Resuscitation 80 (2009) 1066–1069

Contents lists available at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Short communication

Development of a rapid, safe, fiber-optic guided, single-incision cricothyrotomy using a large ovine model: A pilot study☆

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ARTICLE INFO

Article history:
Received 7 May 2009
Accepted 27 May 2009

Keywords:
Airway
Airway management
Cricothyroidotomy
Emergency treatment
Respiration
Artificial
Resuscitation

ABSTRACT

Study aim: We present a pilot study in which we use an ovine model to develop a rapid, safe cricothyrotomy technique using a Melker cuffed 5.0 cricothyrotomy catheter loaded over a fiberoptic stainless steel optical stylet. The technique requires a single incision. The stylet allows easy placement and facilitates visual, tactile, and transillumination confirmation of intratracheal placement. We recorded this process on video to facilitate the development of the procedure and to allow others to replicate it for further research or refinement. All devices used in this technique are currently employed in clinical practice.

Methods: We performed the procedure in four anesthetized sheep, varying the technique to maximize speed, demonstrate pitfalls, and optimize video recording of confirmation methods. We recorded each case using a 4-channel digital video recorder.

Results: After making a single scalpel incision we inserted the stylet and confirmed placement by visualization, transillumination, “click” palpation, and gentle stylet-driven tracheal displacement. We passed the cricothyrotomy tubes without difficulty and easily ventilated the animals.

Conclusion: The procedure is rapid, incorporates redundant safety features, and uses equipment increasingly available to anesthesiologists, emergency physicians, intensivists and surgeons. The promising outcome of this pilot study should be verified in a larger controlled, comparative trial.

1. Introduction

Improved primary airway management techniques have decreased the incidence of cricothyrotomy.[1,2] Inexperienced personnel have difficulty performing standard surgical and wire-guided seldinger procedures.[3] Despite all the improvements in airway management, patients with significant supraglottic pathology may still require emergent cricothyrotomy. As a result, investigators continue to suggest modifications to existing techniques.[4] Our research[5] and clinical experience[6] leads us to believe that fiberoptic stylets can facilitate relatively easy, safe, and fast cricothyrotomies in anatomically challenging patients who fail intubation. Optical stylets are firm, narrow, offer precise control, and closely match the inner diameter of cuffed seldinger-kit cricothyrotomy tubes. As a result, clinicians could insert stylets after a single incision, perform both visual and tactile confirmation maneuvers for redundant safety, and advance the tube without dilation.

We performed a pilot study of fiberoptic stylet-guided cricothyrotomy in sheep. The purpose of the study was to develop this novel approach in a relevant live model and present a standard method to other clinicians and investigators, who may wish to compare it with existing approaches to cricothyrotomy or further refine the technique.

2. Methods

2.1. Choice of animal model

We used a live anesthetized animal model because bleeding, mucous soiling, and other conditions that only such models can duplicate greatly affect the success of both surgical and fiberoptic techniques. We chose 61–74 kg sheep (Barton West End Facilities, Oxford, NJ) because we have experience working with them,[5,7] they provide a well-accepted model of human airway and respiratory physiology and pathophysiology,[8–13] and the anatomic dimensions relevant for modeling cricothyrotomy are comparable to humans.[14,15]

The most detailed paper on comparative anatomy used sheep larynxes obtained from a slaughterhouse and human cadaver data

☆ A Spanish translated version of the abstract of this article appears as Appendix in the final online version at doi:10.1016/j.resuscitation.2009.05.024.

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doi:10.1016/j.resuscitation.2009.05.024

from an earlier publication.[15,16] Although there were meaningful differences in laryngeal anatomy, the dimensions relevant to this work were similar. The anterior–posterior diameter of the inferior aspect of the ovine thyroid cartilage was slightly smaller than the male human specimens. The superior border of the ovine cricoid ring was slightly larger in sheep. Lateral dimensions measured at the inferior cornu and across the superior border of the cricoid ring were also comparable. Because the ovine larynx specimens were obtained from a slaughterhouse (likely near the University of Iowa[15]) the authors do not provide sheep weights. The US Department of Agriculture reports that the average live weight of sheep slaughtered in the US is 142 pounds,[17] close to that of the sheep used in the present study.

