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Office-Based 532-nm Pulsed KTP Laser Treatment of Glottal Papillomatosis and Dysplasia

Steven M. Zeitels, MD; Lee M. Akst, MD; James A. Burns, MD;
Robert E. Hillman, PhD; Matthew S. Broadhurst, MD; R. Rox Anderson, MD

Objectives: Treatment of glottal papillomatosis and dysplasia was mirror-guided and done in surgeons' offices in the 19th century. It migrated to the operating room in the 20th century to accommodate direct laryngoscopic surgery, which required assistants to administer anesthesia and procedural support. The primary treatment goals, which are disease regression and voice restoration and/or maintenance, are tempered by the morbidity of general anesthesia and potential treatment-induced vocal deterioration. To obviate general anesthesia, office-based laser laryngeal surgery was first done in 2001 with the 585-nm pulsed dye laser (PDL), because it employs a fiber delivery system and its energy is selectively absorbed by oxyhemoglobin. Since then, this new angiolytic laser treatment paradigm has become a mainstay of management for many surgeons; however, there are a number of shortcomings of the PDL. To further develop this concept and address the limitations of the PDL, we used a 532-nm pulsed potassium titanyl phosphate (KTP) laser.

Methods: A prospective assessment was performed on 48 patients in 72 cases of recurrent glottal dysplasia (36) or papillomatosis (36). All individuals had previously undergone microlaryngoscopic management with histopathologic evaluation.

Results: Two dysplasia patients did not tolerate the procedure. Of the treatable dysplasia cases, there was follow-up in 29 of 34. Disease regression was at least 75% in 18 of 29 cases (62%), 50% to 75% in 7 of 29 (24%), and 25% to 50% in the remaining 4 of 29 (14%). Papilloma patients returned for treatment when symptoms recurred, so disease regression could not be assessed accurately. Similar to data obtained with the PDL, these data confirmed that dysplastic mucosa could normalize without resection.

Conclusions: Our observations revealed that the 532-nm pulsed KTP laser provided enhanced performance over the PDL laser in a number of ways. The ability to use smaller glass fibers precluded mechanical trauma to the channels of the flexible laryngoscopes and allowed for improved suctioning of secretions. Oxyhemoglobin absorbs energy better at 532 nm than at 585 nm, and the KTP laser can be delivered through a longer pulse width. These factors provide enhanced hemostasis and improved intralesional energy absorbance. Finally, unlike the PDL, the KTP laser is a solid-state laser and is not prone to mechanical failure.

Key Words: dysphonia, dysplasia, glottis, hoarseness, keratosis, KTP laser, laryngoscopy, papillomatosis, vocal cord, vocal fold.

INTRODUCTION

The surgical management of superficial epithelial diseases of the vocal folds was primarily performed in the surgeon's office (Fig 1) in the 19th century[1-5] and in the operating room in the 20th century.[6] This paradigm shift in the administration of care was due to developments in surgical technology and anesthetic approaches. The advances were guided by the principal treatment goals, which were regression of the disease while optimizing function (airway and voice) and minimizing morbidity (ie, discomfort). The transition to the operating room was catalyzed by a shift to direct laryngoscopic[4,5] endolaryngeal surgery. In 2001 we reintroduced office-based treatment for routine management of laryngeal papillomatosis and dysplasia with local anesthesia and the 585-nm pulsed dye laser (PDL), and published that initial trial thereafter.[7] Although we had substantial success, our impression was that this treatment strategy would continue to evolve with further improvements in laser technology.

Office-based surgery with the PDL was often associated with procedural bleeding, which limited precision in a number of ways. Extravasated blood

From the Department of Surgery, Harvard Medical School, and the Center for Laryngeal Surgery and Voice Rehabilitation, Massachusetts General Hospital (Zeitels, Akst, Burns, Hillman, Broadhurst), and the Department of Dermatology, Harvard Medical School, Wellman Center for Photomedicine, Massachusetts General Hospital (Anderson), Boston, Massachusetts. The authors received the KTP laser on loan from Laserscope, but did not receive financial support.

