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Ultrasound Imaging for Endotracheal Tube Repositioning During Percutaneous Tracheostomy in a Cadaver Model: A Potential Teaching Modality

Peter M. Tonui, MD,[1] Andrew D. Nish, MD,[2] Hayden L. Smith, PhD,[3,4] Paul V. Letendre, MD,[4] Dustin R. Portela, DO[5]

[1]*Trauma Services, Iowa Methodist Medical Center, Des Moines, IA*
[2]*Department of Radiology, Iowa Methodist Medical Center, Des Moines, IA*
[3]*Medical Education Services, Iowa Methodist Medical Center, Des Moines, IA*
[4]*Department of Internal Medicine, Carver College of Medicine, University of Iowa, Des Moines, IA*
[5]*College of Osteopathic Medicine, Des Moines University, Des Moines, IA*

ABSTRACT

Background: Percutaneous tracheostomy (PCT) is a widely accepted method for the insertion of a tracheostomy tube in a critically ill patient. Because a patient's preexisting endotracheal tube is manipulated during the procedure, premature extubation with potential catastrophic loss of airway control is a risk. As portable ultrasound imaging becomes increasingly useful in the critical care setting, investigations continue to determine the safety of PCT with the technology.

Methods: Introduction of an endotracheal tube in the proximal airway under bronchoscopic guidance was performed in a cadaver. The endotracheal tube cuff was inflated with agitated water and visualized using a portable ultrasound device. The endotracheal tube cuff was then withdrawn under ultrasound guidance to the proximal trachea.

Results: Sonographic visualization of the endotracheal tube cuff within the trachea was successfully achieved. The endotracheal tube was withdrawn to the proximal trachea, and satisfactory needle cannulation of the trachea was performed.

Conclusion: Ultrasound can be used to identify an endotracheal tube cuff during a PCT, and repositioning the endotracheal tube under ultrasound guidance could decrease the risk of accidental extubation. This approach to PCT may be used in a cadaveric model to teach anatomy and procedural skills to learners and possibly further adopted in real patients to improve the overall safety profile of the PCT procedure.

Address correspondence to
Peter M. Tonui, MD
Trauma Services
Iowa Methodist Medical Center
1200 Pleasant St., S444
Des Moines, IA 50309-1453
Tel: (515) 241-4190
Email: peter.tonui@unitypoint.org

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INTRODUCTION

Nearly 25% of intensive care unit (ICU) patients with prolonged mechanical ventilation require a tracheostomy.[1] Historically, placement of the tracheostomy was achieved with an open surgical approach involving dissection through the anterior neck tissues to the level of the trachea where a stoma was created. In 1985, Ciaglia et al published a landmark paper describing a new minimally invasive technique for percutaneous tracheostomy (PCT).[2] This technique has been increasingly accepted as an alternative to open surgery, and further improvements, such as the use of fiber-optic bronchoscopy, have been adopted over time.[3]

Among the described advantages of PCT is the ability to perform the procedure safely in the ICU rather than in the operating room.[4,5] In the ICU setting, the procedure may be performed by critical care providers without advanced surgery training (eg, anesthesiologists or pulmonary intensivists). Successive studies have found the complication rates of PCT to be comparable to, if not lower than, traditional surgical methods.[4,6,7] Investigations of resource utilization and cost effectiveness have also favored PCT compared to surgical methods.[4,8]

A crucial step in PCT involves bronchoscopic visualization of the needle entering the anterior trachea. Prior to this step, the endotracheal tube

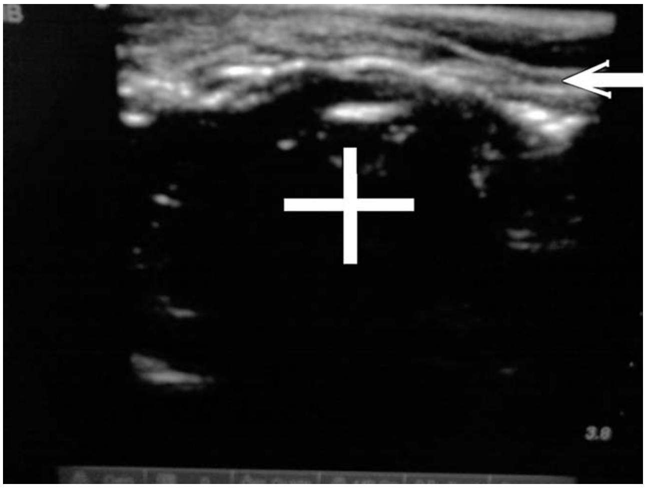

Figure 1. Anterior tracheal wall visible as a hyperechoic stripe on a transverse view of the neck with a probe placed over the suprasternal notch (represented by the arrow), imaged using a point-of-care ultrasound machine. The tracheal lumen lies immediately below the anterior tracheal wall (marked by the white cross).

