Tracheal intubation is an essential component of many general anesthetics in cats. However, a concerning number of traumatic injuries of the larynx and trachea associated with this procedure have been reported in cats.\(^1\)\(^-\)\(^4\) In some instances, it has been speculated that overinflated cuffs were responsible for the lesions; in other cases, a rigid or semirigid stylet was passed through the tracheal tube to aid intubation and might have contributed to the trauma. The frequency with which these complications are reported in cats and the frequent use of stylets suggest that tracheal intubation is particularly problematic in this species. Furthermore, tracheal intubation was identified as a risk factor for increased mortality associated with anesthesia in cats, but not in dogs, underscoring a species-specific problem.\(^5\)

In humans, multiple attempts to intubate have been linked with a higher incidence of complications, including esophageal placement of the endotracheal tube, regurgitation, aspiration, and airway trauma.\(^6\)\(^-\)\(^9\) Hence, maneuvers that improve the success rate for first-attempt intubation may not be simply desirable but might also improve patient safety.

Flexible endotracheal tube introducers (ETIs), also called bougies, are often used in people when difficult intubation is expected or when initial attempts to intubate fail.\(^10\) In people, the use of a flexible ETI improves the success rate of intubation.
in patients with or without difficult airways. In the present study, we evaluated whether the use of a flexible ETI facilitated tracheal intubation of cats by veterinary students who have little or no experience intubating. We hypothesized that the use of a flexible ETI would result in a greater success rate for the first attempt at intubation and a shorter time to intubate compared with traditional intubation using an endotracheal tube without an introducer.

Materials and Methods

This study was conducted under approval of the Cornell University Veterinary Clinical Studies Committee (060821-13) and follows ARRIVE guidelines. Written consent for participation was obtained from the cats’ owners. Cats admitted for ovariohysterectomy and participating in our surgical teaching program during October and November 2021 were enrolled. As part of this program, physical examination, blood work, anesthesia, and surgery were performed by third-year veterinary students under direct supervision. Ten cats were operated on each day between 8 AM and 12 PM. Each cat was admitted the day prior to surgery and underwent physical examination and collection of venous blood for measurement of Hct, total plasma proteins, and blood glucose and urea concentrations. Cats were excluded from this study if they were classified as American Society of Anesthesiologists physical status ≥ 3 or if a difficult intubation was expected based on anatomical abnormalities or an inability to open their mouth. Two weeks prior to the beginning of the surgical exercises program, all students participated in an instructive session on tracheal intubation with and without the use of a flexible ETI led by a faculty member of the anesthesiology section using a simulator. This exercise consisted of a demonstration and instructions regarding how to hold a laryngoscope and perform laryngoscopy and how to hold and place the endotracheal tube, with or without the ETI. All students practiced laryngoscopy and intubations using the model.

General anesthesia—Maropitant (Cerenia; 8 mg total, PO), robenacoxib (Onsior; 6 mg total, PO), and cefovecin sodium (Convenia; 8 mg/kg, SC) were administered the evening prior to anesthesia. Food but not water was withheld overnight prior to anesthesia. On the morning of surgery, cats were sedated with dexmedetomidine (Dexdomitor) at 20 μg/kg and morphine at 0.1 mg/kg, IM. An IV catheter was placed. If further sedation was required for catheterization, ketamine (Ketathesia) was administered IM at 5 mg/kg. Supplemental oxygen was provided for at least 3 minutes via a loose-fitting face mask connected to a pediatric circle rebreathing circuit. General anesthesia was induced with propofol until loss of the palpebral reflex and absence of swallowing in response to direct laryngoscopy. The trachea was intubated with a suitable-sized cuffed endotracheal tube, and anesthesia was maintained thereafter with isoflurane in oxygen.

