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A pilot study evaluating the use of cervical ultrasound to confirm endotracheal intubation in dogs

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Abstract

Objective – To assess the accuracy and usability of cervical ultrasound as a means to confirm endotracheal (ET) intubation in dogs.
Design – Randomized pilot study.
Setting – University teaching hospital.
Animals – Six recently euthanized cadaver dogs.
Interventions – Endotracheal and esophageal intubations were randomly performed. The investigators performing the ultrasound examinations were blinded to the type of intubation. Ultrasound examinations were performed in right and left lateral recumbency. The time taken to obtain the images was recorded.
Measurements and Main Results – The sensitivity, specificity, positive predictive value, and negative predictive value with their correspondent 95% confidence intervals (CI) were 91.7% (CI, 82.7–96.7), 72.7% (CI, 60.4–84.0%), 78.6% (CI, 68.3–86.8%), and 88.9% (CI, 77.4–95.8%), respectively. The overall test accuracy with its correspondent 95% CI was 82.8% (CI, 75.4–88.1%). The mean time for confirmation with ultrasound was 20.2 seconds (standard deviation, 14.3 s). Cervical ultrasound was significantly more accurate at recognizing ET intubations than esophageal intubations (odds ratio, 4.52; 95% CI, 1.43–14.27; $P = 0.010$). There was a significant relationship between increase in body weight and accuracy, indicating that the test is more accurate in larger dogs (odds ratio, 1.04; 95% CI, 1.00–1.08; $P = 0.042$).
Conclusions – Cervical ultrasound has high sensitivity and moderate specificity for ET intubation, and may be a useful tool to confirm ET intubation in dogs.

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Keywords: canine, cardiopulmonary resuscitation, CPR, esophageal intubation, tracheal rapid ultrasound exam, TRUE

Abbreviations

BW	body weight
CI	confidence interval
ET	endotracheal

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Introduction

Endotracheal (ET) intubation is widely used in veterinary medicine to protect the airway in patients with decreased gag reflex, to bypass upper airway obstruction, and to provide oxygen therapy, inhalation anesthesia, and positive-pressure ventilation.[1] While ET intubation is generally a straightforward procedure with appropriate preparation and good visualization of the laryngeal structures, it can be challenging in certain situations. Incorrect placement of ET tubes into the esophagus can increase morbidity and mortality when unrecognized. Situations in which ET intubation may be difficult include upper airway obstruction due to masses, foreign bodies, or secretions; in animals with abnormal or challenging anatomy, such as brachycephalic dogs[1]; or during cardiopulmonary resuscitation (CPR).

Verification of ET tube placement has traditionally been done by direct visualization of the tube entering

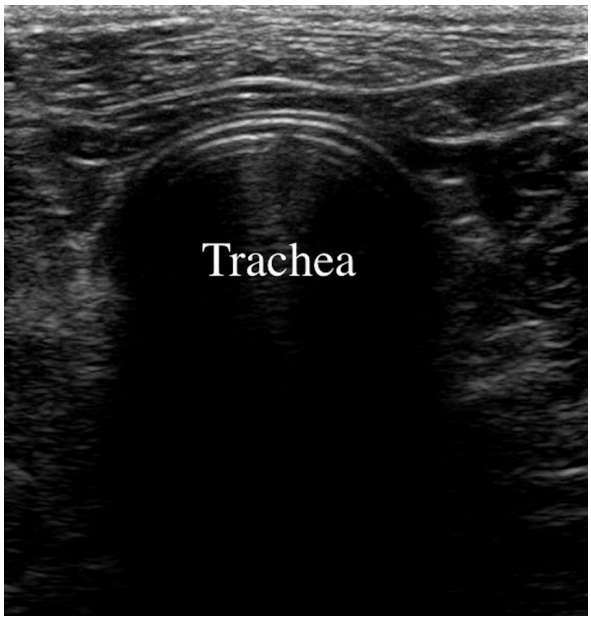

Figure 1: Endotracheal intubation. The presence of air in the trachea produces a reverberation artifact. Note that a second reverberation artifact is lacking, indicating esophageal intubation is not present.

