TITLE: DIFFERENTIATING ESOPHAGEAL FROM TRACHEAL CAPNOGRAMS

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Introduction. Capnography is an important method of differentiating between tracheal and esophageal intubation. Capnograms with tracheal characteristics have been reported following esophageal intubation (1). To better characterize the esophageal capnogram, we used an in-vivo canine model and an in-vitro mechanical model to simulate gastric distention with CO_2-containing gas and subsequent esophageal intubation.

Methods. The animal protocol was approved by the University Animal Care and Use Committee. Anesthesia was induced in a fasted adult mongrel dog with thiopental. The trachea was intubated and anesthesia was maintained with halothane (0.75-1.25%) in O_2. Controlled mechanical ventilation was titrated to an end-tidal CO_2 ($ETCO_2$) of 5 ± 0.25%. Because the Valve of His prevents gas distending a dog's stomach from refluxing into the esophagus, esophageal intubation was simulated by placing a second endotracheal tube (ETT) into the stomach through a gastrostomy. A catheter-tip pressure transducer and a 10-ga catheter were placed through separate gastrostomies, and the abdomen was surgically repaired. The tracheal and intragastric ETTs were each connected to separate circle breathing circuits and mechanical ventilators. CO_2 concentration in each circuit was measured at the Y-piece by separate capnographs. With the intragastric ETT clamped, the stomach was distended by infusing 1000 cc of 5% CO_2 through the intragastric catheter. Esophageal intubation was simulated by simultaneously turning off the ventilator attached to the tracheal ETT, turning on the ventilator attached to the intragastric ETT, and removing the clamp from the intragastric ETT. The capnograms from both breathing circuits were simultaneously recorded. The experiment was repeated using 10% CO_2 and different volumes of gas. Esophageal intubation was also simulated using a mechanical stomach model (2). The stomach was filled with 5% CO_2 until intragastric pressure equaled lower esophageal sphincter pressure (LESP). Gastric ventilation was initiated through an esophageally-placed ETT. CO_2 concentration was recorded continuously at the Y-piece. Studies were conducted with different LESPs and different stomach compliances. Using the mechanical model, we also examined the volume of gas and the concentration of CO_2 that might actually be anticipated in the stomach. After achieving steady-state mask ventilation of the lungs ($ETCO_2$ = 5 ± 0.25%), laryngospasm was simulated by cross-clamping the trachea. Subsequent ventilations were delivered to the stomach. The volume of gas and concentration of CO_2 in the stomach were recorded. Studies were carried out with different durations of laryngospasm and using face masks having different deadspace volumes.

Results. In both the canine and mechanical models, the "exhaled" CO_2 concentration decreased rapidly following simulated esophageal intubation (Table). The capnograms recorded (Figs. 1 and 2) were much different than the typical tracheal capnogram. While changes in gastric CO_2, gastric volume, LESP and stomach compliance affected the rate of CO_2 clearance, the characteristic esophageal capnogram showing a stepwise reduction in CO_2 with each suceeding breath was observed under all study conditions in both models. When laryngospasm was simulated during mask ventilation, one gastric tidal volume resulted in a CO_2 concentration of 3.0%, and additional tidal volumes further decreased this value. Decreasing the mask deadspace volume decreased the amount of gastric CO_2.

Discussion. While CO_2 may be detected for several breaths following esophageal intubation, the esophageal capnogram is much different than a normal tracheal capnogram; predictable CO_2 wash-out is observed with gastric ventilation. The difference between a tracheal and an esophageal capnogram is detectable after two "breaths," and is clearly evident after three. Thus, capnography remains an excellent clinical tool for differentiating esophageal from tracheal intubation.

References.

1. Ping STS: Anesth Analg 66:483, 1987
2. Melker RJ, Banner MJ: Ann Emerg Med 14:397, 1985

Table. "Exhaled" CO_2 (%)--Canine Model

Breath Number	5% CO_2* 1000 cc	10% CO_2* 1000 cc	5% CO_2† 2000 cc	5% CO_2† 3000 cc
1	3.1 ± .46	6.2 ± .81	4.9	5.0
2	1.7 ± .20	3.2 ± .37	2.6	3.5
3	.9 ± .08	1.4 ± .33	1.6	2.0
4	.5 ± .04	.7 ± .23	.8	1.1
5	.3 ± .04	.4 ± .11	.4	.6
6	.2 ± .04	.2 ± .09	.3	.3
7	.1 ± .04	.1 ± .04	.1	.2
8	.0	.0	.0	.1

*Mean ± S.D., N = 4; †N = 1.

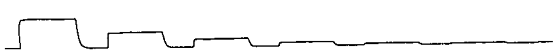

Fig. 1. Esophageal Capnogram--Canine Model

Fig. 2. Esophageal Capnogram--Mechanical Model