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Correspondence: Steven M. Zeitels, MD, Center for Laryngeal Surgery and Voice Rehabilitation, Massachusetts General Hospital, One Bowdoin Square, 11th Floor, Boston, MA 02114.

Fig 1. Jacob Solis Cohen (circa 1872) was first surgeon to become a laryngologist and performed office-based mirror-guided surgery at his home in Philadelphia. (Courtesy of Jefferson Medical School.)

caused obscured visualization of the operative field and often precipitated coughing, both of which diminished opportunities to apply laser energy. This common sequence of events limited the effectiveness of the PDL by diminishing its selectivity for the disorder. The laser energy was inevitably absorbed by free blood, which was primarily on the surface of the epithelial lesion, rather than in the sublesional or intralesional microcirculation. These factors reduced efficiency — important during the therapeutic window of local anesthesia, which is limited to approximately 30 minutes with topical administration of lidocaine.

Bleeding associated with the PDL was due to disruption of the vessel wall, which was due in part to the extremely short pulse width of the PDL (approximately 0.5 ms). When the blood within the vessel lumen heats too quickly, and not uniformly, vessel wall rupture can occur before complete intravascular coagulation. Thus, there is a narrow zone of optimal fluence to achieve complete intravascular coagulation, which is dependent on fiber-to-tissue distance, as well as the energy settings for each pulse.

Office-based surgery with the PDL under local anesthesia through a flexible laryngoscope is unavoidably complicated by a moving laryngeal target. Furthermore, fiber-to-tissue distance cannot be calibrated precisely from a monitor, and medial-surface lesions cannot be treated precisely, since a side-firing fiber is not available. The predisposition of the PDL

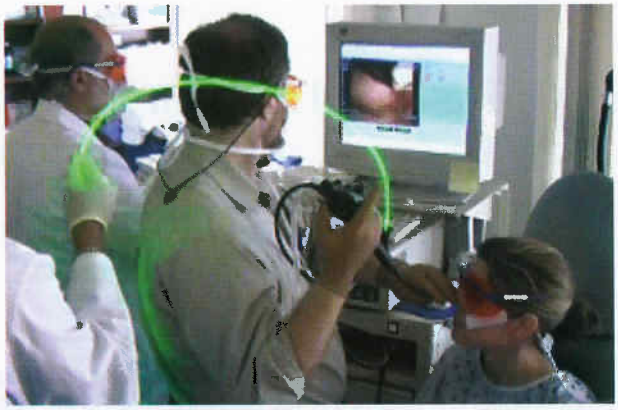

Fig 2. Office-based laser laryngeal surgery with 532-nm (green light) pulsed KTP laser.

to induce uneven intravascular coagulation and associated vessel rupture is a reason that the PDL was originally designed for dermatologic applications to deliver radiation at 585 nm rather than the true peak of oxyhemoglobin absorbance (approximately 571 nm). The laryngeal surgeon perceives these laser-tissue interactions as a somewhat unpredictable response to treatment. This problem was vividly illustrated in treating ectasias and varices with high magnification during microlaryngoscopic treatment of phonotraumatic angiomata in singers.[8]

Another problem with the PDL is that presently, 0.6 mm is the smallest fiber size that is suitable for delivery. This size fiber routinely cut and traumatized the channel of all of our flexible laryngoscopes, the repair of which was expensive and time-consuming. This problem has created a need for fiber sheaths to protect the laryngoscope channel, but effective ones have yet to be perfected. In addition, the outer diameter of an additional sheath diminishes the usable space within the channel of the flexible laryngoscope, which is critical for effectively suctioning secretions during the procedure.

