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**WILEY**
The Glottis Is Not Round: Teardrop-Shaped Glottic Dilation for Early Posterior Glottic Stenosis

Clark A. Rosen, MD; Hailun Wang, MD; Daniel J. Cates, MD; Libby J. Smith, DO

Objectives: Posterior glottic stenosis (PGS) results in severe derangement of laryngeal configuration and function with significant morbidity as a sequela. Presently, there is no treatment for patients with “early” PGS. Dilation is often used for stenotic disease, but present dilation methods are limited to a round shape and the glottis is a sector (teardrop-shaped). Round dilation of the larynx results in compression of the membranous vocal folds (with potential for injury) and minimal expansion of the posterior larynx. We present a novel laryngeal dilation method that matches the unique anatomic shape of the glottis: teardrop-shaped glottis dilation (TSGD).

Methods: We present a clinical series of early PGS patients treated with a TSGD. Five patients with dyspnea and significantly reduced vocal fold mobility due to early PGS were treated with TSGD, which involves placement of a triangular static stent in the anterior glottis, with simultaneous use of a round balloon dilator in the posterior glottis.

Results: All patients reported improved ease of breathing and decrease in Dyspnea Index score and were decannulated following treatment. Video perceptual analysis of pre-/postlaryngoscopy examinations was performed with five blinded reviewers, and all patients were scored to have improved posterior glottic airway space following treatment with a mean improvement of 2.4 on a 11-point scale.

Conclusion: These clinical results demonstrate that there is enormous potential for the identification and treatment of patients with early PGS and use of a laryngeal dilation technique that matches the anatomic configuration of the glottis.

Key Words: Posterior glottic stenosis, PGS, bilateral vocal fold immobility, laryngeal dilation, balloon dilation, dyspnea, laryngeal stenosis.

Level of Evidence: 4

INTRODUCTION

Posterior glottic stenosis (PGS) is a condition that causes partial to complete immobility of the vocal folds. It is commonly induced by trauma from endotracheal intubation, affecting 14% of adult patients following prolonged intubation. While intubated, the endotracheal tube rests in the patient’s posterior commissure. Progression to PGS occurs following development of pressure necrosis, mucosal breakdown, ulceration (and possible infection of the perichondrium/cartilage), the formation of granulation tissue, and subsequent scarring of the anatomic area of the posterior larynx (interarytenoid space and/or cricoarytenoid joints). These pathological changes lead to bilateral vocal fold motion impairment (hypomobility or immobility) via inflammation and fibrosis of the posterior commissure involving one or both of the cricoarytenoid joints, thereby reducing the maximal glottic aperture during abduction, which clinically causes dyspnea. Other risk factors contributing to the development of PGS include immunocompromised states, use of large-diameter endotracheal tubes, prolonged or repeated intubations, excessive endotracheal tube motion during intubation, external trauma, infection, inhalation injury, and ingestion of caustic agents. Complicating the clinical picture, symptoms are often insidious, potentially delaying official diagnosis of the condition. In addition, this condition frequently occurs in individuals who are critically ill and/or recovering from a critical illness, which diverts attention of the healthcare team away from complications of the recent intubation. Thus, patients often present to an Otolaryngologist after scar contraction of the posterior commissure has already contributed to significant stenosis and respiratory distress. Direct laryngoscopy, coupled with manual palpation of the cricoarytenoid joints, is required to definitively diagnose PGS. This will differentiate bilateral vocal fold immobility due to scarring from PGS from bilateral vocal fold paralysis. Flow-volume loop testing provides additional insight into disease severity and treatment response.

Surgical interventions are unlikely to restore motion of the vocal folds in late or chronic presentations of PGS due to the principles of scar maturation. The mainstay of treatment for these patients typically involves a tracheotomy and/or variety of ablative endoscopic or open...
procedures aimed at enlarging the adynamic posterior glottic aperture. Conversely, treatment of PGS during the early stages of wound healing are intuitively more amenable to nondestructive interventions such as conservative debridement, balloon dilation with or without adjunct topical mitomycin C (MMC), steroids, and proton pump inhibitors. No studies have addressed the value of early, conservative interventions, including balloon dilation, to prevent chronic PGS. Effective balloon dilation of the posterior commissure is theoretically problematic because the glottis is sector-shaped (teardrop shape), whereas a traditional balloon is round. Therefore, a round dilation method will apply forces to compressible membranous vocal folds and not toward the posterior glottis (Figure 1). Thus, round dilation of the larynx has the potential to cause injury to the fragile and important membranous vocal fold tissues and not provide potentially therapeutic expansive, dilatory forces to the posterior commissure of the larynx.