Randomization and tracheal intubation—Each day, 10 anesthesia stations were equipped with identical laryngoscopes (No. 1 Miller blade; Welch-Allyn Inc) and endotracheal tubes (Teleflex Medical) with internal diameter sizes of 3.0, 3.5, and 4.0 mm. In 5 of the stations, a flexible 6F ETI (InterGuide; Intersurgical Ltd) was available; in the other 5 stations, only endotracheal tubes were available. Allocation of the ETI was selected at random by coin toss at the beginning of the surgical exercise program, whereby 5 stations were allocated to ETI and 5 to tracheal tube alone. A staff member of the anesthesiology service (licensed veterinary technician, anesthesiology resident, or anesthesiology faculty member) supervised each intubation on a 1:1 ratio with the students. Students performing intubation were assigned a supervisor on a first-come, first-served basis with no regard to allocation to the intubation technique.

Following administration of propofol, the cat’s mouth was held open and the tongue pulled anteriorly by an assistant, and 2% lidocaine at 0.1 mL (2 mg) was sprayed once (MADomizer; Teleflex Medical) on the laryngeal mucosa under direct laryngoscopic visualization. Thirty seconds after lidocaine was administered, intubation began.

The supervisor assisted each student in selecting an appropriately sized tube and in using the graduations on the tube to decide how far, relative to the upper canine teeth, the tube should be inserted so that its tip would be at the thoracic inlet. For those assigned to the use of an ETI, the ETI was inserted through the endotracheal tube prior to intubation, so that it protruded approximately 2.5 cm from the tracheal end of the tube and was anchored to the machine connector of the endotracheal tube by use of a custom-made device (Figure 1). Students per-
formed direct laryngoscopy by placing the blade of the laryngoscope under the epiglottis and attempted to pass the endotracheal tube through the rima glottidis. The cuff of the endotracheal tube was previously lubricated with a water-soluble jelly. If the tube was moved backward and out of the oropharynx during intubation, a failed attempt to intubate was considered to have occurred; a maximum of 3 attempts were allowed for the study. The maneuver was considered complete when the tube was placed in the trachea. The ETI was removed immediately after placement of the endotracheal tube. Correct placement of the tube was confirmed by the supervisor through direct laryngoscopy (after removal of the ETI if used). The endotracheal tube was then tied behind the ears, and the cuff was inflated to prevent leaks at a pressure of 20 cm H₂O. To this end, the adjustable pressure limiting valve was temporarily closed, and a manual positive pressure insufflation up to 20 cm H₂O was provided by squeezing the reservoir bag. If the trachea was not intubated after 3 attempts, the maneuver was considered a failure and data collection ceased. Placement of the tube in the esophagus was also considered a failure and data collection ceased at that point, regardless of the number of attempts performed thus far. Further attempts to intubate after a failed maneuver were allowed for educational purposes at the discretion of each supervisor, but no more data were collected.

Upon completion of surgery and extubation, endotracheal tubes (and ETIs immediately after intubation) were observed for traces of blood after their use. All cats remained in our institution overnight and were examined at 4 PM and 7 PM the evening of surgery and at 7 AM the next day. Cats were discharged if no complications were noticed.

Data collection and statistical analysis—An a priori sample size calculation for the main outcome (success at first attempt) was performed using pilot data from 25 cats intubated by students at a collaborating institution. Those cats were sedated with dexmedetomidine at 10 µg/kg, hydromorphone at 0.1 mg/kg, and ketamine at 4 mg/kg, IM, and anesthesia induced with propofol. That preliminary project was approved by the Institutional Review Board at the University of Georgia (Project 00004259). First-attempt success without use of an ETI from that sample was 50%. Considering an expected success rate of 75% using the ETI, we estimated that 54 animals/group would be sufficient for a power of 80% and an α of 0.05.

The number of attempts and the time to intubate (from beginning of first attempt to correct intubation, up to three attempts included) were recorded. These variables are reported for successful intubations, not for failed intubations. Each student was asked whether they had ever attempted to intubate a cat before and whether the arytenoid cartilages were open and static, moving, or closed prior to intubation (but after desensitization with lidocaine). The age and weight of each cat, size of endotracheal tube (internal diameter in millimeters), tube size to weight ratio, dose of propofol, and whether supplemental ketamine was administered were recorded.

