Concentric Tracheal and Subglottic Stenosis*
Management Using the Nd-YAG Laser for Mucosal Sparing Followed by Gentle Dilatation


Treatment of tracheal stenosis varies with the type and extent of the disease. Tracheostomy with stents, end-to-end anastomosis, or extensive reconstructive procedures often is required, especially when tracheomalacia is present. High recurrence rate is associated with relatively less invasive endotracheal treatments, such as bougie dilatation or total laser ablation. Mucosal sparing technique using Nd:YAG laser photodissection (LPD) and gentle dilatation (GD) can provide durable successful results in selected patients with benign concentric tracheal stenosis (CTS). In our study of 18 patients with CTS, 12 were successfully treated with Nd:YAG LPD and GD. Of these patients, eight required a single treatment while four required two or more treatments. No patients required new tracheostomy to carry out the procedure. Follow-up periods ranging from 2 to 85 months (mean: 32.6 ± 1.5 months) for 12 successfully treated patients have revealed no recurrence of their stenosis. Lengthy scars (>1 cm) and tracheomalacia were the clinical features common to those patients who failed the treatment. We advocate the use of Nd:YAG LPD in conjunction with "gentle" rigid bronchoscopic dilatation as the initial treatment of CTS. (Chest 1993; 104:673-77)

TREATMENT OF TRACHEAL STENOSIS VARIATES WITH THE TYPE AND EXTENT OF THE DISEASE. THE PRESENCE OR ABSENCE OF TRACHEOMALACIA AND SKELETAL DEFORMATION CERTAINLY INFLUENCES THE SELECTION OF THE THERAPEUTIC MODALITY. THE MAJORITY OF PATIENTS WITH SEGMENTAL STENOSIS OR TRACHEOMALACIA REQUIRE EITHER SURGICAL CORRECTION WITH END-TO-END ANASTOMOSIS OR TRACHEOSTOMY AND STENTING. SEVERAL LESS INVASIVE THERAPEUTIC MODALITIES HAVE BEEN TRIED FOR THE PALLIATION OF SYMPTOMS FROM SHORT SEGMENT, MEMBRANOUS, BENIGN, CONCENTRIC TRACHEAL STENOSIS (CTS) NOT INVOLVING THE CARTILAGE WITH VARYING SUCCESS. THESE THERAPEUTIC OPTIONS WHICH DO NOT INVOLVE OPEN SURGERY INCLUDE BOUGIE DILATATION, AIRWAY STENTING, AND Nd:YAG OR CO₂ LASER PHOTOCUTLATION.¹ ONCE AGAIN THE PRESENCE OF CERTAIN ANATOMIC FEATURES SUCH AS TRACHEOMALACIA, CIRCUMFERENTIAL CONTRACTION SCARRING, AND VERTICAL LENGTH OF THE SCAR GREATER THAN 1 CM MAY BE PREDICTIVE OF LPD FAILURE AND ACCOUNT FOR THE REPORTED VARIABLE SHORT- AND LONG-TERM SUCCESS RATES.²,³ COMPLETE MUCOSAL ABLATION OF THE STRICATURE USING LASERS CREATING LARGER OPEN WOUND SURFACE MAY BE ANOTHER FACTOR PROMOTING RECURRENT SCARRING AND POOR LONG-TERM PATENCY RATES. "MUCOSAL SPARING" TECHNIQUES CREATING MUCOSAL TRAP DOOR FLAPS OR RADIAL INCIDENTS FOLLOWED BY AIRWAY DILATATION MAY PRODUCE MORE SUSTAINED RESULTS.⁴,⁵ IN 1987, SHAPSHAY ET AL.⁶ PERFORMED THE TREATMENT USING THE Nd:YAG LASER AND GENTLE DILATATION (GD) WITH THE RIGID BRONCHOSCOPE IN THREE PATIENTS WITH CTS. THE INITIAL OUTCOME WAS SUCCESSFUL, BUT ALL THREE PATIENTS EVENTUALLY REQUIRED REPEAT TREATMENTS. IN ANOTHER REPORT BY SHAPSHAY ET AL.⁷ A MODIFICATION OF THIS TECHNIQUE WITH AIRWAY STENTS PRODUCED SUCCESSFUL OUTCOME IN 67 PERCENT (SIX OF NINE) OF THE CASES. HOWEVER, FIVE OF THESE SIX SUCCESSFULLY TREATED PATIENTS REQUIRED FURTHER LASER TREATMENTS. REGARDLESS OF THE TYPE OF ENDOTRACHEAL TREATMENT, FAILURE RATES HAVE BEEN REPORTED TO RANGE FROM 23 TO 43 PERCENT.⁸,⁹ TO FURTHER DEFINE THE UTILITY OF Nd:YAG LPD AND GD FOR THE TREATMENT OF CTS, WE REPORT OUR EXPERIENCE WITH THIS TREATMENT MODALITY.

