

Ultrasound-guided Tracheal Intubation

A Novel Intubation Technique

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ULTRASOUND has growing applications in medicine. In addition to its role in diagnostic and interventional radiology, ultrasound has been successfully used in several airway-related applications. It has been used to confirm endotracheal intubation, position the endotracheal tube after intubation, assess vocal cord movement, and diagnose endobronchial intubation and pneumothorax.¹⁻⁵ This case report describes a novel use of real-time ultrasonography to direct the insertion of the endotracheal tube during intubation without performing laryngoscopy in a patient who failed traditional direct laryngoscopy.

Case Description

A 14-month-old former full-term baby girl with a history of cutis aplasia congenita of the scalp presented for resection of the lesion under general anesthesia. Her medical history was significant for a patent foramen ovale, ectrodactyly,

wormian bones, and blindness. On physical examination she was noted to have mild micrognathia but normal mouth opening and normal cervical spine mobility. She had a previous anesthetic for syndactyly surgery in which the airway was managed using a laryngeal mask. For the present case, general anesthesia was induced with inhaled sevoflurane, an intravenous catheter was placed, and vecuronium 0.1 mg/kg was administered. Direct laryngoscopy with a Wis-Hipple 1.5 blade revealed a poor view of the airway (Cormack and Lehane Grade 3).⁶ The Wis-Hipple blade is a modification of the Wisconsin blade, with a wider tip than the Miller blade and a straight spatula with an open flange. The patient was repositioned and a second laryngoscopy attempt did not improve the view of the airway. A video laryngoscope was requested and while it was being prepared, we decided to intubate the trachea using real-time surface ultrasound guidance. A malleable stylet (6 French Outer diameter Slick™ stylet (Teleflex Medical, Research Triangle Park, NC) was placed within a 4.0 cuffed tracheal tube (Mallinkrodt, Covidien, Mansfield, MA) and shaped like a hockey stick. A 15–6 MHZ HFL50x linear array ultrasound probe attached to a Sonosite S-nerve machine (SonoSite Inc., Bothell, WA) was lightly placed transversely on the patient's neck at the level of the thyrohyoid membrane. The probe was moved caudally until a view of the vocal cords and surrounding hypopharyngeal tissue was obtained. A second provider opened the mouth and performed a jaw thrust while inserting the hockey-stick-shaped stylet into the midline of the patient's pharynx. The tube was inserted in the midline of the pharynx under the operator's direct vision, it was then advanced slowly along the tongue base at which point it was visualized to the left of the glottis on the ultrasound image. The tube was withdrawn slightly and its trajectory modified to direct it into the glottis; hypoechoic shadowing and widening of the vocal cords was noted as the tube entered the trachea, a characteristic of successful glottic placement of the tube.¹ The stylet was withdrawn and the endotracheal tube advanced into the trachea. The intubation

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was performed in less than 10 s. The patient underwent an uncomplicated clinical course and was extubated uneventfully at the end of the procedure.

Discussion

This is the first report of using real-time (dynamic) surface ultrasound to successfully guide tracheal intubation. We refer to this technique as ultrasound-guided tracheal intubation (UGTI). UGTI represents a novel approach to intubation and may serve as an alternative technique in patients with difficult direct or video laryngoscopy. It is quickly performed and may have particular utility in patients in whom secretions or blood obscures visualization of the airway, or patients with limitations in mouth opening precluding the use of a laryngoscope.

The idea to use ultrasound to guide intubation stemmed from a collaborative effort between intensivists and anesthesiologists at our institution. Our intensive care team desired a rapid and reliable method to confirm successful tracheal intubation when the detection of carbon dioxide was not reliable such as during cardiopulmonary resuscitation, or when the immediate confirmation was warranted without ventilating to detect carbon dioxide. A review of the published literature revealed that ultrasonography could reliably be used to confirm the tracheal tube location immediately after intubation. We began to examine the airway in anesthetized children using ultrasound and quickly realized that the critical structures of the airway could be visualized readily on ultrasound. As lighted stylet intubation is a commonly performed technique at our institution, we considered whether the kinesthetic movements of the lighted stylet technique could be combined with ultrasound to direct the placement of the breathing tube. We performed this technique in anesthetized patients with normal airways and realized that although the tracheal tube and stylet were not hyperechoic they could be immediately identified in the pharynx by their characteristic hypoechoic shadow and could be guided into the trachea using ultrasonography. The required ultrasonographic skill can be obtained by first reviewing images of the ultrasonographic appearance of the airway. Clinical practice using ultrasound to visualize the airway structures and to understand sonographic features of successful tracheal intubation is essential before attempting UGTI. A basic working knowledge of the typical controls and adjustments of the ultrasound machine is also necessary.

