PERFORMANCE OF A PLASTIC OPTICAL FIBER STYLET FOR TRACHEAL INTUBATION OF A DOG

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ABSTRACT. Objective. We set out to establish whether a novel plastic optical fiber incorporated into an endotracheal tube (ETT) stylet could be used for intubation of a dog. A secondary objective examined the need for a direct illumination source from a laryngoscope. Lastly, the fragility of the system was tested. **Methods.** An anesthetized dog was repeatedly intubated using a laryngoscope to elevate the tongue and the view of the larynx conducted through the plastic optical fiber stylet (placed within an endotracheal tube) and displayed on a television monitor. Four prototype identical stylets were tested. Repeated intubations were attempted with each stylet and graded as either successful or failed. All four stylets were tested 10 times each using a Miller 4 blade and direct illumination from the laryngoscope. Two of the four stylets were reused during an additional 10 intubation attempts using a Miller 4 blade and laryngoscope (without batteries) with only ambient light. Finally, one stylet was used for intubation after 10, 20, 30, 40 and 50 sharp 90 degree bend-and-straighten cycles using a Miller 4 blade and laryngoscope for direct illumination. **Results.** All attempted intubations were successful. However, the image quality was dramatically better when direct illumination from a laryngoscope was used than when ambient light was used. One plastic optical fiber stylet was successfully used to intubate after having been used for 20 intubations and 50 sharp 90 degree bend-and-straighten cycles. A partial lens separation occurred between the 41st and 50th bend cycle but the image remained adequate enough to successfully intubate again. **Conclusions.** A novel plastic optical fiber incorporated into an ETT stylet can be used with a laryngoscope for intubation of a dog. Direct illumination from a laryngoscope provides a better television monitor image than when only ambient light is used. The system was durable, withstanding over 20 uses and 40 sharp bend-and-straighten cycles before a lens separation failure occurred.

KEY WORDS. Fiberoptic, stylet, imaging, plastic, intubation, airway.

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INTRODUCTION

A number of fiberoptic imaging and intubation devices are available to assist with indirectly viewing the larynx and vocal cords. They include the fiberoptic bronchoscope, the Bullard® (Circon ACMI, Stamford, CT) and UpsherScope™ (Upsher Laryngoscope Corp, Foster City, CA) laryngoscopes, the WuScope™ (Achi Corp, Dublin, CA) and the Visualized EndoTracheal Tube System™ (Pulmonx, Palo Alto, CA). These systems rely on fragile and expensive glass fiberoptic illumination and image guides to transmit light to the distal (i.e., patient) tip of the system and transmit the image from the device's distal end proximally for display and viewing.

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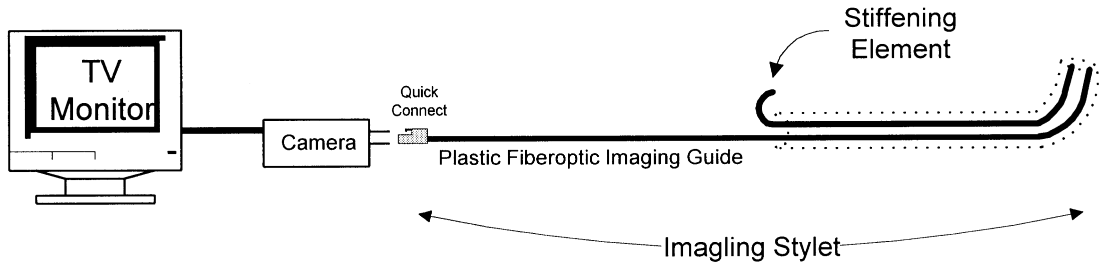

Fig. 1. This diagram shows the components of the plastic fiberoptic imaging system. The stiffening element is inserted into an endotracheal tube and is formed to the desired shape. During laryngoscopy, the airway structures are viewed on the TV monitor and the endotracheal tube with imaging stylet is manually steered between the vocal cords and into the trachea.

