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Transcricothyroid approach to the subglottic airway in a porcine model

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Challenges to subglottic surgery include limited exposure, a long operating distance, and ventilation. Transoral and laryngofissure approaches suffice for minor pathology, while extensive stenoses[1] necessitate an open resection with reanastomosis. Perioperative ventilation often requires a tracheotomy or stenting. Endoscopic/microscopic adaptation to transoral approaches improves visualization but does not address the operating distance.[2] These challenges are amplified as surgery proceeds distally.

In 2001, Valdez et al suggested a perpendicular approach to the posterior glottis and subglottis via an inferiorly based thyroid cartilage flap.[3] This human cadaver model improves exposure and working distance, but ventilation remains an important hurdle. Moreover, the thyrotomy has the potential to create new stenoses and places the vocal folds at risk of injury.

This study describes the establishment of surgical access to the posterior glottis, subglottis, and cervical trachea through an extended cricothyrotomy in an ex vivo porcine model. This novel transcricothyrotomy (TCT) technique facilitates a direct, perpendicular approach with shorter working distances and avoids a thyrotomy. Loupes or an operating microscope, both familiar to the otolaryngologist, further enhances visualization. Moreover, TCT may permit midtracheal jet ventilation with a Hunsaker Mon-Jet tube (Medtronic Xomed, Inc., Jacksonville, FL).[4,5] Passive expiration through the TCT should minimize the risk of barotrauma.

Methods

Institutional review board approval was waived for this study. Three TCTs and three thyroid windows[3] were performed in ex vivo porcine tracheas (Bob Evans Farms, Xenia, OH). The anterior surgical windows were measured and the calculated areas (height × width) were reported in cm^2. Operative times were recorded in minutes. Statistical analyses were omitted secondary to the limited sample size and the inability to control the laryngotracheal specimen size.

TCT Exposure and Application

The laryngotracheas were cleansed and each cricothyroid muscle was isolated with blunt dissection. Complete myotomies were performed sharply through the muscle belly. Next, the cricothyroid membrane incision was made from the midline to the inferior cornu of the thyroid cartilage bilaterally. Care was taken to avoid interruption of the thyroid or cricoid perichondrium. A Weitlander-type retractor was then placed in the craniocaudal direction to extend the opening (Figs 1 and 2). A second retractor can then be positioned to maintain lateral exposure.

One TCT specimen was used to perform a model posterior glottic scar excision in the presence of a Hunsaker tube. The scar was excised in a submucosal plane using a scalpel (#15-blade) and an angled elevator. A free mucosal graft was sutured in place to repair the defect.

Results

TCT afforded an average operative area of 7.2 cm^2 (range 6.3-8.4 cm^2) versus 5.5 cm^2 in thyroid windows (range 5.0-5.9 cm^2). Exposure by TCT required an average of 6.7 minutes compared to 14.7 minutes for thyroid windows. Statistical analysis was not performed. In the thyroid window group, the thyrotomy resulted in bilateral vocal fold injury in one specimen.

In the one TCT laryngotrachea used for a model scar excision, the direct exposure simplified surgery. Resection and mucosal resurfacing required only a pair of forceps and needle driver. The presence of a Hunsaker tube did not impair surgery.

Discussion

These experiments describe a novel technique to facilitate subglottic surgery. TCT is a direct, perpendicular approach

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Figure 1 Transcricothyrotomy approach with the thyroid cartilage oriented at the top and the cricoid below. These cartilages are skeletonized to improve visibility of the cricothyroid opening. Lateral view of the neutral or closed position.

with a short operating distance. Furthermore, TCT facilitates a possible model for ventilation in an in vivo model. The potential applications for this technique include resection of benign tumors, posterior glottic scars, and subglottic stenoses.

Both TCT and thyroid window laryngoplasty provide direct, perpendicular access to the subglottis. Potential advantages of TCT over thyroid windows may include greater area of exposure accomplished in less time, avoidance of a thyrotomy that may lead to new stenoses, and the benefit that the lower incision is theoretically less likely to injure the vocal folds.

Safe and adequate ventilation is a special challenge in the setting of obstructing airway pathology. Select concerns for supraglottic jet ventilation in this setting include barotrauma, inadequate gas exchange, and the path of the jetted gases in relation to the pathology. In contrast, TCT combined with midtracheal jet ventilation delivered through a Hunsaker tube would likely overcome these limitations. The TCT opening should facilitate gas entry and escape, which promotes ventilation while lessening the risk of barotrauma. Furthermore, jetted gases would be distal to the pathology, and this minimizes disruption to airway surgery. For these reasons, midtracheal jet ventilation should be superior to supraglottic jet ventilation.

An example of airway management for subglottic stenosis could be as follows. First, temporize the marginal airway with dilation and ventilation through a rigid tracheoscope or bronchoscope. Second, use TCT to establish surgical exposure and permit improved gas exchange during subsequent jet ventilation. Third, use a Hunsaker tube to replace the rigid bronchoscope to start midtracheal jet ventilation, and airway surgery can begin. At the conclusion, the cricothyrotomy can be repaired and the overlying structures closed over a drain. Ultimately, an in vivo model may provide valuable information to help refine these techniques.

Figure 2 Transcricothyrotomy approach with the thyroid cartilage oriented at the top and the cricoid below. These cartilages are skeletonized to improve visibility of the cricothyroid opening. Open position using a Weitlander retractor to maintain extension.

The major limitation of this study is the ex vivo porcine model. Laryngotracheal specimen size, age, and sex are not easily controlled. Dynamic and histological analyses are also limited. Moreover, there are anatomical considerations, such as the superior and recurrent laryngeal nerves, cricothyroid joint, and cricothyroid muscle. However, the potential advantages of TCT make it a promising answer to the challenges of subglottic surgery, and the technique warrants further research. A future in vivo model may add important insight on this novel technique.

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Author Contributions

Scott L. Lee, conceptualization, experimentation, data analysis, manuscript preparation; **Quyen T. Lee,** experimentation, data analysis; **Stanley M. Shapshay,** conceptualization, manuscript preparation.

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