Given the observed shortcomings of the 585-nm PDL, we explored the use of a pulsed KTP laser, which delivers light at 532 nm, a wavelength that is more strongly absorbed by oxyhemoglobin than the 585-nm wavelength of the PDL. More importantly, the pulse width with the KTP was extended to 15 ms, which distributed the laser energy over a time period approximately 30 times longer than that of the PDL. In managing fragile ectasias and varices of performing vocalists, this extended pulse width has allowed for substantially more efficient and effective intravascular coagulation through slower intraluminal heating and without photothermal injury to the delicate extravascular superficial lamina propria (SLP).[8] In theory, the slower intravascular heating helped avoid the vessel wall rupture and extravasation that were commonly observed with the PDL.[9]

Other advantages of the KTP laser as compared with the PDL are that the KTP laser is a solid-state instrument of which the output can be delivered through even smaller fibers (ie, 0.3 mm or 0.4 mm) and in a continuous wave mode for hemostatic cutting. Recognizing these issues, we performed this investigation to determine the effectiveness of the 532-nm pulsed KTP laser in treating glottal papillomatosis and dysplasia in an office-based setting with local anesthesia.

MATERIALS AND METHODS

A 532-nm pulsed KTP laser (Aura XP, Laserscope, San Jose, California) was used (Fig 2) to photocoagulate the sublesional microcirculation of glottal dysplasia (Fig 3) and the intralesional microvasculature of laryngeal papillomatosis (Fig 4; 15-ms pulse width, 5.25 J per pulse maximum output, 2-Hz repetition rate, 0.4-mm fiber, approximately 20 to 80 J/cm^2 fluence). The output of the lasers was set at approximately 525 to 750 mJ per pulse. Visual guidance was achieved by observing the laser fiber through the distal working channel of a flexible transnasal laryngoscope. A PENTAX model VNL-1530T scope (PENTAX Medical Company, Montvale, New Jersey) was used that has a 2.0-mm working channel and a charge coupled device video chip in the distal end (examination tip) of the scope. The surgical technique, which has been previously described,[7] uses nebulized topical 4% lidocaine and subsequently 2% lidocaine dripped directly on the surgical site through the laryngoscope channel. The study protocol was approved by the human studies institutional review board of the Massachusetts General Hospital. No patient had a specimen retrieved for histopathologic assessment; however, all patients had undergone prior microlaryngoscopic biopsies to establish the pathological diagnosis.

Assessing disease regression was confined to the dysplasia population, because papillomatosis patients were expected to return when symptoms and disease recurred, reflecting a need for another procedure. Furthermore, according to our prior work,[7,10,11] a majority of the papillomatosis patients traveled long distances for management so that they did not return for routine clinic evaluation of the healed surgical result. The dysplasia patients were assessed in the clinic between 4 and 8 weeks after the procedure. A classification scheme had been devised to categorize patient results for prior studies,[7,11,12] and this subjective observational rating scale was used in this investigation as well. Disease resolution was quantified by comparing pretreatment examinations at presentation to posttreatment videoendoscopic evaluations at the conclusion of treatment. A 4-level grading scheme was used to delineate the degree of resolution: 0% to 50%, 51% to 70%, 71% to 99%, and 100%. A favorable outcome was defined as greater than 50% resolution of disease.

RESULTS

From July 2005 to March 2006, a prospective assessment was done on 48 patients who underwent 72 office-based procedures with the 532-nm pulsed KTP laser for treatment of recurrent glottal epithelial disease: keratosis with dysplasia (28 patients and 36 procedures) or recurrent papillomatosis (20 patients and 36 procedures). All of the papillomatosis procedures were successful; however, 2 patients with dysplasia did not tolerate office management. One had a lesion on the undersurface of the vocal fold that could not be adequately exposed, and the other had glottic stenosis and could not be adequately treated in the office. Of the 34 dysplasia cases that underwent successful intervention, follow-up was available in 29. There was 75% to 100% disease regression in 18 of the 29 cases (62%), 50% to 75% disease regression in 7 of the 29 (24%), and 25% to 50% disease regression in 4 of the 29 (14%). Patients with papilloma returned for treatment when symptoms recurred, so disease regression could not be assessed accurately. All individuals had previously undergone microlaryngoscopic management with histopathologic evaluation.