(ETT) is withdrawn to the proximal trachea to guard against needle damage to either the ETT or the bronchoscope. The distance the ETT must be withdrawn varies considerably depending on the patient's size and anatomy. Premature loss of airway may occur during the process. In ventilated and critically ill patients, the consequences can be dire, including possible oropharyngeal trauma during reintubation, hypoxic cardiac arrest, or anoxic brain injury.

Ultrasonography is being increasingly used in the ICU environment, with recognized application in the placement of central venous catheters, insertion of chest tubes, and pericardiocentesis.[9] Ultrasonography's use in tracheostomy for improved anatomical identification was first described in 1995, and subsequent publications described preoperative and real-time ultrasonography use with PCT placement.[10-13] None of the previous studies has specifically discussed sonographic visualization of the ETT cuff for the purposes of repositioning the ETT. We describe a novel approach for decreasing the risk of inadvertent extubation using ultrasound guidance to aid in the repositioning of a patient's ETT and suggest a plausible training modality for learners.

METHODS

This procedure was a cadaver-based feasibility study to assess methods of increasing patient safety during PCT and to serve as a possible model for training physicians. Institutional review board approval was not required for this project.

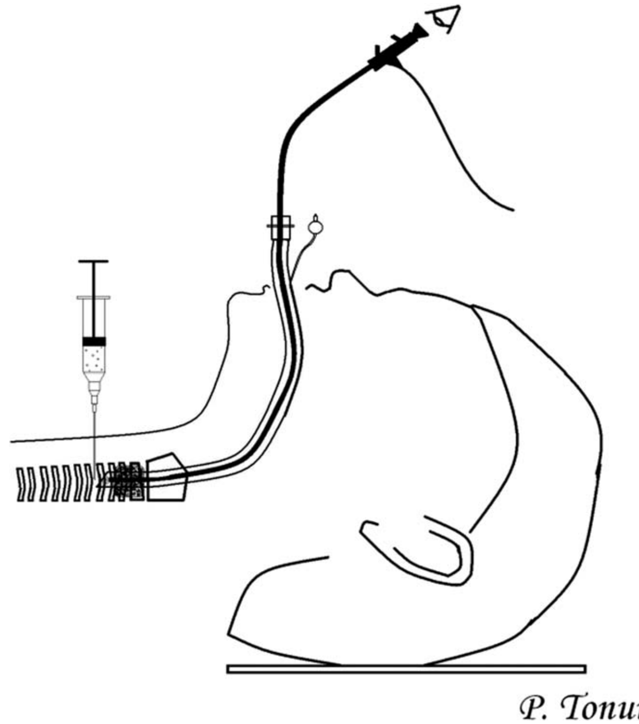

Figure 2. Customary position of the endotracheal tube in the proximal trachea prior to insertion of the introducer needle through the anterior trachea wall with bronchoscopic guidance.

The study cadaver was placed in a supine, neck-extended position, and ultrasound coupling gel was applied to the anterior neck. A Sonosite M-Turbo (SonoSite, Inc.) point-of-care ultrasound with SonoSite HFL50x 15-6 MHx linear array transducer was used to identify and evaluate the laryngeal anatomy. The anterior cartilaginous wall of the trachea was identified as a distinct hyperechoic line casting a strong acoustic shadow posteriorly (Figure 1). The posterior tracheal wall was inconsistently identified as a less distinct hyperechoic line.

A Sheridan size 7.5 cuffed ETT was positioned over a fiber-optic bronchoscope (Pentax FB-19H) and introduced into the proximal trachea (Figure 2). The ETT pilot balloon was inflated with tap water. At this point, the inflated pilot balloon was not readily visualized by ultrasound. To augment visualization, microbubbles were created in the water used to inflate the pilot balloon. The microbubbles were achieved by rapidly transferring water from 1 syringe to another several times. This agitated water was used to reinflate the ETT cuff. Under ultrasound guidance, the cuff was retracted to the level of the cricoid cartilage.