MATERIALS AND METHODS

Flow-volume loop study and flexible fiberoptic bronchoscopy (FFB) were performed in patients suspected of having upper airway obstruction. Neither tracheal tomograms nor computed tomographic scans of the neck or chest were routinely performed in these patients. Patients detected to have short-segment membranous web-like CTSs, based on bronchoscopic findings, underwent Nd:YAG LPD of the stenotic area using FFB and GD with a rigid bronchoscope. Unlike the routine procedure of dilatation with increasing sizes of bougies or rigid bronchoscopes, GD comprised only a single insertion of the largest possible size rigid bronchoscope that the patient's trachea would accommodate following laser dissection. This was done in an effort to minimize surgical trauma of repeated insertions to the treatment site and to spare as much normal mucosa as possible.

Ventilation during the Nd:YAG LPD was provided by a jet
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(JIC).’0" ventilation of cases, were described previously. The amount of total light energy delivered in each case was variable. In all cases, the FFB was introduced transnasally. A rigid bronchoscope was used under telescopic guidance, only for the purpose of dilatation. In the majority of cases, Nd:YAG LPD was utilized to produce radial incisions through the entire vertical length of the TS lesion usually at the 9-, 12- and 3-o'clock positions (Fig 1). This was followed by single GD utilizing a size 7.0, 8.0, or 9.0 rigid bronchoscope while providing ventilation with the JIC system. In three patients, some deviation from the aforementioned procedure was mandated by the presence of significant amounts of granulation tissue which needed to be vaporized prior to the dilatation. All procedures were performed on an outpatient basis. If a significant degree of endobronchial mucopurulent material was noted at the end of the procedure, patients were placed on a 7- to 10-day empiric course of antibiotics. Patients with a history of COPD or bronchial asthma received a 2- to 3-week course of oral corticosteroids after the treatment to prevent acute bronchospasm. In order to suppress laryngeal edema formation, corticosteroids also were prescribed for patients in whom laryngeal trauma from the procedure was suspected. Patients were evaluated initially at 6- to 8-week intervals and then followed up as needed. All patients were contacted for any recurrence of symptoms prior to the publication of this article.

If symptoms and stenosis recurred, treatment was repeated; however, the number of repeat treatments was limited to two (total, three treatments). If stenosis recurred following the third treatment, then the patient was referred to either an otolaryngologist or a thoracic surgeon for more definitive surgical treatment. Only one patient underwent five treatments, since she adamantly refused open surgery. Outcome was judged as successful if bronchoscopically verified patency or near normalization of the flow-volume loop, or both, were present and symptomatic improvement was noted for the entire follow-up period after the initial or two additional treatments (Fig 2). Therapeutic failure was defined as persistence or recurrence of symptoms following more than three treatments or the need for a more definitive surgical procedure.

RESULTS

Eighteen patients underwent Nd:YAG LPD and GD with the rigid bronchoscope from March 1985 to April 1992 (Table 1). The patient population was comprised of 3 men and 15 women with a median age of 55 years (range, 19 to 83 years). Two of the original 18 patients were unavailable for long-term follow-up,
with one of them dying from unrelated causes within a month after the treatment.

Underlying etiologies for CTS included prolonged or traumatic intubation (12 patients) and prior tracheostomy for nonmalignant conditions (4 patients). In two patients with CTS, no etiology was identified by history. In nine patients, the CTS was located in the subglottic area; in 7, the upper trachea; and in the remaining 2, it was in the mid or lower trachea. A total of 28 Nd:YAG LPDs (mean of 1.5 procedures per patient) were rendered, with 18 performed in the successfully treated group (12 patients) and 10 in the failure and unavailable for follow-up groups (6 patients). Of the successfully treated patients, nine required one treatment each and two required two treatments each. As mentioned previously, one patient received five treatments. We consider her a success, since she has been symptom-free for more than three months at the time of writing this article. Of the nine patients with subglottic stenosis, we had five successes, two failures, and two were unavailable for follow-up. Our success rate was 71 percent (five of seven) for subglottic stenosis and averaged 1.5 procedures to success. Longest follow-up among successfully treated patients is 85 months. Three of the four patients who failed the treatment either had some element of tracheomalacia or a scar length of more than 1 cm or both. One of these patients had three thin concentric scars involving a 1.5-cm vertical length of the upper trachea. One successfully treated patient who has required five treatments had a scar length of at least 1 cm. Of the two patients unavailable for follow-up, one patient died of other causes.