DISCUSSION

Successful management of recurrent glottal papillomatosis and dysplasia requires balancing treatment goals (disease regression and voice preservation and/or restoration) with the morbidity and cost of the intervention. Apart from suboptimal treatment outcomes, the procedural liabilities in the 20th century were primarily associated with the general anesthesia necessary for microlaryngoscopic surgery. The use of general anesthesia has been considered worthwhile, because the enhanced precision it afforded resulted in improvements in disease regression and vocal outcome. Since we introduced office-based laser laryngeal surgery,[7] a number of surgeons have adopted this paradigm shift.[13] It is likely that this approach would be more widely implemented if the endoscopic and laser instrumentation were less expensive. Apart from this issue, there are limitations of the 585-nm PDL that have been overcome by using the 532-nm pulsed KTP laser without compromising therapeutic efficacy.

In this study, disease regression of dysplasia with the 532-nm pulsed KTP laser was very effective and compared favorably to the results previously published for dysplasia regression with the

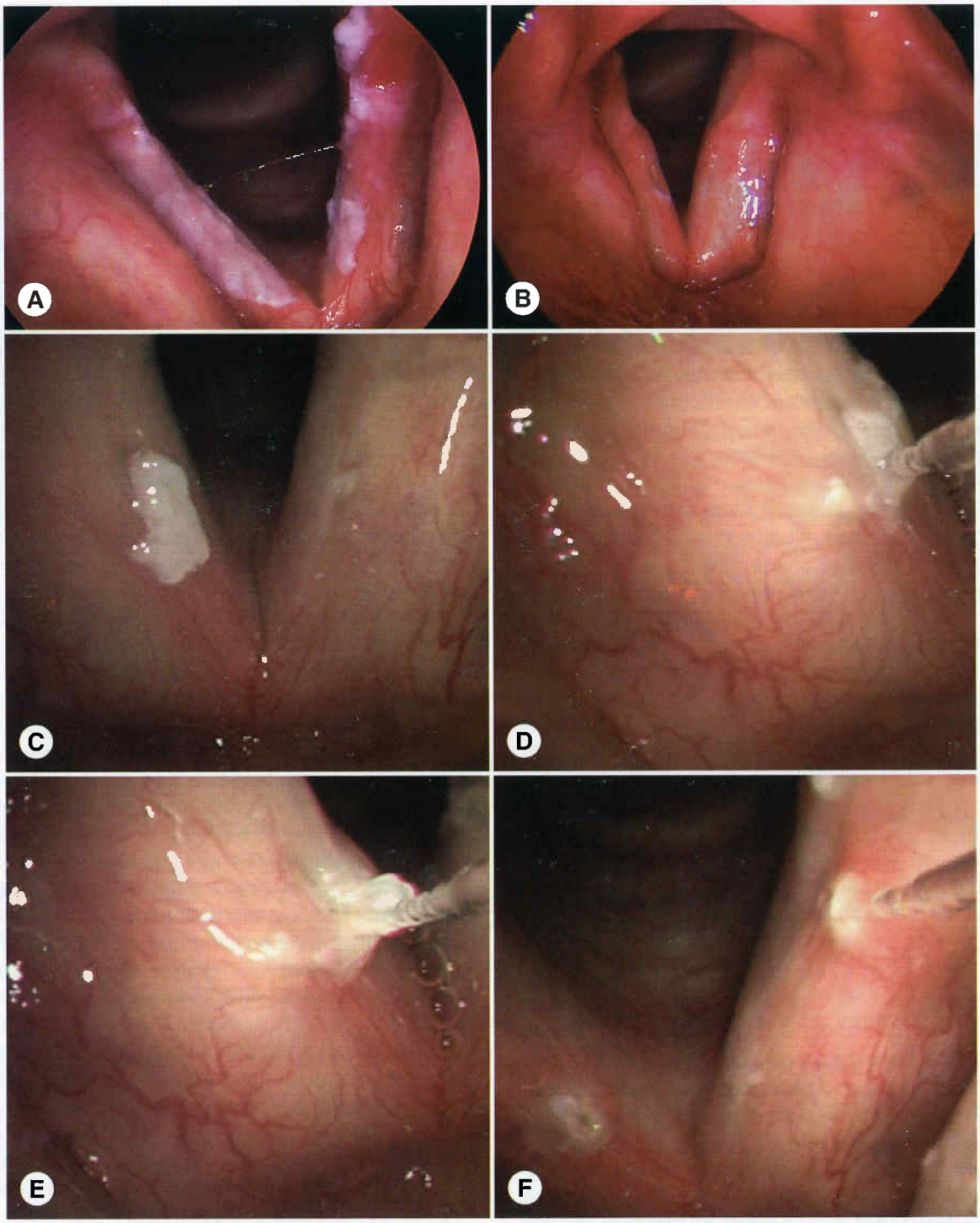

Fig 3. A) Patient presented with diffuse keratosis with dysplasia and carcinoma in situ. His vocal folds had both been "stripped" several times previously at another institution; these procedures resulted in epithelial disease overlying sulcus deformity with lost superficial lamina propria (rigid telescopic examination). **B)** After initial microlaryngoscopic pulsed angiolytic laser treatment and subsequent office-based flexible laryngoscopic treatment, very little disease remained, and voice was dramatically improved. Sulcus depressions can now be clearly seen (rigid telescopic examination). **C)** After initial microlaryngoscopic angiolytic laser treatment, he had prominent persistent area of keratosis with dysplasia of right vocal fold and smaller, more subtle areas on left. **D)** 0.4-mm Laser fiber can be seen directed at right-sided lesion. **E)** 0.4-mm Fiber can be used to mechanically peel off dysplasia. **F)** Several areas of left vocal fold with limited disease were also treated. Result subsequent to this intervention can be seen in **B**. Note that there has been approximately 60% regression of disease on right and complete regression of disease on left.

