Feline Intubation Assist Device
in the context of
MEAM 099

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1 Abstract

A novel veterinary oral intubation assist device optimized for domestic felines with restricted airways was designed and prototyped. Oral endotracheal tubes are inserted through a patient's airway in order to facilitate procedures that require tracheal penetration. Although endotracheal intubation is a routine procedure in animals with uninhibited airways, intubation in cats with restricted airways can be challenging because the procedure would be performed with an available lumen for intubation of less than 1mm. This acute narrowing of the airway can lead to life threatening complications if not addressed immediately. This paper discusses the design of a novel intubation assist device that facilitates the insertion of the conduit by widening the airway in a manner that minimizes trauma.

2 Background and Problem Definition

In one case study, a 5-year-old male domestic shorthair cat underwent intubation as part of the regular anesthesia process. Orotracheal intubation was performed on the feline patient by an anesthesia technician. Following two failed attempts at guiding the tube through the airway, the tube was forcefully inserted, causing some physical trauma of the cat's airway: blood was observed around the arytenoid cartilages where the ETT passed through. A fold of tissue could be seen between the ETT and the patient's left arytenoid. A laceration lateral to the patient's right arytenoid was also observed post-extubation. In both human and veterinary medicine, when general anesthesia is required for medical and surgical procedures, endotracheal tubes (ETTs) are inserted through the patient's larynx to establish and maintain a patent airway. Small domestic animals usually experience no problems when using standard endotracheal tubes, but cats are at higher risk for upper-airway trauma in comparison to dogs. Additionally, emergency situations that involve airway inflammation or tumors make it even more difficult to penetrate the laryngeal opening and intubate the animal. Airway obstruction due to the closing of the vocal cords and inflammation may result from trauma.

Airway Anatomy

The rima glottis lies caudal of the epiglottis and describes the space between the two true vocal cords. The narrowing of the upper respiratory tract can lead to asphyxiation.

In order to minimize injury to the arytenoids and larynx, it would be beneficial if a device that could harmlessly penetrate the rima glottis, then expand into an appropriately sized tunnel allowing for unblocked intubation, were available. This device could potentially be used in both human and veterinary patients...
when immediate access is required for emergency resuscitation procedures, including cases of trauma, oral or airway cancer, and in the intubation of morbidly obese patients.

The most common endotracheal tube device is the Magill tube, an arched and cuffed plastic tube with a beveled end. While the beveled end of the Magill tube does aid placement of the instrument, it has led to unsatisfactory results in the intubation of animals with restricted airways.

3 Solution Development

In developing a solution, the following points were considered:

- Clinical utility
- Ease and speed of insertion and placement
- Compatibility with prevailing surgical equipment and technique
- Adequacy of airway maintenance
- Adaptability to anatomical variation
- Minimization of trauma
- Cost of manufacturing

One existing self-adjustable endotracheal tube design use a memory device that creates a collapsible middle portion, but the proximal and distal ends are rigid [3]. An expansion device based on a stent was previously developed [6]. A sheathed stent is located at the distal end of the conduit used to deliver gases to the patient, and is for inhibiting the body lumen from collapsing. A stand-alone device that aids in the expansion of the airway and allows for regular intubation procedure using the Magill tube is currently lacking.

Specific analysis necessary for the design and fabrication of the intubation assist device include an evaluation of the expected forces exerted by the larynx and trachea on the device in its expanded form, and finding a configuration of material that can withstand and expand against these forces. The pressure in the proposed expanding device and collar will be in the range of 20-30 cm H$_2$O[4].

Collar designs would require an expandable piece. To allow for variations in trachea and neck length, the final collar will also be flexible, although the prototype is not made of the final material. Additionally, the collar:

- will not need to exceed 2 centimeters in length
- will need to be available in assorted sizes for different breeds and situations
- could be tapered (for easier insertion, low risk of fall-through)
- could be spool-shaped (to remain securely in place throughout procedures)
- could be made of hard or soft polymer
- could have crenellated ends to facilitate moving with basket through glottis
- would be disposable in humans, but could be reused if not damaged; autoclavable
- can be fabricated in SEAS facilities: 3D print a pattern, make a mold
4 Final Solution

The final design includes an expansion device and collar 4 that will hold the rima glottidis open during intubation.