Marciniak *et al.*¹ described the ultrasound appearance of the airway during intubation with direct laryngoscopy. They described ultrasound criteria to confirm tracheal intubation. Unlike their use of ultrasonography to simply confirm tracheal intubation we used ultrasonography to direct the placement of the breathing tube in real time. We followed the following procedure in this case as illustrated in the video (see Supplemental Digital Content 1, <http://links.lww.com/ALN/A886>, video of the UGTI technique in a 13-yr-old

child). We obtained consent for intubation and recording of the video from the patient's family.

1. We identified the posterior hypopharynx at the level of the thyrohyoid membrane by its hypoechoic appearance.
2. We identified the vocal ligaments as linear hyperechoic structures that abducted with mask ventilation.
3. We located the tube in the pharynx by means of the ultrasound image and assessed its relationship to the glottic opening.
4. We modified the trajectory of insertion of the tube to place it through the glottic opening.
5. We observed widening of the cords and enhanced posterior shadowing of the trachea as the stylet tube was placed between the cords.

Although we performed UGTI without performing laryngoscopy, the technique can be performed in combination with laryngoscopy. We plan on evaluating this combination approach in patients who fail direct laryngoscopy. If direct line of sight visualization fails, the ultrasound image can be used to guide the insertion of the tube beyond the direct line of sight visual range as the ultrasound view would not be affected by the lack of a direct view.

Some video laryngoscope guided intubations require hyperacute angulation of the stylet breathing tube. This may sometimes result in hang up of the breathing tube on the anterior tracheal wall or glottis during intubation. UGTI is performed with a standard hockey-stick stylet configuration, which has not been associated with hang up of the tube. Once the stylet is withdrawn, the tube is readily advanced down the trachea.

The gold standard for the management of patients with difficult direct laryngoscopy is the fiberoptic bronchoscope. Use of the fiberoptic bronchoscope requires good hand-eye coordination and significant practice. The fiberoptic bronchoscope is expensive, not easily portable, and requires special cleaning between uses. Portable ultrasound machines are now ubiquitous in many hospitals, they are quickly readied between uses and have a fixed cost. A stylet is all that is additionally needed for UGTI, making this a relatively inexpensive, quick approach to intubation. A disadvantage of fiberoptic bronchoscopes and similar devices such as optical stylets is that visualization is performed through an optical channel within the device; this means that any encroachment of airway soft tissue on the device will result in a loss of the view. Hang up of the breathing tube on the arytenoid cartilage during fiberoptic intubation is well recognized. This difficulty is usually managed with blind maneuvers because the view from the fiberoptic scope is usually distal to the anatomical structures impeding the advancement of the tube. UGTI does not rely on internal visualization of the airway, the intubation process is guided by the external view of the airway, allowing the assessment of the relationship between the breathing tube and the glottic

structures throughout the intubation process. Furthermore the breathing tube is not advanced off the stylet; rather, the stylet is withdrawn after the tube has been inserted into the trachea, making hang up less likely. If resistance is encountered during advancement of the stylet tube the ultrasound provides, visual information regarding the location of the resistance either the arytenoid cartilages or the vocal cords and adjustments in trajectory can be made to bypass the resistance. A Parker flex-it™ tube (Parker Medical, Highlands Ranch, CO) may be an alternative endotracheal tube for performing this technique, the tip flexes when resistance is encountered allowing the tube to slide past any impeding tissue.

Disadvantages of UGTI include the need for two providers: one to provide ultrasound visualization and the second to perform intubation. Also, its utility may be limited in patients with poor ultrasound images.

We are pursuing a prospective evaluation to further characterize this technique in a large number of patients. Although we used a hockey-stick stylet configuration, further evaluation is necessary to determine the optimal stylet configuration. Airway injury is a potential complication of this technique as correct positioning requires accurate interpretation of the ultrasound image; however, most providers can readily interpret ultrasound images of the airway with minimal instruction. As with any intubation procedure, advancement of the breathing tube should cease if resistance is encountered at any point. There remain risks of injury to airway soft tissue and glottic structures if inappropriate force is applied during the intubation process.

In summary, we have presented a novel approach to intubation using real-time ultrasonography. UGTI represents a new way of thinking about endotracheal intubation (looking from the outside in rather than from the inside). Further research in airway ultrasonography may lead to devices that facilitate this technique, such as tracheal tubes or stylets that are highly reflective or simple tongue retractors to facilitate the technique or anatomically shaped ultrasound probes or articulating probe holders to allow hands-free placement of the probe. New ultrasound probes and machines with processors that enhance visualization of the airway would facilitate UGTI. However, limitations related to the poor penetrance of ultrasound through air remain.

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