In this case series, we present a novel surgical technique of anatomically appropriate dilation of the larynx, which would address the unique teardrop shape of the glottis in patients with early PGS (Figure 2).

MATERIALS AND METHODS

Early PGS is defined for the purpose of this study as symptom onset within 3 months after injury (i.e., intubation) to the posterior commissure. The patient registry of the University of Pittsburgh Medical Center Voice Center was queried to identify patients treated with early PGS (University of Pittsburgh Institutional Review Board # PRO13030372). Five patients presenting with early PGS were treated with a unique, anatomically appropriate dilation technique to enlarge the posterior commissure teardrop-shaped glottis dilation (TSGD). This surgery involved simultaneous use of an anterior triangular stent and posterior commissure balloon dilation and selective use of adjunctive procedures of steroid injection, application of MMC, and wound debris excision. All patients had severe bilateral vocal fold motion impairment and dyspnea complaints. Initial evaluation was comprised of flexible laryngoscopy, and when possible, flow-volume loops. Posterior glottis stenosis was confirmed by the presence of severely restricted or absent passive cricoarytenoid motion during vocal fold palpation throughout direct microlaryngoscopy and visualization of interarytenoid scarring tissue. Once early PGS is found during microlaryngoscopy, posterior glottic dilation can be done during the operative microlaryngoscopy session using an intermittent apneic technique. Laryngeal treatment involved dilation of the larynx with a compliant balloon (CRE Single-Use Pulmonary Balloon Dilator Model M00550350, M00550310, M00550320, ranging from 3.0–5.5 cm in length and from 12–20 mm in diameter; Boston Scientific, Marlborough, MA) in the posterior larynx with concurrent anterior placement of a Jackson laryngeal dilator (Model #507501, 22–30 French, Teleflex, Morrisville, NC) (Fig. 3). This method addresses the “teardrop” shape of the glottis by directing the force posteriorly onto the scarred posterior commissure and minimizing soft tissue compression (injury) of the membranous vocal folds. The anteriorly placed triangular stent serves to leverage the posterior dilatory force from the thyroid cartilage at the anterior commissure, reflecting the expansion force to the posterior commissure, and to minimize pressure applied to the membranous vocal folds. Balloon inflation was maintained for 60 seconds or until the patients’ oxygen levels began to desaturate. Postdilation, topical MMC (0.4 mg/mL) was applied for 4 to 5 minutes; gross granulation tissue was removed with microcup forceps in a conservative manner; and submucosal steroid injection was administered (triamcinolone acetonide 40 mg/dL via 27-gauge needle (Oro-Tracheal needle, Medtronic, Minneapolis, MN).

Posttreatment outcomes were assessed using the Dyspnea Index (DI) and pulmonary function testing whenever possible. Due to the limitations of obtaining these measures in patients who were in the intensive care unit, additional quantitative approaches to objectively analyze changes in glottic opening were incorporated. Video perceptual analysis of pre-postlaryngoscopy examinations was performed with five reviewers blinded to the clinical scenarios.

Video perceptual analysis of pre- and posttreatment laryngoscopy examinations was performed by five fellowship-trained laryngologists in a blinded fashion. The mean years of laryngology experience (after fellowship) of the reviewers was 5.2 years. All videos were provided without accompanying audio. Reviewers were asked to rate the change in maximum glottic opening in the posttreatment exam compared to the pretreatment exam. The possible ratings were assigned on an 11-point scale (−5 to +5), with −5 being significantly worse, +5 being significantly improved, and 0 being no change (Supporting Appendix 1). Reviewers rated 12 pairs of video clips. The presentation sequence of the paired video clips were selected randomly. The reviewers were asked to rate all five patients pre–posttreatment video pairs; three of the five pairs were repeated for intrarater reliability; two additional video pairs were presented as post–pretreatment; and two pairs were consisted of the same video clip (pre–pre and post–post). Reviewers were allowed to watch the video clips as many times as they wished. Interrater and intrarater reliability were estimated by calculating intraclass coefficients (ICC) using SPSS 23 (IBM Corp., Armonk NY). Intrarater ICC was calculated using a mean-rating, consistency-agreement, two-way random-effects model, whereas intrarater ICC was calculated using single-rater, absolute-agreement, mixed-effects model.

