart.

The experiment was repeated for five FIO₂ values (1.0, 0.5, 0.3, 0.2, and less than 0.2) for each dog. Normocapnia (arterial carbon dioxide tension of 32-40 mm Hg) was maintained during the period of endobronchial intubation without changes in ventilator settings. The statistical significance of the mean changes was determined by one-sided t testing.

### RESULTS

The data from a typical endobronchial intubation at an FIO₂ of 0.5 are shown in Figure 1. The measured oxygenation variables (PaO₂, PtcO₂, OpPo₂, and SpO₂) are plotted versus time from endobronchial intubation. PaO₂, as determined by the blood gas analyzer, and OpPo₂ began to fall immediately, and PtcO₂ fell by 25% in less than 2 minutes. However, SpO₂ did not fall significantly at any time in this particular case. The average decrease for all 4 dogs at this FIO₂ value was 4.0%. The average PaO₂ decrease at an FIO₂ of 1.0 was 1.3%.

Figure 2 shows similar data for an endobronchial intubation at an FIO₂ of 0.3. In this case the baseline PaO₂ before intubation was much lower than in Figure 1: 99 mg Hg as compared with 365 mm Hg. During the first minute of endobronchial intubation, the PaO₂ fell to less than 60 mm Hg and the SpO₂ fell to 85%. The PtcO₂ also fell significantly within less than 2 minutes, and continued to fall for the first 5 minutes. After 15 min-