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Ultrasound-guided percutaneous dilatational tracheostomy using a saline-filled endotracheal tube cuff as an ultrasonographic puncture target: A feasibility study

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ABSTRACT

Purpose: The saline-filled endotracheal tube (ETT) cuff can be easily identified under cervical ultrasound and can serve as an ideal puncture target during percutaneous dilatational tracheostomy (PDT). The authors present their initial experience with this novel technique.
Materials and methods: The records of 38 consecutive critically ill patients who underwent saline-filled cuff puncture PDT between October 2016 and December 2017 were retrospectively reviewed. The saline-filled ETT cuff was easily identified using ultrasound. Ultrasound-guided puncture into the cuff, followed by an inward-push of the ETT through the tube exchanger, facilitated accurate passage of the guidewire through the needle tip into the tracheal lumen.
Results: Of 38 consecutive procedures, 37 (97.4%) were performed successfully, with only one converted to surgical tracheostomy due to guidewire displacement. The median procedure time was 8 min. There were no complications, such as accidental extubation, major bleeding, or posterior tracheal wall laceration or pneumothorax, and no procedure-related mortalities.
Conclusions: PDT performed using a saline-filled cuff as the ultrasound-guided puncture target and an endotracheal tube exchanger is feasible, and appeared to be easier to perform than standard PDT. Larger studies are required to confirm the safety and benefits of this technique.

1. Introduction

Percutaneous dilatational tracheostomy (PDT) is commonly performed for critically ill patients who fail to be weaned from mechanical ventilation. Compared with traditional open surgical tracheostomy, PDT reduces wound infection, bleeding-related mortality, and operative time, and is a more cost-effective procedure [1,2]. PDT became the prevailing modality, not only because non-surgeons were able to perform it in the intensive care unit (ICU) [3], but also more surgeons preferred to use PDT in semi-surgical approaches for the above-mentioned benefits [4].

Bronchoscopy guidance was the established standard and the initially recommended method for PDT [5]. However, there were clinical burdens [6-8], including accidental loss of the airway, needle damage to the optical fiber, and a shortage of devices and operators, which made many specialists reluctant to perform it with bronchoscopy [9]. With easy accessibility in the ICU, ultrasound has been increasingly used as an alternative to guide the PDT procedure [10,11]. It provides an overall evaluation of the cervical area, including the tracheal anatomy and vascular structures [12], and can facilitate accurate entry into the trachea without vascular injury, especially in patients without clearly palpable tracheal anatomy [11]. With these advantages, ultrasound-guided PDT has been demonstrated to improve efficacy and reduce complications compared with the landmark-guided method [13], and has also been proven to be non-inferior to bronchoscopy guidance in several clinical studies, including one randomized trial [14,15]. However, the method involves a learning curve to accurately interpret tracheal ultrasound and its application to real-time tracheal puncture. Unlike vessels, the trachea contains air and is difficult to assess using ultrasound, which makes it unreliable to directly verify the depth of endotracheal tube (ETT) placement using an ultrasound probe, despite recent case series reporting otherwise [14].

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The saline-filled cuff technique has been described for confirming correct positioning of the ETT using ultrasound before performing PDT [16] and after endotracheal intubation [17,18]. As the saline-filled cuff contacts the endotracheal lumen, it can provide excellent visibility under neck ultrasound, and the cuff can be easily detected by the ultrasound probe without impedance from air. Similar to the technique of central venous puncture via ultrasound-guidance, the saline-filled cuff can provide an excellent puncture target for tracheal access.

We present our initial experience with ultrasound-guided PDT using the saline-filled cuff as a puncture target, followed by bougie-assisted needle-cuff detachment and completion of the Seldinger technique. This is the first series report to describe percutaneous tracheostomy under ultrasound-guidance with direct puncture of a saline-filled ETT cuff.

2. Materials and methods

Ethics approval for this study was obtained from the National Taiwan University Hospital Research Ethics Committee (Approval No.: 201608104RINC). Given the retrospective nature of the present study and the use of anonymized patient data, requirements for informed consent were waived. All procedures were performed by a single thoracic surgeon (SMY) or trainees under his supervision. The authors began use of the saline-filled cuff technique to guide PDT in February 2016, which has subsequently been modified in a stepwise fashion to the current standard operating procedure characterized by filling the ETT cuff with colored saline to confirm intra-luminal puncture of the trachea, and using an endotracheal tube exchanger to assist inward/outward repositioning of the ETT during the procedure.

The present study retrospectively reviewed 38 consecutive ultrasound-guided saline-filled cuff-puncture PDT (USCP-PDT) procedures performed with an endotracheal tube exchanger between October 2016 and December 2017.

2.1. Timing and indications for tracheostomy

In this study, all the patients were in the ICU, intubated, and on mechanical ventilation before undergoing the tracheostomy procedure. The decision to perform tracheostomy was made according to routine ICU practices at the authors' institution, and the surgical team were routinely consulted for performing the procedures. Cardiopulmonary dysfunction with weaning difficulty and neurosurgical event were the most common indications, and tracheostomy was usually considered after 3 weeks of mechanical ventilation. Suboptimal cervical anatomy, including tracheal deviation or calcified goiter, and obesity (body mass index ≥30 kg/m^2) were not considered to be contraindications. However, high-dose inotropic agent use, high oxygen demand (fraction of inspired oxygen [FiO_2] > 60%), airway edema, and uncorrectable coagulopathy were absolute contraindications.