RESULTS

All five patients regained some degree of vocal fold mobility with reported improved subjective dyspnea. Dyspnea Index was not available for all patients (Table I). Three of the five patients underwent repeat dilation (Table II). One patient (patient B), who presented later...
than the others in the cohort (3 months) underwent tracheostomy prior to dilation and was successfully decannulated following treatment. A tracheostomy was avoided in the remaining patients. The length of follow-up ranged from 2 to 44 weeks. A preoperative flow-volume loop was available for one patient (patient C) for post-TSGD comparison (Fig. 4). Interrater and intrarater reliability were found to be excellent, with an ICC of 0.911 and 0.951, respectively. All patients were scored on video perceptual analysis and were found to have improved posterior glottic airway space following treatment, with a mean improvement of 2.4 on a 11-point scale (Fig. 5).

**Patient A**

Patient A presented with severe bilateral hypomobility and acute dyspnea 10 days after extubation. The patient was intubated for 7 days after undergoing CPR and hypothermia protocol following an electrocution accident. At 3-week follow-up from TSGD, the patient had subjective improvement of dyspnea and improvement of vocal fold hypomobility (mild/moderate). Patient A was ultimately lost to follow-up. (Appendix 2)

**Patient B**

Patient B presented with progressively worsening dyspnea and bilateral vocal fold immobility 3 months after extubation following a myocardial infarction. The patient underwent a tracheostomy at the time of TSGD. After the initial dilation, the patient regained some mobility of the left vocal fold. The patient developed a bulky granuloma at the right posterior commissure. The granuloma was surgically resected, and a repeat TSGD was performed simultaneously ~14 days after the first surgery. The granuloma recurred but was successfully treated with conservative management (omeprazole 40 mg by mouth twice daily; Nasacort [Sanofi, Bridgewater, NJ] 55 mcg, 6 sprays inhaled by mouth). At 11-month follow-up, patient B remained tracheostomy-free, and subjective dyspnea was significantly improved with Δdyspnea index ~23 (pre-DI minus post-DI or vice versa). (Appendix 2)

**Patient C**

Patient C presented with bilateral vocal fold immobility 20 days after an esophageal dilation under general

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**TABLE I.**

Preoperative and Postoperative Follow-up Dyspnea Index Scores

<table>
<thead>
<tr>
<th>Patient</th>
<th>DI at Presentation</th>
<th>DI at Last Follow-up</th>
<th>Tracheostomy Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>–</td>
<td>20</td>
<td>None</td>
</tr>
<tr>
<td>B</td>
<td>28</td>
<td>5</td>
<td>Tracheostomy, decannulated</td>
</tr>
<tr>
<td>C</td>
<td>29</td>
<td>22</td>
<td>None</td>
</tr>
<tr>
<td>D</td>
<td>–</td>
<td>–</td>
<td>None</td>
</tr>
<tr>
<td>E</td>
<td>36</td>
<td>34</td>
<td>None</td>
</tr>
</tbody>
</table>

DI was not available for all patients due to operational constraints in the clinical setting. Where unavailable, patients were asked about their dyspnea with all patient reporting improved dyspnea.

DI = Dyspnea Index (abnormal score > 10; maximum score = 40).

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**TABLE II.**

Summary of Operations Performed

<table>
<thead>
<tr>
<th>Patient</th>
<th>Laryngeal Jackson Dilator</th>
<th>CRE Balloon* (mm)</th>
<th>Adjunct Procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>22 Fr</td>
<td>13.5</td>
<td>TA, MMC</td>
</tr>
<tr>
<td>B1</td>
<td>22 Fr</td>
<td>14.0</td>
<td>MMC, TA</td>
</tr>
<tr>
<td>B2</td>
<td>22 Fr</td>
<td>15.0</td>
<td>Excision of granuloma</td>
</tr>
<tr>
<td>C1</td>
<td>30 Fr</td>
<td>15.0</td>
<td>MMC, TA</td>
</tr>
<tr>
<td>C2</td>
<td>30 Fr</td>
<td>16.5</td>
<td>MMC, TA</td>
</tr>
<tr>
<td>D</td>
<td>22 Fr, 26 Fr</td>
<td>15.0</td>
<td>TA</td>
</tr>
<tr>
<td>E1</td>
<td>22 Fr</td>
<td>15.0</td>
<td>TA, MMC</td>
</tr>
<tr>
<td>E2</td>
<td>22 Fr, 24 Fr</td>
<td>15.0, 18.0</td>
<td>TA</td>
</tr>
</tbody>
</table>

*Boston Scientific, Marlborough, MA.

Fr = French gauge; MMC = mitomycin C; TA = triamcinolone acetonide.

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Fig. 2. Diagram of teardrop-shaped glottic dilation with anteriorly placed triangular stent and posteriorly placed round balloon.