2.2. Care of animal participants

This study was approved by the SUNY Downstate Medical Center Animal Care and Use Committee and followed American Association for Laboratory Animals care guidelines.

The sheep were stored in livestock pens with free access to food and water until 8 h prior to the experiment. We pre-medicated the sheep with IM glycopyrrolate (A.H. Robins, Richmond, VA) 0.15 mg/kg, and sedated them with IM ketamine 15 mg/kg (Fort Dodge Animal Health, Fort Dodge, IO) and xylazine 0.01 mg/kg (Bayer, Shawnee Mission, KA) and then transported them to lab. There we weighed the sheep, placed them on the operating table, and initiated oxygen saturation and heart-rate monitoring. We obtained intravenous access, administered thiopental 3 mg/kg (Abbot, North Chicago, IL), and orotracheally intubated them. We did not use neuromuscular blockers, and the animals were carefully monitored for any sign of distress. We provided additional 1–3 mg/kg boluses of thiopental as needed. The animals were ventilated through an endotracheal tube during set-up. We discontinued ventilation during cricothyrotomy and restarted it using the cricothyrotomy tube once the latter was in place. The animals were sacrificed using intravenous pentobarbital 30 mg/kg (Fort Dodge Animal Health, Fort Dodge, IO).

2.3. Video

We used a 4-channel digital video recorder (Model DMR-5, Supercircuits, Austin, Texas) to display and collect all images. The recorder employed a capture rate of 30 frames/s with 720 × 480 lines/in. resolution, and integrated two exterior cameras as well as all endoscopic images into the same monitor display.

2.4. Development and documentation of the technique

We performed cricothyrotomy by palpating the cricothyroid membrane, making a single horizontal incision through it, inserting a Levitan fiberoptic stylet (Clarus Medical, Minneapolis, MN), and confirming tracheal placement (see below). We then advanced a pre-loaded Melker 5.0 mm ID cuffed cricothyrotomy tube (Cook, Bloomington, IN) over the fiberoptic stylet (Fig. 1), and withdrew the stylet. To clear the optical stylet of blood and mucus, we wiped the lens against the tracheal mucosa. This method is routinely used by otolaryngologists during endoscopic nasal sinus surgery.

Before advancing the tube, we confirmed cricothyroid membrane puncture and tracheal placement by

(1) Tracheal visualization: tubular shape/rebound/rings (Fig. 2).
(2) Transillumination (Fig. 3).
(3) Palpation of clicks, enhanced by trapping the tracheal cartilage and skin between the operator's finger and stylet tip.
(4) Gentle side-to-side tracheal displacement using the stylet.

Fig. 1. A 5.0 mm ID Melker cuffed cricothyrotomy tube mounted on a Levitan optical stylet. Note the #20 scalpel.

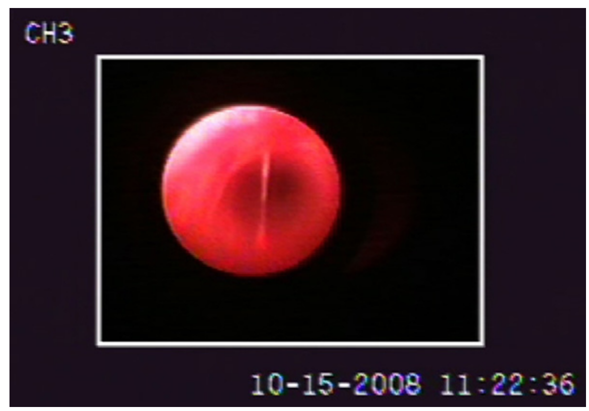

Fig. 2. Monitor display of trachea obtained cricothyrotomy procedure, showing characteristic round shape and mucous dripping from anterior wall.

2.5. Planned variations in technique

For the first two animals we wished to obtain video through the endotracheal tube, so we left it in place, without ventilation, during and after the cricothyrotomy. We also performed low tracheotomy and inserted a Shikani optical stylet (Clarus Medical, Minneapolis, MN) in order to facilitate video capture of the optical stylet and cricothyrotomy tube entering the airway. In the third and fourth animals we did not perform tracheotomy and with-

Fig. 3. Transillumination of trachea, seen in well-lit room (image taken from video).