Three-Dimensional Direct Laryngoscopy and Bronchoscopy

Enhanced Visualization of the Airway

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**Importance:** This is the first description of 3-dimensional (3D) pediatric airway endoscopy in the otolaryngology literature detailing the superior visualization with this technology. Ultimately, enhanced optics may further improve the treatment of airway pathology.

**Objective:** To report the first case series examining the use of 3D direct laryngoscopy and bronchoscopy (DLB) in the diagnosis and management of laryngotracheal pathology.

**Design:** Case series.

**Setting:** Tertiary care pediatric hospital.

**Participants:** Three patients underwent both telescopic 2-dimensional (2D) and 3D DLB for comparison purposes: a 12-year-old boy for visualization of complete tracheal rings, a 23-year-old man for dilation of tracheal stenosis, and a 4-month-old boy for resection of subglottic cysts.

**Main Outcome Measures:** Enhanced visualization of laryngotracheal pathology and facilitated endoscopic surgery.

**Results:** To our knowledge, this is the first case series in the otolaryngology literature examining the use of 3D DLB for the resection of subglottic cysts, dilation of tracheal stenosis, and visualization of complete tracheal rings. We believe that the 3D view offers qualitatively improved depth perception, accuracy of balloon placement, and appraisal of subglottic cyst resection margins.

**Conclusions and Relevance:** This emerging technology has vast potential for improving endoscopy, surgical precision in airway interventions, tissue preservation, and methods of teaching. More research is needed in this area regarding the benefits and advantages of 3D compared with 2D endoscopy.


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**METHODS**

Consent was obtained for both 2D and 3D airway endoscopy. The 2D 4.0-mm 0° telescope (model Storz Hopkins 7200; Karl Storz Endoscopy America, Inc) was then passed through the vocal cords down to the subglottis, trachea, and right and left main stem bronchi with photographic documentation and video recording. Next, the 3D 5.0-mm 0° rigid endoscope (VSII; Visionsense Corp) was carefully inserted into the airway in a similar fashion. The video (http://www.jamaoto.com) is an exact 3D re-creation of what is visualized in the operating room.

**Video available online at www.jamaoto.com**
The 3D endoscope uses interlaced displays for the stereoscopic video streams via a 3D monitor. To view the stereoscopic video, users must wear polarized glasses that contain a pair of different polarizing filters. This creates a 3D effect by projecting the same scene onto both eyes but from slightly different perspectives. To recreate the 3D effect for the purposes of this article, we blended the 2 original video streams (one for each eye) into a single anaglyph 3D video stream. In anaglyph 3D viewing, the stereoscopic 3D effect is achieved by encoding the 2 video streams with different-colored filters, typically red and cyan. We then substituted the polarized glasses used in the operating room for the plastic-framed red-cyan glasses required for the readers to experience the 3D effect. Red-cyan glasses are necessary to view the 3D images (and video) in this article correctly; in the operating room, however, the surgeon needs only polarized glasses, which do not impair off-screen acuity. All 3 patients described here underwent both telescopic 2D and 3D DLB for comparison purposes.

RESULTS

CASE 1

A 12-year-old boy with a history of a repaired pulmonary sling and unrepaired complete tracheal rings underwent surveillance endoscopy to evaluate his airway (Figure 1A). Three-dimensional high-definition endoscopy confirmed a distal segment of complete tracheal rings (Figure 1C and video). No further intervention was required, given the patient’s minimal respiratory symptoms, and he continues to be active in sports. In our view, the superior visualization from the 3D telescope provided enhanced depth perception. This optical improvement for the surgeon is striking compared with conventional 2D endoscopy (Figure 1A vs B and C). Owing to the lack of depth perception with conventional 2D telescopes, an airway lumen appears larger when the image is obtained from a very short distance. The 3D endoscopic technology markedly avoids this limitation and provides a much more accurate assessment of the airway caliber at initial gross inspection. Similar to outcomes in other children with congenital tracheal stenosis, this patient continues to do well with a conservative nonsurgical management.

CASE 2

A 23-year-old man with no significant medical history sustained a tracheal stenosis after cardiac arrest requiring urgent intubation. He presented with severe tachypnea, increased work of breathing, and retractions. A neck radiograph revealed tracheal stenosis, and urgent endoscopy revealed an immature midtracheal stenosis, 5 cm long (Figure 2A). The patient’s distal trachea was normal below the stenotic segment down to the carina. Initial assessment of his airway caliber revealed no leak with a 3.5-mm uncuffed endotracheal tube. Given the patient’s severe tracheal stenosis, we performed dilation with a high-pressure, noncompliant airway balloon (Acclarent), beginning with 10 mm and then progressing to 12 and 14 mm (video); this markedly improved the tracheal stenosis (Figure 2B and C) and allowed for extubation. Before terminating the procedure, we determined that the patient had an expanded airway with no leak around a 6.0-mm endotracheal tube. Although this patient’s airway stenosis remains improved, he has required 3 interval balloon dilations since this initial procedure. We believe that the enhanced depth visualization from the 3D endoscope depicts the entire stenotic length more accurately and facilitates balloon dilation.
placement in the desired segment. This can be helpful for dilating only the appropriate affected subglottic or tracheal airway segment.