We investigated the feasibility of using a novel fiberoptic imaging and intubation aide. Instead of glass fibers, the device utilizes a plastic fiberoptic imaging system (Nanoptics, Inc, Gainesville, FL) incorporated directly into an endotracheal tube (ETT) stylet (Figure 1). The so-called "imaging stylet" has a diameter of 6.0 mm and consists of a 2.2 mm diameter malleable metal stiffening element and 1.6 mm diameter plastic fiberoptic image guide (Optiplast™; Nanoptics, Inc, Gainesville, FL) contained within a sheath (Figure 2). The image guide is a 1000 filament fiber with attached lens. The lens has a 5 mm focal length and a 70 degree field or view. The fiber's allowable radius of curvature is 10 mm. It runs the 35 cm length of the stiffening element and extends as a free length approximately 50 cm beyond the stiffening element's proximal end. On the free length end is a quick snap connector that attaches to a board level camera (PC-30XC, SuperCircuits, Leander, TX). The camera features included a 0.33 inch Charge Coupled Device with a 330 line resolution, 2.5 lux low level light detection limit, automatic gain control, and automatic white and black balance. The camera image was displayed on a 9 inch color video monitor (Symphonic TVCR9F1; Funai Corp Inc, Teterboro, NJ).

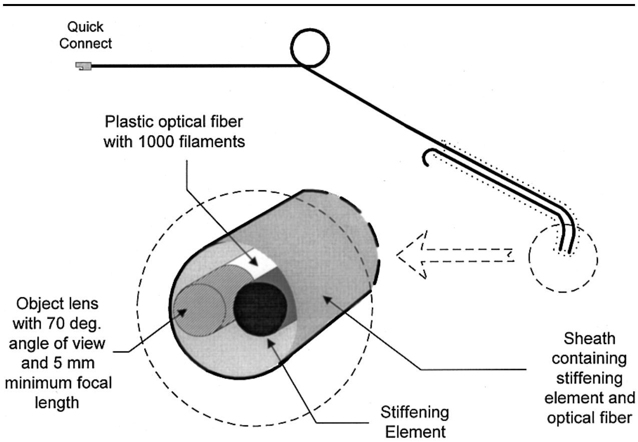

Fig. 2. An illustration of the components and specifications of the imaging set.

METHODS

After Institutional Animal Care and Use Committee approval, a 23 kg mongrel dog was studied under general anesthesia after an antisialagogue had been administered. A low tracheostomy was performed after induction of anesthesia and an 8.0 mm inner diameter ETT placed into the tracheostomy to facilitate ventilation during the repeated tracheal intubations of the research protocol.

Intubations using the imaging stylet were performed orally using a 7.5 mm ID ETT with the dog in the supine position. The ETT was mounted over the imaging stylet and formed into a slight "hockey stick" configuration. During intubation, the laryngoscope was used to elevate the tongue and illuminate the larynx. Direct visualization of the larynx with the laryngoscope was not attempted. Illumination of tissue structures was either provided by the laryngoscope light source or ambient light. No light source was connected to these imaging stylets. The laryngoscopist intubated using only the image of the larynx conducted through the imaging stylet and viewed on the video monitor. The intubation was repeated 10 consecutive times for each of four identical imaging stylet assemblies. To test the image in the absence of direct illumination, two stylets were re-used to intubate the dog's larynx in a similar fashion an additional 10 times each but this time with the laryngoscope light off using only ambient light. The camera iris was opened fully to permit maximum collection of light for these intubations. All intubation attempts were graded as either "successful" or "failed."

The fiber's robustness was tested by taking one stylet

Table 1.

Imaging stylet	No. 1	No. 2	No. 3	No. 4
Group A	10	10	10	10
Group B	10	X	10	X
Group C	50	X	X	X

This table shows the number of consecutive intubations accomplished with each of four stylets. Group A intubations were performed with a laryngoscope light. Group B intubations followed completion of Group A tests and were performed without a laryngoscope light. Regular room light with the camera iris fully opened provided the illumination. Group C tested fiber robustness by intubating after 10, 20, 30, 40, and 50 sharp 90 degree bend-and-straighten cycles. Partial lens separation occurred after the 40th cycle. There were no failures to intubate. Stylets not tested in any group are identified by an 'X'.