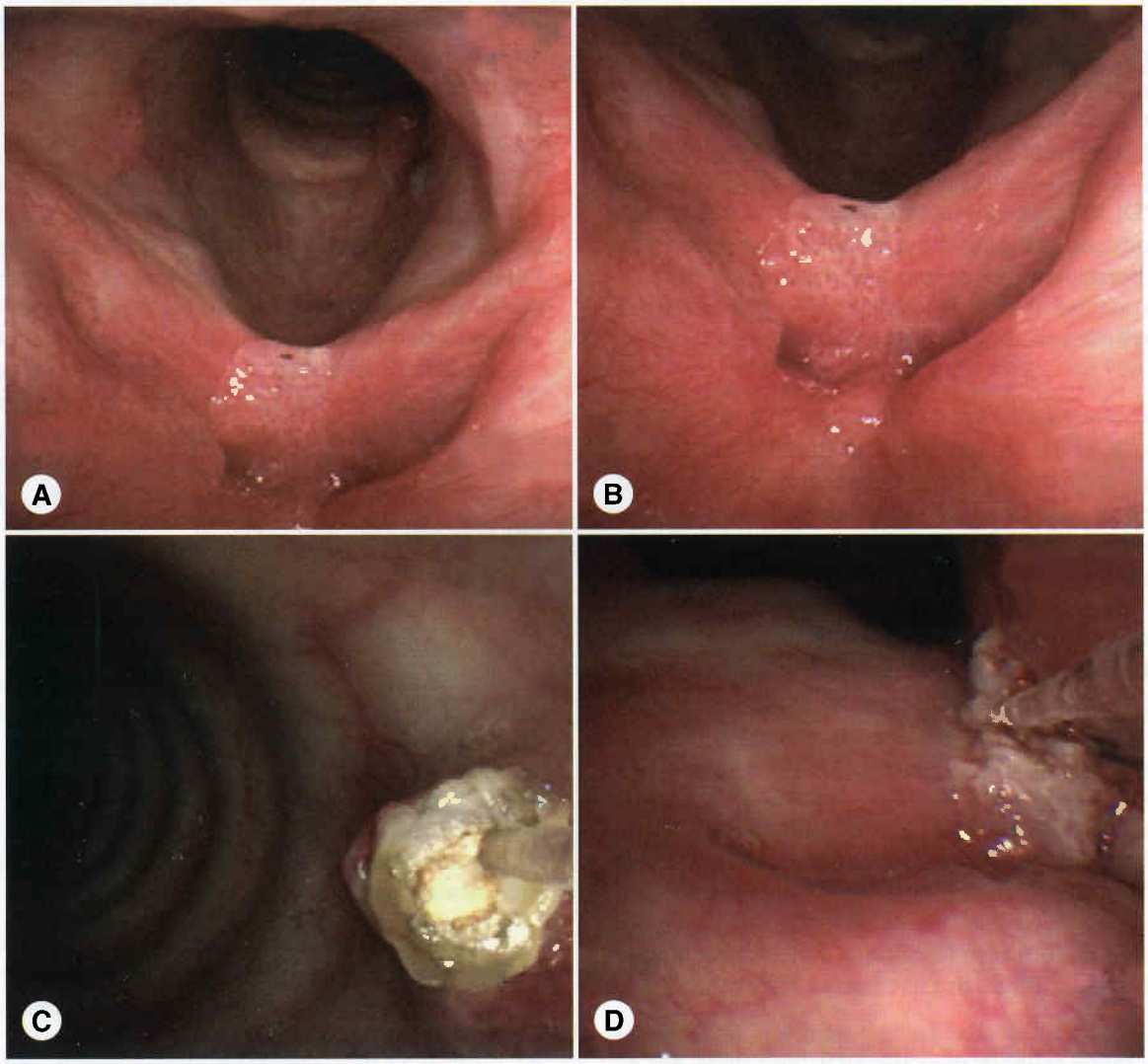

Fig 4. A) Patient has undergone many procedures for recurrent respiratory papillomatosis of glottis and subglottis at other institutions with cold instruments, as well as carbon dioxide laser. He has diffuse disease in anterior commissure that overlies web and extends to infrapetiole supraglottis. There is isolated focus of disease noted in left subglottis, at superior rim of cricoid. **B)** Mesolaryngeal disease is seen closer, with extension into ventricle, primarily on right. **C)** Left subglottic disease has been devascularized, and there is no extravasated blood. Fiber is placed in contact with exophytic disease. Note that proximal trachea is free of disease. **D)** Anterior commissure disease is being treated. There is small amount of extravasated blood, which occurred from mechanical trauma when patient unexpectedly swallowed and fiber contacted sublesional soft tissue.

585-nm PDL.[7] We could not effectively study disease regression in the patients with papillomatosis in this study, because at present, a majority of these patients only return when they are in need of a procedure, similar to a laryngeal dystonia population seeking a Botox injection. Furthermore, many of our patients with papillomatosis now travel long distances for the treatment advantages afforded by this management strategy. We had fewer patients in this study (4.2%) who could not be treated than in our initial investigation (6.5%).[7] We believe that this difference simply represents our technical learning curve and the fact that our population with papillomatosis has mostly undergone multiple procedures so that some patients now have enhanced tolerance.