In order to define a common underlying pathology in the recurrence and failure categories, records of pathology specimens were extracted from patient charts. In two of the three successfully treated patients, endotracheal biopsy specimens were obtained through the FFB at the time of surgery. Surgical pathology specimens also were available for review in three of the four failure patients. All these specimens revealed areas of extensive fibrosis, granulation tissue formation, and squamous metaplasia, but there was no evidence of inflammation or infection of underlying cartilaginous airway structures. There was no difference in pathologic findings between these groups.

Following the procedure, antibiotics were prescribed for eight patients in order to treat possible airway infections. Seven patients with a history of reactive airways and COPD received a 2- to 3-week course of corticosteroids to prevent bronchospasm and/or laryngeal edema. The dose and duration of antibiotic therapy varied for each patient as did the dose and duration of therapy with corticosteroids.

Nonfatal respiratory complications (infections, airway perforation, and hemorrhage) were not recorded for any patient during the follow-up and treatment periods. A small laceration (<1 cm) of the upper lip was the only complication that occurred during insertion of the rigid bronchoscope in one patient. One successfully treated patient died suddenly of an unrelated cause prior to routine reevaluation. No other fatalities were noted in our patient group. None of the patients required a new tracheostomy in order to perform the procedure. Only one patient (patient 3, Table 1) had a preexisting tracheostomy.

**DISCUSSION**

Surgical resection and end-to-end anastamosis is the currently accepted definitive treatment for CTS.

<table>
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<tr>
<th>Case/Age, yr/Sex</th>
<th>Stenosis Etiology</th>
<th>Stenosis Degree, %</th>
<th>Laser Therapy, Total No.</th>
<th>Laser Therapy Results</th>
<th>Duration of Follow-up, mo</th>
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*PI, prolonged intubation; UK, unknown; TR, tracheostomy; S, success; F, failure; Un, unavailable for follow-up.
†Lower trachea.
Even so, Maggi et al.\textsuperscript{12} reported a failure rate of 17.8 percent in 28 cases of benign tracheal stenosis. They reported dehiscence in 3.6 percent, restenosis in 7.1 percent, and death in 7.1 percent of cases. Grillo and Mathisen\textsuperscript{13} had excellent results with a failure rate of only 4 percent and a mortality of 1.8 percent in 279 patients with tracheal stenoses. Maassen et al.\textsuperscript{14} however, reported an alarming failure rate of 27 percent and a total mortality of 19 percent. This disparity in results is probably related to the surgical technique and patient selection in each series.

Maddalozzo and Holinger\textsuperscript{15} reviewed laryngotracheal reconstruction using autologous costal cartilage grafts in 20 children with subglottic stenosis. This form of therapy was offered where endoscopic management had failed. They reported a failure rate of 20 percent and a complication rate of 30 percent with a total mortality of 5 percent. Hence, while laryngotracheal reconstruction does offer definitive treatment in most cases, careful patient selection is needed to ensure success.

Initial success reported by a number of authors utilizing the CO\textsubscript{2} laser to produce complete ablation of the scar was not reliably followed by long-term durable cure.\textsuperscript{3,5} Ossoff et al.\textsuperscript{8} noted a success rate of 57 percent (8 of 14 patients) for the treatment of CTS with the CO\textsubscript{2} laser. However, most if not all of the successfully treated patients required multiple retreatments. In addition, the duration of follow-up and outcome for the successfully treated patients was not reported by these authors.

Historically, subglottic stenosis has been managed with dilatation alone using Jackson dilators and rigid bronchoscopes. Success in these cases was measured by the ability to wean these patients off their tracheostomy tubes. Hawkins\textsuperscript{16} managed eight patients in this manner. However, the process was laborious and required an average of six dilatations over an 8-week period. Other workers have alluded that acquired subglottic stenosis is commonly refractory to dilatation alone.\textsuperscript{17,18} Koufman et al.\textsuperscript{4} had 6 patients who underwent dilatation ranging from 1 to 12 times without much success. Alternative "mucosal sparing" techniques which may limit the amount of postlaser scar formation by providing an organized nidus for tracheal epithelial restructuring in addition to minimizing airway trauma may produce better long-term results. Dedo and Sooy\textsuperscript{9} used the CO\textsubscript{2} laser to raise mucosal flaps, vaporize underlying scar tissue, and return the flap to its original position. Reportedly, eight of nine patients were "successfully" treated although information on long-term follow-up was not provided. Shapshay et al.\textsuperscript{6} utilized the Nd:YAG or CO\textsubscript{2} laser to produce radial incisions coupled with dilatation using the rigid bronchoscope. Initially performed in five patients, durable success was noted in three patients after the application of one to five treatments at the end of a 1-year follow-up period. A modification of this technique\textsuperscript{6} utilizing T-tube airway stents in patients with preexisting tracheostomies after application of laser incisions and rigid bronchoscope dilatation was successful in 8 of 12 patients. However, six of these eight patients required additional laser treatment over a variable follow-up period of 1 to 5 years.