The flexible expandable device will first be inserted into the airway and expanded fully, as shown in figure 4.
Collar

Collar and Bayonet Connection

Collar Passing Over Expansion Device

Collar Interdigitating with Expansion Device
A small collar 4 will be manually slid along the expandable device and interdigitate with the expanded portion, where it will fit snugly against the expanded airway. The collar will be released from the white placement device when the user turns the placement device slightly, adjusting the bayonet mount. The placement device is then removed. The expandable device is pulled into its closed configuration and removed from the airway, while the collar remains inside 4. Regular intubation can then proceed. While it is not shown in the prototype, the collar will be tapered to prevent sliding further down the airway. After the Magill tube has passed through the rima glottidis, collar will either be slid out naturally later removed using forceps after extubation.

4.1 Prototype Materials
The expansion device is fabricated using a 1/128 diameter solid steel shaft and the following two types of Tygon tubing supplied from Cole Parmer Instrument Co:

1. Tygon tubing with Inner Diameter 1/16, Outer Diameter: 1/8

2. Tygon tubing with Inner Diameter 1/256”, Outer Diameter: 1/128

The collar prototype is fabricated out of aluminum. Its distal end consists of three grooves to interdigitate with the expanded basket. Its proximal end consists of a bayonet mount to attach to a separate tube that
will facilitate placement of the collar in the airway.

Lastly, the handle of the prototype is made of a sliding tin box for ease of fabrication and functionality. While a functioning prototype has been developed, the images 4 depict a collar that is much larger than that of the actual design. Some refinement will be necessary to modify the expanding device so that each loop of the expansion device behaves like a beam undergoing deflection with fixed and simply supported end conditions.

1. Expandable mainspring collar:
A self-expanding sheet-metal or inert polymer mainspring strip initially coiled into thin tube and held by two thin shafts.

![Mainspring Collar](image)

Intubation:

1. sheet coiled tightly for insertion
2. release string and/or shafts to allow expansion of the collar
3. mainspring will expand in glottal area
4. remains in glottal area during intubation

Extubation:

1. remove endotracheal tube first
2. rewind mainspring using a coiled mechanism such as that in USB rewind devices
3. remove coiled mainspring safely from airway

Advantages:

- separate part allows usage of unmodified endotracheal tube
- provides easy access for tube
- protects glottis from further damage

Disadvantages:

- separate procedure necessary for insertion of tube
- recoiling of mainspring can be inconsistent
- risks associated with using metal sheets and springs

2. Inflatable collar A silicone rubber balloon cuff will form a collar in the rima glottidis when inflated.

Intubation:
1. select collar and place loosely around the flexible cable
2. guide the cable to and through the glottis via laryngoscope
3. expand the basket end of the cable to force the glottis open to the desired degree
4. advance the collar over the basket
5. advance collar and basket together slightly, and through the glottis
6. contract the basket and withdraw the cable entirely from the airway, leaving the collar in place
7. proceed with intubation normally

**Extubation**

1. release and withdraw the trach tube
2. withdraw the collar, presumably by grasping with forceps

Disadvantages:
- difficult to control the volume of the lumen when expanded
- difficulty of fabrication

3. Expandable "stent" Interface The Patient end of the endotracheal tube would be replaced with a sheathed expandable mesh that would originally be of small diameter, then expand upon entering the airway.

**Intubation:**

1. insert sheathed tube
2. pull back sheath to allow tube to expand in airway
3. proceed with intubation normally

**Extubation**

1. slide sheath over conduit and expandable mesh, recapturing it
2. withdraw the ETT

Advantages:
- separate part allows usage of unmodified endotracheal tube
- provides easy access for tube
- protects glottis from further damage

Disadvantages:
- difficulty of interfacing stent design with traditional ETT
- difficulty of guiding expandable portion through the rest of the airway
- difficulty of recapturing sheath
- difficulty of fabrication
- uncertainty if mesh is strong enough to hold open airway
- requires modification of traditional ETT
5 Conclusion and Further Recommendations

Some refinement will be needed to transform the prototype into a clinically feasible product. The design currently awaits cadaver testing at the Ryan Veterinary Hospital at the University of Pennsylvania.

The planning and development of the intubation assist device highlighted a number of concerns related to designing products for use in veterinary medicine. First, the selective coverage of veterinary pet insurance encourages the development of reusable, assistive products over that of completely new products that would replace tools that are currently widely used and mass-produced. Additionally, the product must be something that can be sterilized for use near living patients. And lastly, the anatomy and needs of veterinary patients can differ greatly amongst dissimilar breeds and species. This specific tool is developed to meet the needs of feline patients with restricted airways - a subcategory of domestic cats.
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