Group characteristics included the age, weight, use of ketamine, dose of propofol, tube size (which was considered a categorical variable), tube size-to-weight ratio, and whether the student had prior experience intubating cats. Outcome variables were success at first attempt, number of attempts and time to intubate. Discrete and continuous variables were compared between groups with Fisher exact tests or χ² tests and with Wilcoxon signed rank tests, respectively. Multivariate logistic regression with backward elimination was used to assess the effect of the following variables on the binary outcome first-attempt success: intubation technique, weight, tube size, tube size to weight ratio, position of arytenoid cartilages, prior intubation experience, use of ketamine, dose of propofol, and supervisor, on the. The statistical analyses were performed with JMP Pro 15 (SAS Institute Inc). Significance was considered when P < 0.05.

Results

One hundred thirty-two cats were enrolled. After exclusions, data were collected from 125 cats (Figure 2).

Blood was not observed in any endotracheal tube or on any ETI, and all cats were discharged the morning after surgery without complications.

Demographic characteristics of both groups are shown (Table 1). Sixty-four cats were allocated to ETI and 61 to endotracheal tube alone. Eighty-six percent of students intubating with an ETI and 79% intubating with the endotracheal tube alone reported having never intubated cats before; there was no difference between groups (P = 0.493).

Success rate at first, second, and third attempts and failure to intubate are shown (Figure 3). The first-attempt success rate was higher (ETI, 79%; endotracheal tube, 46%) and the total number of attempts lower when an ETI was used (both P < 0.001). Two (3%) cats intubated with an ETI and 5 (8%) cats intubated with an endotracheal tube alone were considered failures (P =
Multivariate logistic regression showed that the use of the ETI was associated with success at first attempt (P = 0.0002). Use of a tracheal tube with a 3-mm internal diameter was associated with a lower success to intubate at first attempt (P = 0.001). Heavier cats and smaller tube size to weight ratio were associated with a nonsignificant higher success of first-attempt intubation (both P = 0.086). No other covariate was significantly associated with success at first attempt.

Discussion

The main finding of this study is that the use of a flexible ETI resulted in a greater success rate for first-attempt at intubation by veterinary students with little to no experience with this maneuver.

Repeated attempts to intubate result in an increased incidence of complications in people.6–9 While this association is yet to be studied in cats, it is reasonable to expect that repeated unsuccessful attempts to intubate are likely to contribute to traumatic injury of the larynx or the anterior portion of the trachea. Therefore, efforts to minimize the number of attempts to intubate might decrease the risk or magnitude of such injuries and expedite the administration of high concentrations of oxygen, positive pressure ventilation, and capnography monitoring. The latter might be of particular importance if apnea occurs during induction in cats with pulmonary disease or in those at increased risk of regurgitation or vomiting, among others.

Different methods to aid intubation in cats have been studied, including topical desensitization of the larynx17,18 and the use of neuromuscular blocking agents to prevent laryngospasm.19–21 Rigid styles have been used in some cases, presumably to strengthen otherwise flexible tracheal tubes and overcome the resistance encountered at the larynx.1 In the present study, we investigated an alternative technique: the use of a flexible ETI. Flexible ETIs, also called gum-elastic bougies, are typically reserved for complicated intubations when visualization of the larynx is difficult. In those situations, the ETI is usually

Table 1—Group characteristics of 125 anesthetized cats for ovariohysterectomy and randomized to be intubated with the aid of a flexible endotracheal tube introducer (ETI) or with an endotracheal tube alone. All cats were sedated with dexmedetomidine (20 µg/kg) and morphine (0.1 mg/kg, IM). Ketamine (5 mg/kg, IM) was administered to cats in which sedation was insufficient. Anesthesia was induced with propofol, and the larynx was desensitized with atomized 2% lidocaine at 0.1 mL.