Procedural equipment consisted of a puncture needle and guidewire. The procedural plan called for the needle to enter the trachea between the second and third tracheal rings, as close to the midline as possible. A 1.5-inch 16-gauge needle was loaded onto a 10 mL syringe that had been partially filled with water. The needle was then introduced perpendicular to the skin and slowly advanced until the needle tip entered the trachea. Gentle suction was applied to the syringe as the needle passed through the soft tissues. Entrance into the trachea was marked by a decrease in soft-tissue resistance and aspiration of air into the partially filled syringe. The syringe was detached from the needle and a guidewire introduced into the distal trachea through the 16-gauge needle, as is customary in PCT procedures.

RESULTS

Inflation of the ETT pilot balloon with agitated water permitted ultrasound-guided repositioning of the ETT tip to the proximal trachea. On sonographic imaging, microbubbles from the agitation were detectible and the cuff was visualized. Visualization of the echo-dense fluid-filled cuff within the trachea facilitated ETT withdrawal to the proximal trachea, as is desired during PCT. Concurrent ultrasound screening of pretracheal structures and anatomical soft tissue landmarks in the anterior neck allowed for accurate placement of the ETT. Needle cannulation of the anterior tracheal wall was then performed, with needle entry occurring within the bronchoscopic field of view and distal to the ETT tip.

DISCUSSION

PCT continues to gain popularity and is supplanting open tracheostomy as the method of choice for tracheostomy tube insertion in many ICUs.[14-16] Utilizing bronchoscopy, we were able to intubate a cadaver and inflate the ETT pilot balloon with manually agitated water. The microbubbles in the water enhanced the sonographic visualization of the ETT cuff and helped facilitate ETT withdrawal to the proximal trachea. This technique could potentially decrease the rate of premature loss of airway control via sonographic visualization of an echo-dense fluid-filled ETT pilot balloon during the PCT procedure.

An inherent technical difficulty with employing a cadaveric model was the inability to identify important vascular structures of the neck, mainly the carotid artery, jugular vein, and any vascular anomalies. The postmortem rigidity of the cadaver's neck and mandible presented additional procedural difficulty. Performing the procedure on a cadaver model, however, permitted the less experienced members of the study team to familiarize themselves with neck anatomy and with key steps of PCT. If the procedure is halted after passage of the guidewire into the distal airway and prior to sequential dilation, the procedure could conceivably be performed by a series of medical trainees.

Limitations of the study included the use of a single cadaver, which may pose difficulty in extrapolating procedural results. Additionally, introducing fluid into the trachea and lungs could be harmful if the ETT cuff leaks during an actual procedure. This risk is likely to be acceptably low, as comparable volumes of lavage fluid (eg, saline) are frequently lost to the distal airways with no observable adverse effects during bronchoalveolar lavage. Alternative liquids, such as saline, would potentially function well in the procedure. Specially designed microbubble contrast agents are also commercially available that may be safe for use in this setting. Fluid inflation of ETT cuffs also already occurs in hyperbaric medicine, where increasing hyperbaric chamber pressures would be expected to cause progressive collapse of an air-filled ETT cuff. Fluid is also used to inflate ETT cuffs in operating rooms where nitrous oxide is administered for general anesthesia.[17]

Two alternative methods for repositioning the ETT to the proximal trachea exist. The first method uses an external handheld laser light to illuminate the tissues overlying the proximal trachea.[18] The focused light of the laser is assumed to be visible using the PCT bronchoscope when inspecting the anterior tracheal wall. However, in practice, the light may be difficult to see in patients with excess adiposity or who may require significant anterior neck tissue dissection. The second method would be to attempt direct visualization of the ETT cuff from above the vocal cords as the ETT is pulled back. Visualization of the vocal cords through the patient's mouth is achieved either by bronchoscope or intubating laryngoscope. This approach may have varied success based on the amount of secretions in the oropharynx, the presence of other orogastric and nasogastric tubes, and the size of the patient's mouth and tongue.

CONCLUSION

In this study, we were able to successfully reposition an ETT with a fluid-filled cuff to the proximal trachea under sonographic guidance in a cadaver model. This approach to ETT repositioning may provide an incremental improvement to the PCT technique by decreasing the risk of accidental extubation. The cadaver-based model could be applied in physician training and to further improve the safety of the procedure.

