Visualization of the Supraglottis in Laryngomalacia With 3-Dimensional Pediatric Endoscopy

Philip Gaudreau, MD, LCDR, MC, USN; M. Taylor Fordham, MD; Tiffany Dong, BA; Xinyang Liu, PhD; Sukryool Kang, PhD; Diego Preciado, MD, PhD; Brian K. Reilly, MD

IMPORTANCE The use of 3-dimensional (3D) endoscopy has been described in the pediatric airway and has been shown to improve visualization of complex airway anatomy. Laryngomalacia is one of the most common airway disorders evaluated in pediatric otolaryngology offices. Whether 3D visualization is superior to standard endoscopy as a means for assessment and surgical management of complex airway anatomy is unclear.

OBJECTIVE To describe a pilot case series using 3D endoscopy to facilitate supraglottoplasty and to assess surgical outcomes.

DESIGN, SETTING, AND PARTICIPANTS A prospective case series was conducted of 11 children undergoing supraglottoplasty from July 1, 2010, to June 31, 2014, at a tertiary care pediatric hospital. Infants and children with symptomatic laryngomalacia were eligible for the study. Follow-up was completed on December 31, 2014, and data were assessed from February 1 to 15, 2015.

INTERVENTIONS Supraglottoplasty performed using 3D endoscopy.

MAIN OUTCOMES AND MEASURES The outcome data collected included length of hospital stay and frequency of complications (ie, aspiration, granuloma formation, supraglottic narrowing, revision surgery, tracheostomy, and gastrostomy).

RESULTS Eleven children were treated for laryngomalacia with supraglottoplasty (6 boys and 5 girls; mean [SD] age, 29 [85] months). Four of these children (36%) also had grade I subglottic stenosis. The 3D endoscope was judged by all participating senior surgeons to improve visualization of the supraglottic anatomy and to permit more precise tissue removal. No complications occurred after the surgery. Hospital stay was found to be an unreliable indicator owing to multiple comorbidities in many children. Worsening of aspiration occurred in 1 child (9%) who subsequently required gastrostomy tube placement. This child demonstrated progressive neurologic impairment and had severe hypotonia and developmental delay. Another child with subglottic stenosis and subglottic cysts required a tracheostomy owing to severe rhinovirus tracheitis. The remaining 9 children (82%) had good outcomes, with a mean follow-up of 14.7 (range, 12-24) months.

CONCLUSIONS AND RELEVANCE The anatomy of the supraglottis in laryngomalacia is better visualized using 3D techniques. Use of 3D endoscopy may allow for more precise tissue removal. The outcomes and complication rates are similar to those of standard 2D techniques. This study provides a platform to begin comparative analysis between 3D and standard 2D techniques.
Laryngomalacia is the most common cause of stridor in newborns. Onset of laryngomalacia occurs shortly after birth, and patients present with inspiratory stridor that can be louder during feeding and/or sleeping. The causes of stridor are thought to be a combination of laryngeal neural immaturity with specific anatomic findings of shortened aryepiglottic folds, an ω-shaped curved epiglottis, and redundant arytenoid mucosa with resulting infolding toward the laryngeal inlet. Most infants have minimal impairment of feeding with normal weight gain and no significant increase in the work of breathing. More than 90% will have resolution of their symptoms from 19 months to 2 years of age. In approximately 10%, the symptoms will extend beyond stridor to include respiratory distress with retractions and cyanosis and failure to thrive as a result of the inability to coordinate breathing with swallowing and maintain adequate caloric reserves. Supraglottoplasty has proved to be successful for surgical management in this small subset of infants with severe symptoms. Surgical correction (supraglottoplasty) is directed to the surgical division of the aryepiglottic folds and the removal of excess mucosa and cartilage that are prolapsing into the airway (Video). Multiple techniques have used scissors and cup forceps, microdebriders, and lasers. Visualization of the surgical field for this procedure has relied on the laryngeal operating microscope or 2-dimensional (2D) endoscopes. The benefits of the microscope include the surgeon’s ability to use both hands for tissue manipulation, combined with 3-dimensional (3D) visualization of the tissues. The interactions of the supraglottic structures with the dynamic airway are better visualized in a 3D view and allow for precise tissue removal of the areas that affect the airway. Traditional 2D endoscopes have the advantage of allowing a much higher-power view of the airway. The 2D endoscopes can be placed in a specific location to allow indirect visualization of areas that may not be well visualized with the line of sight required for the microscope.

The use of 3D endoscopy has expanded rapidly in neurosurgical, skull base, and laparoscopic applications. Previous studies have shown that 3D technology has facilitated teaching and more precise dissection in complex anatomic regions. The use of 3D endoscopy has also been described to improve visualization of complicated airway lesions. At present, whether 3D visualization is superior to standard endoscopy to assess and manage complex airway lesions surgically is unclear. In pediatrics, supraglottoplasty to treat laryngomalacia is one of the most common laryngeal surgical procedures performed. Supraglottoplasty involves precise visualization and manipulation of the tissue to optimize the airway without increasing the risk for supraglottic scarring or postoperative aspiration. We herein report a 4-year pilot series in which 3D endoscopy was used for supraglottoplasty.

Methods

This pilot study was performed at the tertiary care Children’s National Medical Center. The parents of infants and children diagnosed as having symptomatic laryngomalacia with failure to thrive or respiratory distress with cyanosis were approached about having their child undergo supraglottoplasty using a rigid 5.0-mm 3D endoscope (VSII; Visionsense Corp) from July 1, 2010, to June 31, 2014. Intraoperative 3D and standard 2D endoscopy were performed to provide real-time comparisons between the images obtained and the ease of surgical manipulation of the tissues (Figure 1). Postoperative data were collected concerning the length of hospital stay, presence of aspiration, granuloma formation, supraglottic stenosis, need for revision surgery, need for tracheostomy, and need for gastrostomy tube placement. Follow-up was completed on December 31, 2014, and data were assessed from February 1 to 15, 2015. The institutional review board of Children’s National Medical Center approved this prospective study. All parents provided written informed consent.

