Contemporary Review

Advances in Office-Based Diagnosis and Treatment in Laryngology

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INTRODUCTION

Many leading laryngologists have revived the century-old tradition in the field of laryngology of providing therapeutic treatment to patients in an office-based setting. The history of laryngology is rooted in an office-based, local anesthesia tradition. Laryngology developed over 100 years ago with the focus of treating conditions of the airway due to obstruction from infectious etiologies. As medical science advanced (general anesthesia, endotracheal intubation, surgical microscope, the surgical laser) the majority of therapeutic interventions in the field of laryngology were moved to the operating room, which afforded the laryngeal surgeon increased precision and bimanual dexterity. With this move from the office to the operating room, the field of laryngology "lost" or "forgot" the many advantages achieved with evaluating and treating patients when they are awake, sitting in an upright position and, most importantly, able to phonate. The biggest of these advantages is the ability to monitor voice quality before, during, and after a therapeutic intervention, which is vital to most laryngologic procedures. In addition, office-based procedures often increase patient safety and decrease patient cost compared to the operating room. This article is aimed at describing many of the recent advances in office-based diagnosis and treatment in laryngology, completing on a selective basis, the return of the field of laryngology to its office-based roots.

A variety of factors have allowed laryngologists to dramatically expand their office-based diagnostic and therapeutic armamentarium. Most of these advances have been in the area of technology changes. These technologic advances include high-speed imaging, chip-tip flexible endoscopes, ultrathin esophagoscopes, new injection materials, and fiber-based lasers. As with any time period of exploration, a great amount of introspection and critical review is required to optimize the advances and make cogent decisions regarding different treatment options and different approaches. There are still many patients who benefit from surgical treatment in an operating-room environment (general anesthesia using the operative microscope). The distinct advantages of high-powered magnification, a still operating field, and bimanual dexterity, will most likely never be replaced in certain aspects of laryngology. On the other hand, there is an exciting opportunity for otolaryngologists to provide high-quality laryngologic care for their patients in an office-based setting that will be equivalent, and in many situations superior, to performing a similar procedure under general anesthesia in an operating room.

The term "office-based setting" for this article refers to an awake patient in an upright position, typically with no sedation and receiving local topical anesthesia alone. Some otolaryngologists have found that the procedures described here and the technology required to perform them can be best achieved not in their office, but rather a hospital-based site of service, similar to a gastroenterology or pulmonary procedure care center, where hospital staff are present to assist with patient care, and hospital resources can be used to procure critical resources for these procedures, but maintaining the core concept of office-based treatment: an awake patient, sitting upright, and able to provide phonatory feedback throughout the therapeutic intervention.

The goal of this article is to introduce and explore the present possibilities of office-based laryngologic procedures, including diagnosis and treatment of a host of laryngologic disorders. The indication, contraindications, and technology required to perform many of these procedures are outlined in great detail and are heavily referenced. Given this renaissance period of office-based diagnosis and treatment in laryngology, dissemination and implementation of these new approaches for the treatment of laryngologic disorders is vitally important for the quality of care provided to our patients. The authors hope that this document will encourage otolaryngologists to expand the role of office-based diagnosis and treatment in laryngology for the betterment of their patients' care.

VISUALIZING THE LARYNX AND PHARYNX

Laryngoscopy—more aptly termed laryngopharyngeal endoscopy—has always been central to both diagnosis and treatment in laryngology. The renewed interest in office-based aspects of laryngology, which is the subject of this article, owes its momentum in large part to important advances in laryngopharyngeal endoscopy. Without these, many of the procedures described herein would not be feasible. Advances are built upon the coevolution of optical quality and illumination. Because of the central importance of these, it is useful to have a thorough and precise understanding of each topic and of the relationship between the two.

