Title: AUSCULTATION AT THE STERNAL NOTCH DOES NOT DISTINGUISH BETWEEN ENDOTRACHEAL AND ESOPHAGEAL INTUBATION

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Introduction: The passage of an endotracheal tube through the larynx and into the trachea causes a loud noise when conventionally auscultated at the suprasternal notch. We hypothesized that this noise might be used to reliably distinguish between esophageal and endotracheal intubation.

Methods and Materials: After approval by the UCSD Human Subjects Comittee, 14 consenting ASA physical status I and II patients who had normal airways, no history of hypertension, and required general endotracheal anesthesia for elective surgery were enrolled. A miniature microphone implanted within a precordial stethoscope was placed on the anterior aspect of the patients neck at the suprasternal notch. Recordings during all intubations were made using a high fidelity tape recorder. Loudness was measured in volts (V) with the same fixed level of microphone amplification for all recordings. General anesthesia was induced, laryngoscopy was performed, and if the larynx was fully visible, an endotracheal tube was passed into the esophagus, withdrawn, and then placed endotracheally. Audiograms of all intubations were electronically analyzed for mean maximum amplitude and frequency distribution. Esophageal and tracheal mean maximal amplitude and 90% spectral edge data were compared by paired two tailed t analysis.

Results: The mean maximum amplitude of the tracheal signals (0.25 $\pm$0.06 V) was greater than the esophageal signals (0.15 $\pm$0.05 V, $p < 0.01$). Based upon signal amplitude and frequency power spectra, the patients fell into three groups: In group 1 patients, there were distinct differences between esophageal and tracheal audiograms with esophageal and tracheal mean maximum signal amplitudes of 0.14 $\pm$0.05 V and 0.24 $\pm$0.06 V (p=0.03), respectively, and significantly ($p<0.01$) different mean 90% spectral edge frequencies of 164 $\pm$41 and 287 $\pm$44 Hz, respectively. Group 2 patients showed a different pattern with significantly different (p=0.04) esophageal and tracheal mean amplitudes of 0.10 $\pm$0.02 and 0.20 $\pm$0.05 V, respectively, and 90% spectral edges that were similar at 195$\pm$10 Hz and 220$\pm$12 Hz, respectively; In this group, tracheal 90% spectral edge frequencies *always* exceeded esophageal spectral edge frequencies by at least 10 Hz. Group 3 patients, the spectral edge frequencies for both esophageal and tracheal intubations were nearly 100 Hz higher than Group B (approximately 300 Hz) and there was no consistent 90% spectral edge difference between esophageal and tracheal signals. The mean maximum Group C amplitudes were 0.19 $\pm$0.04 V and 0.28 $\pm$0.06 V (p=0.04), for esophageal and tracheal, respectively.

Discussion: We have quantitatively analyzed audiograms taken during esophageal and tracheal intubations and our data show that when auscultated at the sternal notch, the frequency distribution of the noise is often (70% of patients) nearly identical for the two maneuvers. Although there is nearly a 2:1 difference in mean maximum loudness between tracheal and esophageal intubations and the measured difference in the loudness of the signals is significant, the difference can only be appreciated when *both* signals are obtained for comparison. It would be extremely difficult to detect successful tracheal intubation using a single audiogram. We conclude that audiometric analysis of mean maximum amplitude or frequency distribution of suprasternal notch sounds during endotracheal intubation may not be a clinically useful sign of endotracheal intubation.

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TITLE THE SCIMED OXYGENATOR AND FENTANYL UPTAKE

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INTRODUCTION Uptake of fentanyl by the cardiopulmonary bypass circuit has been a recognized phenomenon since the publication of Koren's articles in 1984.[1] Rosen, *et al.*, determined that the primary site of binding in the cardiopulmonary bypass circuit was the SciMed® Membrane Oxygenator.[2] Both investigations confirmed that the uptake occurred rapidly, and Koren reported the reaction as being irreversible.[1] Neither study was able to define uptake in terms of what actually occurred at the membrane level. Understanding how the binding takes place is important for predicting how other drugs will be affected by the membrane oxygenator. The purpose of this study is to define how the binding of fentanyl occurs on the membrane in the SciMed Membrane Oxygenator.

METHODS Phase 1: Fentanyl solutions (170 ng/ml) were prepared in Normosol-R. The pH was adjusted to 6.4, 6.9, 7.43, 7.88, and 8.8 at 37°C. A 1 cm^2 piece of the SciMed membrane oxygenator was placed in a tube containing 2 ml of the fentanyl solution. The solution was agitated for 24 hours at 25°C. Phase 2: Fentanyl saturated Scimed membrane squares were placed in Normosol-R containing no fentanyl, and the membranes were agitated. At regular time intervals, the membranes were removed and analyzed for fentanyl content. All fentanyl analyses were performed by liquid scintillation techniques.

RESULTS

TABLE 1

pH	6.40	6.90	7.34	7.88	8.80
1. Initial Solution (ng/ml)	170	171	174	167	176
2. Solution A (ng/ml)	44	45	43	49	41
3. Solution B (ng/ml)	43	43	41	39	41
4. Membrane A (ng/cm^2)	125.7	125	125	125	125
5. Membrane B (ng/cm^2)	126.3	127	127	127	125

TABLE 2

Time (hrs)	Membrane Concentration of Fentanyl (ng/cm^2)
0	117.2
6	116.6
12	116.5
24	113.6
48	111.4
72	111.0

DISCUSSION Fentanyl bound rapidly to the membrane oxygenator. The fentanyl was shown actually to dissolve into the membrane material. The fact that the albumin in the solution did not affect binding confirms that its affinity for the membrane is greater than for plasma proteins.[3] This explains why the isolated membrane experiments of Rosen, *et al.*, in which the membrane was exposed on both sides, correlate with the intact studies done by Rosen, *et al.*, in which the oxygenator was exposed on only one side.[2] Skacel, *et al.*, postulated that the binding was pH-dependant hydrophobic uptake.[4] Our experiment demonstrates that the binding was unaffected by pH. The issue of irreversibility was proposed by Koren, *et al.*, and was also found not to be true.[1] The reversibility is very slow, and would not be observed during the normal cardiopulmonary bypass run during heart surgery, but would occur during long term cardiopulmonary bypass, such as in ECMO. The drug dissolves into the silicone in the membrane oxygenator. Drug uptake can be predicted based upon a silicone water partition coefficient. Because the membrane's affinity for the fentanyl is so great, it would be expected that fentanyl would be removed from the patient binding sites and bound by the membrane oxygenator during cardiopulmonary bypass. We therefore recommend pre-saturating the SciMed Membrane Oxygenator with fentanyl prior to initiating bypass.

[1] *Anesth Analg* 63:175-184, 1984. [2] *J Cardiothoracic Anesth* 2:619-26, 1988.
[3] *Anesthesiology* 65:A225, 1986. [4] *Br J Anaesth* 68:947-49, 1986.