**CASE 3**

A previously healthy 4-month-old boy (born prematurely at 24 weeks’ gestation) with a history of prolonged intubation presented with a 2-week history of progressive stridor. A lateral neck radiograph revealed subglottic narrowing with soft tissue density. Endoscopy revealed obstructive subglottic cysts arising from the posterior lateral cricoid ring (Figure 3). The Lindholm laryngoscope was used for suspension, and under 3D endoscopic guidance the cysts were resected and microdebrided with a 2.9-mm laryngeal skimmer blade without irrigation (XOMED Surgical Products). The infant was extubated after the procedure, and the stridor and respiratory difficulties resolved completely. He continues to be without respiratory symptoms 4 months after surgery. In our opinion, 3D endoscopy provided improved resection capability because the tissue planes are more readily determined (video) and the improved depth perception was more similar to that of a binocular microscope. This eased the surgical experience and enabled less traumatic and faster surgery in an infant, without the need for the cumbersome binocular microscope.

The Visionsense system uses a miniature stereoscopic 3D sensor integrated into a conventional rigid endoscope. The 3D display monitor, along with the associated computer system and glasses, presents each eye with different images, thus providing the basis for the stereo display. In a process known as stereopsis, the human visual system interprets the slight differences between these 2 images and obtains binocular depth information. Although monocular 2D vision provides some depth information (eg, relative motion, shading, or perspective), the addition of stereopsis is responsible for the more accurate sense of depth provided by 3D perception.

Three-dimensional endoscopy is not a new concept in otolaryngology and has been described in sinus and skull base surgery. The era of transoral robotic surgery ushered in the use of 3D endoscopy in otolaryngology. The da Vinci Surgical System (Intuitive Surgical, Inc) used in transoral robotic surgery not only utilizes a 3D stereoscope but also allows for tremor filtration and scaling of movement. Manes and colleagues3 noted the advantages of improved depth perception and endoscopic orientation in all cases of endoscopic sinonasal and skull base surgery, with the added advantage of lack of physical discomfort and fatigue by the operator compared with 2D endoscopy.

The 3D stereoscopic image theoretically allows for more accurate visualization of the anatomy, thereby improving hand-eye coordination and overall performance. Compared with 2D systems, 3D imaging systems have been shown to provide significant benefits. The use of a 3D system significantly improves efficiency by decreasing the number of errors and the time required to complete tasks for both novice and experienced users.7-10 These promising benefits of 3D vision were recently supported by the findings of Wagner et al,11 who showed that regardless of the surgical method used—open, laparoscopic, or robotic—3D vision improved task performance and decreased task completion time.

In this case series, use of the 3D endoscope improved visualization for resection of subglottic cysts, allowing for more efficient resection by obviating the need for the operating microscope, while retaining the precise 3D view. Additional advantages that we noted include ease of setup, enhanced interaction of operating room staff and trainees with the large display on a 3D monitor, better understanding of related structures, and easier resection of masses. Although we did not assess the technique and

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**Figure 3.** Subglottic cysts in patient 3. A, Two-dimensional endoscopy. B, High-definition single-channel image obtained from the 3-dimensional scope, as seen in 2-dimensional endoscopy. C, Three-dimensional endoscopy; red-cyan glasses are recommended for viewing this image correctly.
outcomes quantitatively, trials comparing 2D and 3D visualization for set tasks are pending.

The potential for this technology is vast, but objective improvement over standard of care will require further study. Based on the feasibility of the 3D endoscope, we plan to use this instrument for our common pediatric laryngeal procedures, specifically supraglottoplasty, comparing operative time, precision, and efficiency of motion. In addition, we plan to test the new technology alongside standard 2D endoscopy in a laryngeal simulator model to compare operative efficiency and precision. For tasks requiring depth perception, we anticipate an improvement in these outcomes. The 3D endoscope may not completely supplant conventional 2D endoscopy but may serve as an important adjunct for specific cases requiring improved depth perception.

A major limitation of 3D endoscopy is start-up cost, not only for the endoscope but also for the image display system; replacement endoscopes are accordingly more expensive. The use of 3D endoscopy requires that operating room personnel wear polarizing glasses to view the display. Although this does dim vision slightly, it does not have an appreciable effect on visual acuity.

Given the promising results that other studies have shown,\textsuperscript{7-10} the use of a 3D visual system for DLB procedures seems a logical next step. As technology continues to advance and costs decline, there is good reason to believe 3D endoscopy will become a preferred modality, if not a new standard of care.

In summary, this is the first case series in the otolaryngology literature examining the use of 3D DBL for the resection of subglottic cysts, dilation of tracheal stenosis, and visualization of complete tracheal rings. We noted improved depth perception with the use of this technology and improved facilitation with resection. We believe that the potential for this emerging technology is vast and may improve surgical precision for airway intervention, tissue preservation, and improved teaching. More research is needed in this area regarding the benefits and advantages of 3D compared with 2D endoscopy.

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Conflict of Interest Disclosures: None reported.


REFERENCES