Although the 585-nm PDL was initially used for office-based laser laryngeal surgery, this laser tended to cause vessel wall disruption and visible extravasation of blood due to its extremely short pulse width.[7] This is an acceptable occurrence in dermal applications; however, it is not ideal for treating phonatory mucosa. Any extraluminal blood located on the surface of the epithelial disease preferentially absorbed laser energy over the intralesional or sublesional microcirculation. Although this bleeding was generally mild, frequently it would be aspirated into the trachea and often cause coughing and po-

tentially more bleeding. Consequently, the therapeutic time window provided by the local topical anesthesia would be diminished. When blood extravasated into the delicate SLP, there was indiscriminate absorbance of the 585-nm irradiation into the blood-stained but otherwise normal SLP. Although the PDL is generally a safe laser, we have already encountered patients from another institution who have permanently lost vocal fold pliability from injudicious use of the PDL during subepithelial bleeding, which resulted in photothermal trauma of the SLP.

Our observations thus far reveal that the 532-nm pulsed KTP laser is superior to the 585-nm PDL in a number of ways beyond enhanced microcirculatory hemostasis, which the surgeon perceives as more predictable laser-tissue interactions and response to treatment. All of our flexible laryngoscopes became unusable from repeated trauma to the operating channel from passing the 0.6-mm fiber necessary to use the 585-nm PDL. This required expensive and time-consuming repairs. Since changing to a 0.4-mm fiber with the 532-nm pulsed KTP laser, we have not had laryngoscope failure or problems. The increased space within the operating channel for suctioning secretions associated with using the 0.4-mm fiber also enhanced procedural efficiency. For this reason, we are concerned about industry suggestions to manage laryngoscope channel trauma by encasing the 0.6-mm fiber with a protective sheath, which would diminish the channel lumen.

Given its solid-state energy medium, the KTP laser is more reliable than the PDL and does not require dye changes. Therefore, the KTP laser has not been prone to the intermittent mechanical failures that we encountered with the PDL. Because of the fragility of the PDL, centers that have one laser typically do not move the laser between the clinic and the operating room, despite its value in both locations. Another important advantage of the KTP laser is that it is substantially less expensive.

On the basis of the experience herein, we believe that office-based treatment of glottal papilloma and dysplasia of the vocal folds with the 532-nm pulsed KTP laser is an advancement that should broaden the use of this approach for epithelial disease in the larynx. It is likely that there will continue to be further innovations in endoscopic and laser instrumentation. We continue to believe that typically, glottal papillomatosis and keratosis should not be treated by means of local anesthesia without a prior histopathologic diagnosis and an established pattern of recurrent disease. Even though we had not speculated about use of the 532-nm pulsed KTP laser at the time of our last investigation, then, as now, we expected that fiber-based laser treatment of mucosal diseases "will likely serve as a driver for a variety of future innovations in management of laryngeal diseases, as well as disorders of other areas of the body that involve superficial diseased mucosa (ie, Barrett's esophagus, dysplasia of the cervix, granulation in the nose and ear)."[7(p274)]

CONCLUSIONS

1. The 532-nm pulsed KTP laser is an *angiolytic laser* that can provide relatively safe and effective treatment for laryngeal dysplasia and papillomatosis in an office-based setting.

2. Most patients tolerated 532-nm pulsed KTP laser treatment of glottal papillomatosis and keratosis by means of flexible fiberoptic laryngoscopy and local anesthesia.

3. Observations revealed that the 532-nm pulsed KTP laser was more effective and easier to use than the 585-nm PDL for involuting dysplasia and papillomatosis by minimizing blood extravasation onto the surface of the epithelium and/or into the SLP.

4. Disease regression was judged to be similar when we compared use of the 532-nm pulsed KTP laser with our prior experience with the 585-nm PDL.

5. Converging technological advancements continue to serve as a harbinger of a substantial paradigm shift in the management of selected mucosal diseases, especially in the vocal folds. This experience warrants further investigations and applications of office-based laser treatment in other medical fields, as well as continued development in otolaryngology.

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