the larynx.[1] However, confirmation of appropriate placement by direct visualization can be challenging in situations of difficult intubation. In people, the gold standard is quantitative waveform capnography with bilateral lung auscultation. However, capnography has limitations, especially during emergency intubations.[2] When cardiac output is extremely low, such as during the initial moments of CPR or when CPR is unsuccessful, end-tidal carbon dioxide tension is typically low or not detectable, which makes capnography an unreliable method to confirm appropriate ET tube placement. Recently, several studies have demonstrated the usefulness of cervical ultrasound to confirm ET tube placement in people.[3–7] Multiple human studies have shown that ultrasound has a high sensitivity and specificity at confirming ET intubation in patients undergoing emergency intubations[4] and during CPR.[5] Also, cervical ultrasound has good correlation with waveform capnography for confirming ET intubation.[6] A recent human study demonstrated the positive effect that experience and training has on the accuracy of ultrasound to confirm endotracheal intubation.[7] In this study, the overall sensitivity and specificity were 62.0% of 37.9%, respectively; however, when subgroup analysis was performed, ultrasound performed by the most experienced sonographers (> 150 scans performed) had 75.0% sensitivity and 62.5% specificity.

The primary objective of the current investigation was to demonstrate that ultrasound can be a useful tool to confirm ET intubation in dogs. Other goals were to identify potential situations or patient characteristics that could influence the accuracy of the test.

Materials and Methods

Six privately owned dogs euthanized within the prior 2 hours were used in the study. The owner's consent for participation in the study was obtained at the time of euthanasia. All dogs were euthanized due to medical reasons. Specific exclusion criteria included: preexisting history of tracheal or esophageal disease, abnormalities in the oral cavity or larynx, inability to completely open the mouth, and inability to visualize the laryngeal area. Breeds included in the study were 4 mixed breed dogs, 1 Irish Setter, and 1 Boxer. Mean body weight (BW) was 22.5 kg (range 10.0–32.4 kg). The hair around the cervical area was not clipped for the examinations and alcohol was used instead of acoustic gel. It was decided not to clip the hair to simulate emergency situations, when clipping is less likely to be done. All ultrasound examinations were performed with a portable ultrasound machine using an 8 MHz curvilinear probe.[a] The probe was placed on the ventral neck just caudal to the larynx near the jugular furrow.

A 1-hour session of ultrasound training specifically intended to aid in identification of ET and esophageal intubations was provided by a board-certified radiologist (R.C.) before the study began. All subsequent ultrasound examinations were performed by 3 house officers (V.H.B., K.W.K., P.J.B.) and a board-certified criticalist (L.M.B.). Endotracheal intubation was recognized by the presence of 1 hyperechoic curved line with its associated reverberation artifact produced by the presence of air inside the tracheally placed ET tube (Figure 1), whereas esophageal intubation was recognized by the presence of 2 hyperechoic curved lines produced by the presence of air inside the trachea and, separately, air inside the esophageally-placed ET tube (Figure 2). Endotracheal and esophageal intubations were randomly performed in each dog. The type of intubation was assigned randomly by flipping a coin. The type of intubation was confirmed by direct visualization of the tube entering the trachea or esophagus by the agreement of 2 clinicians simultaneously. The investigators performing the ultrasounds were blinded to the types of intubations performed. Examinations were performed by 4 of 4 investigators in 5 dogs and by 3 of 4 in 1 dog. Each investigator performed a total of 6 assessments per dog: 3 in right lateral recumbency and 3 in left lateral recumbency. Accuracy at recognizing the type of intubation and the time needed for recognition were recorded.

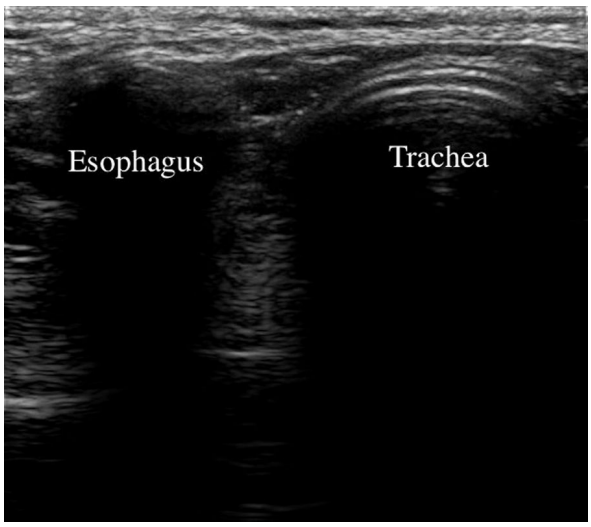

Figure 2: Esophageal intubation. The presence of air in both the trachea and in the tube within the esophageal lumen produces 2 reverberation artifacts, indicating esophageal intubation.