(that had been used for 20 previous intubations) and repeatedly bending it about 4 cm from its distal tip to a 90 degree angle and then straightening it again. After every 10 bend-and-straighten cycles of the imaging stylet, an oral intubation was attempted with it.

At the conclusion of the study the dog was sacrificed.

RESULTS

The dog was successfully intubated without any failures using only the view from the imaging stylet displayed onto a screen in all 40 intubation attempts where direct illuminiation was provided by the laryngoscope blade lamp (Table 1). The image produced by each of the four imaging stylets used was comparable although there were minor differences in fiber quality observed as some dark pixels in each of the stylets.

The dog was also successfully intubated without any failures using only the view from the imaging stylet displayed onto a screen in all 20 intubation attempts where no direct illumination was provided (Table 1). Although not objectively graded, the image produced using only ambient light and fully-opened camera iris was dramatically dimmer than the image produced when direct illumination was used but was nevertheless sufficiently bright to allow successful intubations.

Imaging stylet No. 1 was successfully used to orally intubate the dog's trachea after 10, 20, 30, 40, and 50 sharp bend-and-straighten cycles (Table 1). There was no change in the displayed image until the system was tested after the 50th cycle when half the image was hazy. This was found to be caused by a partial lens separation from the distal tip that must have occurred sometime after the 40th bend-straighten cycle.

DISCUSSION

This study established that the study dog's trachea could be easily intubated using a standard laryngoscope with a Miller 4 blade either with or without the aid of the laryngoscope light when a novel plastic imaging stylet was used.

All stylets had been ethylene oxide (ETO) sterilized once with no obvious image compromise. Although the system withstood one ETO sterilization without compromised image quality, it remains to be established if quality will remain so after multiple sterilizations.

The four imaging stylets tested produced comparable image quality. The image quality was sufficient to allow successful intubation with every attempt; although, subjectively, the image quality is obviously inferior to glass fiberscopes with 5000 to 10 000 pixels used in clinical practice.

Dark pixels observed in all stylets were thought due to impurities in the plastic or gas bubbles that formed during manufacture. Failure testing of one stylet demonstrated that image quality remained adequate for intubation even after multiple 90 degree bend maneuvers. Failure occurred after 40 sharp 90 degree bends due to partial separation of the lens. No pixels were lost during these 40 bend-straighten cycles, suggesting the plastic fiberoptic fibers are durable. The other three stylets did not fail during their uses for 10 to 20 intubations.

The imaging stylet has a number of performance features that it shares with other commonly used devices. It provides a view of the vocal cords and trachea during intubation. This beneficial feature of a fiberoptic assisted intubation has been recognized since its earliest description [1]. The plastic imaging stylet can also be easily formed into any desired configuration and hand-steered in a natural manner. The advantages of a steerable imaging system has been known for many years [2, 3]. The imaging stylet's position within the lumen of the ETT also provides the laryngoscopist with a continuous and unaltered view of the larynx during intubation, a value recognized by the developers of the optical stylet (K Storz, KG, Tuttlingen, Germany) [4]. The conventional glass fiberoptic devices are fragile and expensive, have a tip that flexes at a fixed length in one plane, and can be difficult to rotate. In contrast, the imaging stylet uses plastic optical fiber which makes the device durable and potentially inexpensive to manufacture. Furthermore, it allows the tip to be bent at any angle at any length and the stylet to be easily rotated with natural hand and wrist movements.

In conclusion, a plastic imaging system incorporated into a stylet can be used to intubate a dog. The system's appeal lies with its location within the ETT, intuitive steering control and robustness. The image achieved with direct illumination from the blade light was vastly superior to only ambient light. Preliminary work at our institution with a new version of the imaging stylet suggests that intubations of human patients will be possible without the need to visualize the larynx directly. Other enhancements that may add value to this method of intubation include the addition of an open channel for suction, irrigation and insufflation of oxygen through the imaging stylet and smaller sizes to permit use with smaller ETTs.

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