Fig. 3. Clinical image of teardrop-shaped glottic dilation: anteriorly placed triangular stent and posteriorly placed balloon dilator (*).
anesthesia. The patient had a history of esophagectomy and postoperative chemotherapy. The patient underwent two TSGD procedures, each occurring 1 week apart. Postdilation, patient C regained partial mobility of vocal folds bilaterally, reported with subjective improvement of dyspnea and had improved pulmonary function testing (Table III). (Appendix 2)

Patient D

Patient D presented with progressively worsening dyspnea, right vocal fold immobility, and severe left vocal fold hypomobility 5 days after extubation. Patient D underwent TSGD and successful extubation at the conclusion of the case. Two-week follow-up showed return of right vocal fold mobility and improved left vocal fold mobility, with no respiratory symptomology. (Appendix 2)

Patient E

Patient E initially presented with bilateral vocal fold immobility 6 days after undergoing microlaryngoscopy surgery for Reinke’s edema resulting from caustic ingestion. Postoperative flexible laryngoscopy showed bilateral vocal fold immobility due to suspected early PGS. The patient complained of progressively worsening dyspnea. Patient E underwent TSGD twice and 12 days apart with improvement of subjective dyspnea and glottic airway during vocal fold abduction tasks. (Appendix 2)

DISCUSSION

This study is the first to report the results of “early” conservative intervention in the attempt to prevent chronic formation of PGS, which often requires a destructive surgical procedure or tracheotomy. In addition, this article describes a unique posterior glottic dilation technique. Teardrop-shaped glottis dilation utilizes an anteriorly placed triangular glottic stent in combination with a round dilation balloon in the posterior larynx to direct dilatory, expansive forces to the posterior commissure. The combination of TSGD and conservative microlaryngeal

TABLE III. Pulmonary Function Results (Patient C)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Preoperative</th>
<th>Postoperative</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC (L)</td>
<td>2.10</td>
<td>3.43</td>
</tr>
<tr>
<td>FEV1 (L)</td>
<td>1.29</td>
<td>2.53</td>
</tr>
<tr>
<td>FEV1/FVC</td>
<td>0.61</td>
<td>0.74</td>
</tr>
<tr>
<td>FEF25–75% (L/s)</td>
<td>1.12</td>
<td>2.21</td>
</tr>
<tr>
<td>PEFR (L/s)</td>
<td>1.27</td>
<td>3.39</td>
</tr>
<tr>
<td>Vext (%)</td>
<td>1.73</td>
<td>3.24</td>
</tr>
</tbody>
</table>

FEF = forced expiratory flow; FEV = forced expiratory volume; FVC = forced vital capacity; PEFR = peak expiratory flow rate; Vext = extrapolated volume.
adjunctive procedures in cases of early PGS appears to be effective in preventing the significant morbidity of chronic PGS. Similar findings in the subglottis and trachea were reported by Nouraei et al. They reported earlier intervention with balloon dilation was associated with less subsequent endoscopic treatments and avoiding open surgery for airway stenosis. Limitations of this study include its small sample size and short length of follow-up. Additionally, qualitative and quantitative measures can be difficult to obtain because patients often present in extremis, necessitating emergent treatment. Despite these limitations, the present case series suggests that detection of PGS in the early phase may improve outcomes (i.e., subjective dyspnea, avoidance of tracheostomy, return of vocal fold mobility). Furthermore, our results suggest that balloon dilation in combination with an anteriorly placed glottic stent effectively directs balloon dilation pressure toward the posterior glottis, the site of stenosis/inflammation. Cates et al. compared round balloon dilation of the larynx and TSGD in a three-dimensional printed laryngeal model and found that TSGD provided superior posterior glottis dilation to the use of a round dilation device. With increasing awareness of early posterior glottic stenosis and use of anatomically appropriate laryngeal dilation, it may be possible to improve functional outcomes while decreasing rates of tracheostomy and the need for destructive glottal enlargement surgeries for chronic PGS. Now that a conservative, effective treatment approach may be in the otolaryngologist’s arsenal, there should be an increased motivation to identify patients with early PGS to prevent the significant of chronic PGS sequela.

CONCLUSION

To date, there has been no research that has adequately addressed the clinical utility of conservative, early interventions such as balloon dilation to prevent development of chronic PGS. This study is the first to report the results of “early” conservative intervention in an attempt to prevent chronic formation of PGS, in addition to a novel posterior glottic dilation technique that utilized an anteriorly placed glottic stent to direct dilatory, expansive forces to the posterior commissure of the larynx. This case series supports the notion that increased awareness and detection of “early” PGS, coupled with teardrop-shaped glottis dilation, improves laryngeal airway size and prevents formation of chronic PGS. Future directions will include research into the optimal timing of dilation, ratio of stent to balloon diameter, and stent design.

Acknowledgments

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BIBLIOGRAPHY