Statistical Methods

The sensitivity, specificity, positive predictive value, and negative predictive value with their corresponding 95% confidence intervals (CI), as well as test accuracy, were calculated using standard formulas for the binomial proportion. Sensitivity in this study denotes the ability to correctly identify an ET intubation, whereas specificity denotes the ability to correctly identify an esophageal intubation. The time taken to obtain the measurement was expressed as mean and standard deviation (SD), in seconds. Generalized estimation equations using logit link function were used to assess factors associated with diagnostic accuracy, and an exchangeable working correlation matrix was used to account for correlation between repeated measures from the same dog. The factors assessed in the analysis included the different investigators, type of intubation (ET versus esophageal), patient positioning (right lateral versus left lateral recumbency), and BW (treated as a continuous covariate). Results were presented as odds ratio and 95% CI. Three different odds ratios were obtained for the 4 different investigators using the most accurate as a reference. Significance level was set at $P < 0.05$ for all analyses. All statistical analysis was performed using a commercial statistical software package.[b]

Results

A total of 138 intubations were performed, 72 (52.2%) of them ET and 66 (47.8%) esophageal. Sixty-nine examinations were performed in right lateral recumbency and 69 in left lateral recumbency. Of the 72 ET intubations, 34 were examined in right lateral and 38 in left lateral recumbency. Of the 66 esophageal intubations, 34 were examined in right lateral and 32 in left lateral recumbency. Table 1 shows the statistical characteristics of the test, with results separated by investigator. Since sensitivity in this study denotes the ability to correctly identify a tube placed in the trachea and specificity denotes the ability to correctly identify a tube placed in the esophagus, for these investigators, it was easier to correctly identify a tube placed in the trachea than to correctly identify a tube placed in the esophagus ($P = 0.010$). The fact that the positive predictive value was lower than the negative predictive value (78.6% versus 88.9%, respectively) shows that the number of false positives (esophageal intubations misidentifed as ET intubations) was higher than the false negatives (ET intubations misidentified as esophageal intubations).

The type of intubation and BW affected the accuracy of the test, but there was not statistical significance when difference in investigator or patient positioning was assessed (Table 2). Cervical ultrasound was significantly more accurate at confirming ET intubations than esophageal intubations. Generalized estimation equations showed a significant statistical relationship between accuracy and BW, suggesting the test is more accurate in larger dogs. The mean time to obtain images was 20.2 seconds (SD, 14.3 s).

Discussion

This study showed overall less sensitivity, specificity, and accuracy than most human studies when cervical ultrasound was used to identify ET intubation.[3–6] Possible causes for this variance include anatomic differences between dogs and people, presence of fur, presence of fluid or air in the esophagus following euthanasia, patient positioning, and level of experience. Although this investigation found no statistical difference among individual investigators, there was subjectively high interobserver variability in terms of sensitivity and specificity between investigator 4 and the rest of investigators. Although there was not a difference in the experience level in cervical ultrasound between investigator 4 and the other investigators, this interobserver variability may represent different levels of learning or confidence. In the human medical literature that evaluates the use of ultrasound to diagnose ET intubation, most emergency physicians had undergone formalized training in emergency ultrasonography.[3–5,7] The American College of Emergency Physicians released in 2008 a policy statement on emergency ultrasound guidelines[c] covering topics such as specific training and credentialing. To the authors' knowledge, similar guidelines have not been produced in small animal medicine. Level of

Table 1: Sensitivity, specificity, PPV, NPV, and accuracy of ultrasound at identifying ET intubation in dogs by investigator