We noted an overall success rate of 75 percent (12 of 16 patients) utilizing Nd:YAG LPD and GD with the rigid bronchoscope, a technique originally described by Shapshay et al.\textsuperscript{6} Simpson et al.\textsuperscript{2} and Ossoff et al.\textsuperscript{8} reported success rates of 68.3 and 57 percent, respectively, using the CO\textsubscript{2} laser to completely ablate the tracheal stenosis. In the majority (50 percent [8 of 16]), successful outcome was established with a single treatment. The number of procedures that had to be performed to achieve success in our series of patients was comparable to that of Simpson et al.\textsuperscript{2} (1.5 vs 2.44). None of the patients with a successful outcome had evidence of either tracheomalacia or scars of vertical length exceeding 1 cm. No patient needed a new tracheostomy to perform the procedure. Tracheomalacia and a lesion greater than 1 cm in length was not in a patient who experienced treatment failure. Extensive scar length was noted in two other patients classified as treatment failures. These anatomic factors may be predictive of poor outcome from laser intervention and thus will aid in patient selection.

In the majority of patients, the etiology of tracheal stricture is some form of trauma, and our results support the notion that preventing further trauma during the treatment of CTS is essential for a successful outcome. Areas of intact mucosa at the stenotic site spared by the Nd:YAG radial incisions and the GD technique may serve as a platform promoting normal reepithelialization and airway repair.\textsuperscript{19} As a result, scar formation and the recurrence of stenosis may be minimized. Techniques in which treatment results in complete destruction of all normal airway mucosa at the stenotic site may thus predispose to disorganized healing by second intention, excessive fibrous tissue proliferation, and scar recurrence. Similar consequences of mucosal damage may occur following conventional procedures of dilatation, using progressively increasing sizes of bougies or rigid bronchoscopes.

In this series of patients, there appeared to be no correlation between the degree, etiology, and location of stenosis and response to treatment. Similarly, postoperative therapy with antibiotics and corticosteroids advocated by some authors\textsuperscript{4} to reduce inflammation and potential scar formation did not appear to influence outcome. Others\textsuperscript{6} have opposed the use of steroids postoperatively, since epithelial migration and normal reparative processes may be impeded by the
anti-inflammatory properties of steroids. There are, however, no controlled data to substantiate or refute the efficacy of steroids in this setting in the literature. In our series, 41 percent (5 of 12) of successfully treated patients were placed on a 2- to 3-week course of corticosteroids following the procedure.

Besides the use of FFB for all our tracheal procedures, another unique aspect of our laser therapy was the use of jet ventilation and an experimental steel JIC during photoablation surgery. The JIC provided uninterrupted concomitant airway access and ventilation during Nd:YAG LPD because of its small diameter and mobility. The nonflammable nature of the steel cannula also enhances the procedure’s safety by eliminating the threat of endobronchial ignition. Gentle dilatation with the rigid bronchoscope also was performed with the JIC in place, thus providing constant ventilation throughout the procedure. Thus, none of the patients required a new tracheostomy to carry out the procedure.

We do not propose that Nd:YAG laser per se was responsible for the successful outcome. In our study, selection of Nd:YAG laser was due to its availability and ease of its application through the FFB. Any of the other lasers such as CO₂ or KTP would have been equally successful. The choice is really operator-dependent and subject to its availability. Between the CO₂ and Nd:YAG lasers, the latter has greater depth of penetration (5 mm) and hence should at all times be directed parallel to the tracheal wall, skimming the surface of the target tissue to avoid damage to the underlying cartilage rings, which may otherwise lead to tracheomalacia. Certainly the CO₂ laser is less traumatic and a more precise cutting instrument than the Nd:YAG laser. Whichever the case, the principle is to use a laser for a clean dissection and minimize trauma to the normal mucosa. In conclusion, successful sustained cure of short-segment membranous, web-like CTS can be performed safely with Nd:YAG LPD and CD with the rigid bronchoscope without requiring tracheostomy. The metal JIC enhances visualization, reduces ignition risk, and allows for continuous ventilation during delivery of laser energy through the FFB as well as during dilatation through the rigid bronchoscope. We advocate this technique in selected cases as the initial therapy for benign CTS prior to open surgical intervention.

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