2.2. USCP-PDT technique

In the authors' institute, most patients are intubated using standard polyvinyl chloride ETTs with a high-volume, low-pressure cuff (CURITY™ Tracheal Tubes, Covidien, Dublin, Ireland), with an inner ETT diameter (ID) ranging from 7.0 mm to 8.0 mm. A single-stage dilator percutaneous tracheostomy kit (Ciaglia Blue Rhino®, Cook Medical Inc., Bloomington, IN, USA) is regularly used for most percutaneous tracheostomies. Before the setup for the procedures, the latest plain film chest radiograph is reviewed to verify the position of the ETT cuff, and the distance from the ETT cuff to the planned puncture site is estimated. Once anesthesia induction is complete, the patient is positioned with the neck in extension, except for those with cervical spine injuries, who are maintained in the neutral position. Mandatory airway suction to remove secretions and enhanced preoxygenation with pure oxygen for 5 min are performed before the procedure. The ETT is repositioned to a point where the ETT cuff is immediately below the planned tracheostomy site, which was usually determined by manual palpation at the level of one finger-width below the cricoid cartilage (usually between the first and third tracheal ring). The ETT cuff is deflated then refilled with 20 mL colored-saline (mixed with 0.5 mL 1% Gentian violet solution), which can be easily visualized using an ultrasound equipped with a 5–12 MHz linear transducer (Fig. 1A). If the saline-filled cuff is not initially detected by the ultrasound (Fig. 1B), the depth of the ETT is gently adjusted until the cuff is fully visualized under ultrasound (Fig. 1C). In addition, the cervical anatomy can also be verified by ultrasound for vascular structures and any possible anomalies. After adequate repositioning of the ETT, a small incision is made following administration of local anesthetic (1% lidocaine with epinephrine) in the middle of the trachea at the level where the ultrasound probe is placed. After inserting the ETT exchanger (C-CAE-14.0-83, Cook® Airway Exchange Catheter, Cook Medical Inc., Bloomington, IN, USA) into the distal trachea through the side opening of the swivel connector, the puncture procedure begins by using an introducer needle puncture through the incision with a 15–30° tilt toward the distal trachea. As the needle advances into the ETT cuff, the formerly infused colored-saline (Fig. 2A) can be withdrawn with steady inflow into the syringe (Figs. 2B, 3A), which is followed by inward pushing of the ETT through the airway exchange catheter; care should be taken to hold the needle tip firmly to prevent displacement during advancement of the ETT. Therefore, the ETT cuff can be detached from the needle while the needle tip remains in the tracheal lumen, which is confirmed via air aspiration in a saline-containing syringe (Fig. 3B). The guidewire is, subsequently, inserted through the introducer needle (Fig. 3C), and the trachea is dilated in sequence (Fig. 3D, E). After dilatation of the tracheostomy tract, the ETT is withdrawn to the previous position through the airway exchanger before placement of the tracheostomy tube (Fig. 3F). The entire procedure is demonstrated in Video Clip 1 (Video 1.

In cases of technical failure, including needle displacement or a large cuff leak, the procedure can be salvaged and reattempted by exchanging

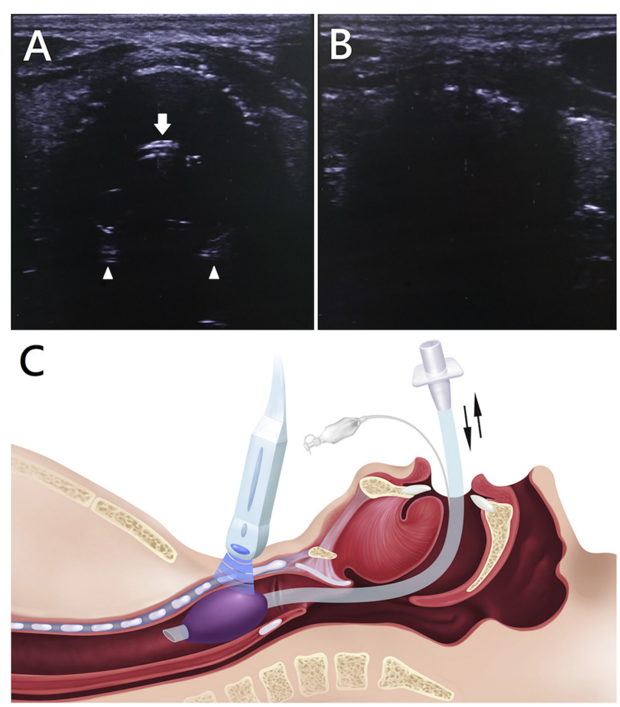

Fig. 1. Transversal ultrasound view of the trachea inside the endotracheal tube. (A) Saline-inflated cuff enables visualization of the center tubing with "double arc" sign (arrow) and parts of the posterior tracheal wall (arrowheads), which is masked by air within the endotracheal tube (ETT). (B) Tracheal air causes acoustic shadowing that eliminates visualization of deep structures. (C) Before percutaneous dilatation tracheostomy, the probe is held to the selected puncture site, and the ETT is repositioned until the saline-filled cuff is fully visualized.