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REFERENCES

1. Esteban A, Anzueto A, Alía I, et al. How is mechanical ventilation employed in the intensive care unit? An international utilization review. *Am J Respir Crit Care Med*. 2000 May;161(5): 1450-1458.
2. Ciaglia P, Firsching R, Syniec C. Elective percutaneous dilatational tracheostomy. A new simple bedside procedure; preliminary report. *Chest*. 1985 Jun;87(6):715-719.
3. Bhatti N, Mirski M, Tatlipinar A, Koch WM, Goldenberg D. Reduction of complication rate in percutaneous dilation tracheostomies. *Laryngoscope*. 2007 Jan;117(1):172-175.
4. Heikkinen M, Aarnio P, Hannukainen J. Percutaneous dilational tracheostomy or conventional surgical tracheostomy? *Crit Care Med*. 2000 May;28(5):1399-1402.
5. Delaney A, Bagshaw SM, Nalos M. Percutaneous dilatational tracheostomy versus surgical tracheostomy in critically ill patients: a systematic review and meta-analysis. *Crit Care*. 2006; 10(2):R55.
6. Hazard P, Jones C, Benitone J. Comparative clinical trial of standard operative tracheostomy with percutaneous tracheostomy. *Crit Care Med*. 1991 Aug;19(8):1018-1024.
7. Holdgaard HO, Pedersen J, Jensen RH, et al. Percutaneous dilatational tracheostomy versus conventional surgical tracheostomy. A clinical randomised study. *Acta Anaesthesiol Scand*. 1998 May;42(5):545-550.
8. Kollig E, Heydenreich U, Roetman B, Hopf F, Muhr G. Ultrasound and bronchoscopic controlled percutaneous tracheostomy on trauma ICU. *Injury*. 2000 Nov;31(9):663-668.
9. Inboriboon PC, Lumlertgul S. A cadaveric model for pericardiocentesis training. *J Emerg Med*. 2013 Mar;44(3): 661-662. Epub 2012 Oct 28.
10. Bertram S, Emshoff R, Norer B. Ultrasonographic anatomy of the anterior neck: implications for tracheostomy. *J Oral Maxillofac Surg*. 1995 Dec;53(12):1420-1424.
11. Sustić A. Role of ultrasound in the airway management of critically ill patients. *Crit Care Med*. 2007 May;35(5 Suppl): S173-S177.
12. Rajajee V, Fletcher JJ, Rochlen LR, Jacobs TL. Real-time ultrasound-guided percutaneous dilatational tracheostomy: a feasibility study. *Crit Care*. 2011;15(1):R67. Epub 2011 Feb 22.
13. Rudas M, Seppelt I. Safety and efficacy of ultrasonography before and during percutaneous dilatational tracheostomy in adult patients: a systematic review. *Crit Care Resusc*. 2012 Dec;14(4): 297-301.
14. Kluge S, Baumann HJ, Maier C, et al. Tracheostomy in the intensive care unit: a nationwide survey. *Anesth Analg*. 2008 Nov; 107(5):1639-1643.
15. Flint AC, Midde R, Rao VA, Lasman TE, Ho PT. Bedside ultrasound screening for pretracheal vascular structures may minimize the risks of percutaneous dilatational tracheostomy. *Neurocrit Care*. 2009 Dec;11(3):372-376. Epub 2009 Aug 13.
16. Vargas M, Servillo G, Arditi E, et al. Tracheostomy in Intensive Care Unit: a national survey in Italy. *Minerva Anestesiol*. 2013 Feb;79(2):156-164. Epub 2012 Nov 22.
17. Navarro LH, Braz JR, Nakamura G, Lima RM, Silva Fde P, Módolo NS. Effectiveness and safety of endotracheal tube cuffs filled with air versus filled with alkalinized lidocaine: a randomized clinical trial. *Sao Paulo Med J*. 2007 Nov 1;125(6):322-328.
18. Shen LY, Helmer SD, Tran MT, Nold RJ, Thomas BW, Vasquez DG. Percutaneous tracheostomy placement with external laser light transillumination identifies proper tracheal orientation and improves surgeon insertion confidence. *Am J Surg*. 2007 Sep; 194(3):409-412.

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