Results

Eleven patients (6 boys and 5 girls; mean [SD] age, 29 [8.5] months) underwent 3D supraglottoplasty. Of these, 4 children had grade I subglottic stenosis noted on their initial bronchoscopy. Intraoperatively, the 3D endoscope was believed subjectively to improve visualization of the supraglottic anatomy.
and to allow for more precise tissue removal by all participating surgeons. The 3D technology was specifically helpful in determining the appropriate depth for division of the aryepiglottic folds (Figure 2) and for identifying the prolapsing elements overlying the arytenoids and removing only the tissue that was contributing to airway obstruction (Figure 3). In the postoperative evaluation, the length of the hospital stay in patients who underwent 3D supraglottoplasty was found to be an unreliable indicator owing to significant comorbidities in many patients. All patients with isolated laryngomalacia who underwent 3D supraglottoplasty were discharged on postoperative day 1 after admission to the pediatric intensive care unit, which is the standard protocol for our patients who undergo supraglottoplasty.

Aspiration with feeding is a common postoperative concern after supraglottoplasty. One infant who underwent 3D supraglottoplasty was noted to have worsening aspiration postoperatively. This infant also had progressive neurologic delays and severe hypotonia, congenital cardiac anomalies, and developmental delay and ultimately required gastrostomy tube placement. No cases of supraglottic scarring or stenosis occurred. Another infant who underwent 3D supraglottoplasty had multiple synchronous airway lesions, including subglottic stenosis and subglottic cysts. This infant ultimately required a tracheostomy in the setting of respiratory failure caused by severe rhinovirus tracheitis. No additional complications were detected in our cohort, with follow-up ranging from 12 to 24 months (mean follow-up, 14.7 months).

Discussion

The use of 3D technology increasingly helps to facilitate surgical resections. The surgical robot and its resulting 3D view or the newer applications of 3D endoscopy are used in gynecology, general surgery, neurosurgery, and otolaryngology. The use of 3D technology has been shown to increase the speed with which novice surgeons are trained to perform laparoscopy with the ability to decrease errors in complex tasks. A recent systematic review also described a decrease in errors and an increase in speed by surgeons using 3D laparoscopy when compared with 2D laparoscopy in simulated environments. For expert surgeons, the transition to 3D technology in a laparoscopic field has been shown to occur without significant difficulty. Outcomes are currently no different between the 2 techniques, and surgeons who have used 3D techniques prefer the visualization obtained.

At present in otolaryngology, 3D endoscopy has been described in rhinology and skull base resections. Although the field of view may be decreased when compared with that of 2D endoscopes, the understanding of the anatomy was im-
proved, particularly when dissecting at the skull base, in the ethmoids, and in the region of the sphenoid sinus. \textsuperscript{6,9} In these areas, critical structures are in close proximity. The improved depth perception described by surgeons using 3D technology may help to avoid injury in these areas.

Previous investigators\textsuperscript{15} have published their experience with the use of this technology in the airway for subglottic cysts, airway stenosis, and complete tracheal rings. Depth perception, balloon placement, and cyst resolution were all better visualized using the 3D endoscope.\textsuperscript{15} The routine use of 3D endoscopes for direct laryngoscopy and bronchoscopy has not been advocated. Three-dimensional endoscopes have significant initial costs. Without improved outcomes or specific surgical advantages, the additional cost may be difficult to justify.

Laryngomalacia is a dynamic airway process involving collapse of the supraglottis in neonates and infants. Laryngomalacia is typically related to specific anatomic changes and neuromuscular immaturity. The anatomic changes vary from patient to patient but typically include the \( \omega \)-shaped epiglottis, shortened aryepiglottic folds, and excess arytenoid tissue. The variability between patients in conjunction with the neuromuscular immaturity seen in many neonates results in different patterns of supraglottic collapse. As a result of this variability, multiple classification schemes have been described, but none have gained widespread acceptability.\textsuperscript{17-19} The failure to universally accept a classification system may again be directly related to the combination of anatomic and functional problems that can lead to supraglottic collapse on inspiration. Given this variability, the small subset of patients with severe disease that requires surgical repair can have very different causes of their airway obstruction. Optimal visualization of the airway is critical to maximize surgical efficacy while preventing complications like supraglottic scarring or aspiration. The visualization obtained using the 3D endoscope for supraglottoplasty was subjectively superior to that obtained with the 2D endoscope. The addition of depth perception allowed for more precise tissue removal and facilitated division of the aryepiglottic folds. In patients with a significant epiglottic component, tissue removal from the epiglottis was more controlled without putting the child at increased risk for aspiration. Although the 3D view can be obtained using the surgical microscope, the 3D endoscope placed immediately overlaying the supraglottis afforded a vastly superior view (Figure 4).

The potential for this technology needs to be explored further. In most of our patients, 2D and 3D endoscopes were used to allow for direct comparison of the surgical view. Comparative outcomes data are the next step to determine whether 3D endoscopy has a true use in supraglottoplasty for laryngomalacia.

Conclusions

Three-dimensional endoscopy for supraglottoplasty is an effective technique that provides improved visualization and allows for precise tissue removal. Outcomes and complications did not differ in this small series. Further comparative study to determine whether surgical outcomes are improved should assess whether the use of this technology for supraglottoplasty is worth the costs involved.

**ARTICLE INFORMATION**

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**REFERENCES**