	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	Accuracy (95% CI)
Investigator 1	95% (75.1–99.2%)	75% (47.6–92.6%)	82.6% (61.2–94.9%)	92.3% (63.9–98.7%)	86.1% (70.9–94.4%)
Investigator 2	95% (75.1–99.2%)	81.3% (53.3–95.7%)	86.4% (65.1–96.9%)	92.9% (66.1–98.8%)	88.9% (74.1–96.2%)
Investigator 3	100% (73.4–100%)	72.2% (46.5–90.2%)	70.6% (44.1–89.6%)	100% (75.1–100%)	83.3% (65.9–93.1%)
Investigator 4	80% (56.3–94.1%)	62.5% (35.5–84.7%)	72.7% (49.8–89.2%)	71.4% (41.9–91.4%)	72.2% (55.9–84.3%)
Total	91.7% (82.7–96.7%)	72.7% (60.4–84.0%)	78.6% (68.3–86.8%)	88.9% (77.4–95.8%)	82.8% (75.4–88.1%)

Each investigator performed 6 cervical ultrasound studies (3 in right lateral recumbency and 3 in left lateral recumbency) in each of the 6 cadavers after randomized ET or esophageal intubation. CI, confidence interval; ET, endotracheal; NPV, negative predictive value; PPV, positive predictive value.

Table 2: Factors affecting the ability of investigators to correctly identify ET intubation using ultrasonography

Factor	Odds ratio		95% CI	*P*-value
Body weight	1.04		1.00–1.08	0.042
Investigator	Inv. 2 vs. Inv. 4	0.30	0.03–3.23	
	Inv. 2 vs. Inv. 1	0.72	0.06–8.08	0.533
	Inv. 2 vs. Inv. 3	0.60	0.09–4.16	
Patient positioning	1.41		0.61–3.24	0.419
Type of intubation	4.52		1.43–14.27	0.010

The factors that significantly affected accuracy were patient BW ($P = 0.042$; the test was more accurate in larger dogs than in smaller dogs) and type of intubation ($P = 0.010$; the test was more accurate at diagnosing ET versus esophageal intubation). No statistical difference was found among different investigators or between right and left lateral recumbency. Investigator 2 was used as reference when comparing different investigators as this investigator had the best accuracy. BW, body weight; CI, confidence interval; ET, endotracheal; Inv., investigator.

training and experience has been shown to affect the accuracy of cervical ultrasound in a human study,[7] in which more experienced physicians' scans had better sensitivity and specificity than those of less experienced colleagues. Although 1 hour of training seemed appropriate when the current study was designed, a longer period of training with more hands-on practice may have improved its sensitivity and specificity. Moreover, a clinician's proficiency in performing and interpreting cervical ultrasound to identify ET intubation may improve over time with practice.

The mean time and SD taken to identify the type of intubation was 20.2 seconds (SD, 14.3 s). The authors believe that this is a reasonable time period, and it is similar to times noted in human studies.[6,7]

This investigation did not find any difference in accuracy when the patient was in right versus left lateral recumbency. Examinations were not performed in dorsal or sternal recumbency. The authors chose these positions since they are the patient positions most commonly used during CPR. It is unknown whether other positions could have improved the characteristics of the test, and this warrants further research. Cervical ultrasound is more accurate at correctly identifying ER intubation in larger dogs. This effect is most likely due to the bigger anatomical structures in larger dogs. Further research with a bigger sample size is needed to confirm this finding, and to identify other patient characteristics such as breed variation or body condition score that may influence the test results.

The biggest limitation of this pilot study is the small sample size. Only 6 dogs could be recruited for the study, which limits the reliability of the BW analysis. Another limitation of the study is the use of cadavers. While the dogs had been recently euthanized, postmortem changes such as esophageal dilation or onset of rigor mortis may have influenced the results. The effect of motion, such as during CPR, was not assessed, and it could also affect the procedure.

In summary, the high sensitivity and moderate specificity of cervical ultrasound in identifying tube position indicates that ultrasound may be a useful tool to confirm appropriate airway tube placement when traditional confirmation methods are inconclusive. This pilot study has shown the feasibility of this test and has identified possible factors that can affect its accuracy. Prospective studies with live patients and a bigger sample size are needed to confirm these observations.

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Footnotes

[a] Sonosite VetMed, Sonosite Inc. Bothell, WA.
[b] SPSS, IBM North America. New York, NY.
[c] American College of Emergency Physicians. Policy statement. Emergency ultrasound guidelines. 2008.

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