<table>
<thead>
<tr>
<th></th>
<th>ETI (n = 64)</th>
<th>Endotracheal tube (n = 61)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>0.6 (0.3–5.0)</td>
<td>0.8 (0.3–4.0)</td>
<td>0.516</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>2.5 (0.8–3.9)</td>
<td>2.8 (0.8–4.3)</td>
<td>0.220</td>
</tr>
<tr>
<td>Ketamine (No.)</td>
<td>Yes (27)</td>
<td>Yes (11)</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>No (36)</td>
<td>No (50)</td>
<td></td>
</tr>
<tr>
<td>Propofol (mg/kg)</td>
<td>3.7 (0–8)</td>
<td>3.9 (0–8)</td>
<td>0.705</td>
</tr>
<tr>
<td>Endotracheal tube internal diameter (No.)</td>
<td>3.0 mm (9)</td>
<td>3.0 mm (18)</td>
<td>0.118</td>
</tr>
<tr>
<td></td>
<td>3.5 mm (28)</td>
<td>3.5 mm (34)</td>
<td></td>
</tr>
<tr>
<td>Tube size-to-weight ratio (mm/kg)</td>
<td>1.4 (0.89–3.75)</td>
<td>1.25 (0.81–3.37)</td>
<td>0.043</td>
</tr>
<tr>
<td>Position of arytenoid cartilages</td>
<td>Open (15)</td>
<td>Open (22)</td>
<td>0.076</td>
</tr>
<tr>
<td></td>
<td>Closed (1)</td>
<td>Closed (4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moving (47)</td>
<td>Moving (34)</td>
<td></td>
</tr>
</tbody>
</table>

0.356). Of those, 2 students were unable to intubate after 3 attempts (1 in each group). Esophageal intubations occurred in 1 cat with an ETI and in 4 cats with an endotracheal tube alone. Time to intubate is shown (Figure 4); it was not different between groups (P = 0.464).

Figure 3—Success rate of intubation at the first-attempt, second attempt, and third attempt and the rate of failed intubations in 64 cats intubated with a flexible ETI and 61 cats intubated with only an endotracheal tube. All cats were intubated under direct laryngoscopy. Success of first-attempt intubation was significantly higher with an ETI. There were no differences in the failure rate between groups.

Figure 4—Box plots (median, IQR) and individual times to complete intubation in 64 cats using a flexible ETI and 61 cats using only an endotracheal tube. All cats were intubated with direct laryngoscopy. There were no differences between groups.
passed into the trachea first, and the endotracheal tube is then passed over it. In practice, even under direct laryngoscopy, this procedure is cumbersome because it usually requires 2 operators so that the ETI is secured in the trachea while the tracheal tube is passed over it. We modified this technique so that it could be performed by a single anesthetist. To this end, we constructed an adaptor that attaches to the standard 15-mm connector of the endotracheal tube and secures the ETI in place relative to the tube. The length of the ETI protruding from the tracheal tube can be adjusted, but in the present study, it protruded approximately 2.5 cm. During intubation, the endotracheal tube and ETI are held together as a unit. The ETI is introduced into the trachea while holding the endotracheal tube. Then, the endotracheal tube and ETI assembly is advanced so that the tip of the endotracheal tube approximates the thoracic inlet; the tip of the ETI will be located approximately 2.5 cm closer to the carina. The ETI is removed upon placement of the endotracheal tube. Although the ETI is flexible, an error underestimating depth of insertion might allow the ETI to pass the carina and enter smaller airways. In humans, purposefully inserting the flexible ETI until it reaches the carina has been described; however, damage to the smaller airways may occur.\textsuperscript{22} Hence, safe application of the technique described here requires estimation of how far the endotracheal tube is to be inserted prior to insertion. Nevertheless, we did not observe any indications of trauma during intubation, and all cats were discharged from our institution without complications.

While fewer attempts were required to intubate cats when the ETI was used, the time to complete intubation was not different between groups. Considering that more attempts were required when the ETI was not used, it is difficult to speculate why no difference was found in the total time to complete the maneuver. It is possible that first attempts were abandoned promptly when the ETI was not used because of an inability to pass the endotracheal tube through the larynx, while some students using the ETI might have felt encouraged to continue the first attempt as they could observe that the ETI had already passed the larynx and was situated in the trachea. Despite an absence of difference in the time to intubate and an absence of difference in the failure rate, the improved success at first attempt and lower number of attempts required to intubate suggest an advantage with the use of the ETI. Data for humans show that repeated attempts to intubate are associated with increased risk of complications. Our data set does not allow us to confirm a similar observation in cats, but it suggests a hypothesis that might be worthwhile testing in a larger group of cats (ie, that use of an ETI reduces the incidence of intubation-related complications in cats).

We performed multivariate regression to examine whether various factors would be associated with the success rate of first-attempt intubation. Different instructors and previous experience of the students were not associated with the probability of first-attempt success; however, the number of students with prior experience intubating in cats was small and likely insufficient to draw conclusions. A similar uneven distribution within groups was observed for position of the arytenoid cartilages prior to intubation; in both groups, arytenoid cartilages were moving in most cats, while closed or open rima glottides were observed only in a small proportion of animals. Weight of the cats and tube size-to-weight ratio were not associated with the probability of success but were close to reaching significance. Predictably, cats of greater weight and smaller tube size-to-weight ratios were related to higher success of intubation. The internal diameter of the tube by itself (not as a ratio of the cat’s weight) was a significant covariate, whereby small tubes were associated with a lower success rate for first-attempt intubation. It is possible that this observation is associated not only with the tube size, but also with the size of the cats, as smaller tubes were selected for smaller animals. It is also possible that tubes with an internal diameter of 3 mm are more flexible than larger ones; hence, more difficult to pass through the larynx and into the trachea if resistance is encountered. After all nonsignificant covariates were eliminated, only use of an ETI and internal diameter of the tracheal tube remained as significant factors.

This study evaluated first-attempt success to intubate by veterinary students, with minimal to no experience intubating cats. While our results show that the use of the ETI improved this outcome, it is difficult to predict whether the ETI will provide an advantage to more experienced anesthetists. However, our data, and those of others obtained in humans,\textsuperscript{12} suggest that it might be worth considering the use of ETI during first-attempt intubation in cats, rather than as a salvage maneuver after intubation has failed, or when the airway is anatomically abnormal and visualization of the larynx is suboptimal. Unlike rigid styles, flexible introducers such as the ones used here are probably less likely to result in traumatic injury to the airway and might be superior for routine use during intubation of uncomplicated airways.

Both groups of cats studied were similar in terms of demographic characteristics and anesthetic drugs used, except for the use of ketamine; more cats assigned to ETI received ketamine to enhance sedation prior to catheterization. However, ketamine was not a significant covariate associated with a higher probability of success of first-attempt intubation; hence, it is unlikely that this difference substantially biased the results. There are other limitations to this study: the sample size was sufficient to test our primary hypothesis but was possibly insufficient to evaluate whether the proportion of failed intubations differs with the intubation technique, since this was an infrequent event. We were not able to perform tests to evaluate any possibility of mild trauma to the larynx. While no blood was observed on the ETI or endotracheal tubes and cough was not observed in the postoperative period, more sensitive evaluation techniques might provide more information regarding complications with either technique, such as direct laryngeal visualization or upper airway endoscopy performed at extubation.
Small tubes were associated with a lower success rate for first-attempt intubation. While no differences were found between groups in terms of distribution of tube sizes, it is possible that the sample size was insufficient for that variable.

In summary, the use of flexible ETI improved the success of first-attempt intubation of cats by veterinary students. This technique might help minimize the number of attempts during intubation and incidence of complications that could arise from multiple attempts.

References