Laryngoscopy or laryngopharyngeal endoscopy can be performed with direct, rigid instrumentation or indirect instrumentation. Office-based laryngology is principally concerned with indirect laryngoscopy. Indirect endoscopy involves using mirrors, prisms, fiberoptic rods, or miniature chip cameras to bend or reflect the image of the pharynx and larynx back to the surgeon's eye. Direct endoscopy, in contrast, is currently most commonly performed in the operating room under general anesthesia. Indirect laryngoscopy allows the patient to maintain a relatively comfortable position while the examiner views the larynx and pharynx. This allows observations and procedures to be performed without general anesthesia, and thus allows dynamic assessment of larynx and pharynx. Various aspects of pharyngeal and laryngeal function can thus be observed and evaluated including respiration, vegetative tasks, phonation, and swallowing.

Historical Background

A reliable technique for visualizing the laryngopharynx in an awake and cooperative patient was not developed until the middle part of the 19th century. The technique of peroral mirror laryngoscopy was developed by Manuel Garcia, a vocalist and celebrated voice instructor. The description of his "eureka" moment, while walking in the gardens of the Palais Royal in Paris, is one of the foundation stories of laryngology. Struck by the flashing of sunlight on the many window panes surrounding the enclosure, Garcia suddenly saw how two mirrors could be aligned to direct sunlight to the larynx and return an image to the examiner. He reported his subsequent laryngeal observations to the Royal College of Surgeons in 1855, but his technique was not immediately embraced. Two years later, the Viennese physician Ludwig Turck, claiming no prior knowledge of Garcia's work, worked to adapt the same technique for clinical use. His efforts, including his important cadaver investigations, provided scientific validation of the technique, but were stymied by the poor and inconsistent illumination provided by sunlight, and abandoned the laryngeal mirrors as impractical.

The illumination problem was solved by Johann Cermak, who borrowed Turck's instruments and substituted artificial light for sunlight. This transformed mirror laryngoscopy into a useful clinical tool, and—not by coincidence—serves to illustrate the dependence of optics and illumination, a central and recurring theme in laryngological progress. Unfortunately, it also set off a vicious and unseemly brawl over precedence, with both Turck and Czermak hurrying to publish and demonstrate the technique, compete for the same prizes, and threaten at least one lawsuit. Czermak, at least, had the courtesy to credit Garcia for his pioneering work.[1]

Development of Endoscopic Technology

The technique of mirror laryngoscopy requires some manual dexterity and finesse. Over the century since introduction, the technique of indirect mirror laryngopharyngoscopy has been supplanted by technological developments that allow better visualization of the structures through improved image resolution, improved light transfer, and greater patient comfort.

In 1927, Baird, a British physicist, described light transmission down a glass fiber through internal refraction. Baird went on to show that if fibers produced from glass with a high refractive index are surrounded by fibers with a lower refractive index, then light from one end is transmitted efficiently through the highly refractive central core. This led to the development of the "clad fiber," the core technology for fiberoptic image transmission.[2]

In 1959, Harold Hopkins, another British physicist, patented rod-lens technology. Essentially, Hopkins had found that if high-quality rod-shaped lenses were placed in a series, an endoscope could be produced that transmitted an image from the distal tip to the proximal end. By placing a prism at the distal end of the endoscope, objects at various angles from the distal tip could be

visualized and then transmitted through the rod lenses back to the proximal end of the endoscope. Provided the lenses were aligned properly, high image quality was preserved.[3] The importance of Hopkins' work was not recognized by his countrymen. However, Karl Storz, a German medical instrument manufacturer, grasped the potential of the technology, and married the principles of fiberoptic light transmission combined with rod-lens image transmission. The resulting so-called Hopkins rod telescope remains a mainstay of otolaryngologic endoscopy. Indirect endoscopy through the rod-lens system provides excellent visualization due to the high fidelity of the optical system and stability of the light transmission system. In combination with a 70° or 90° prism, peroral laryngeal observations can be made in most patients. However, due to expense and the need for technical skill in examination similar to those required for mirror laryngoscopy, indirect endoscopy with a rod-lens system has never become the principal method for laryngeal and hypopharyngeal examination. The resolution provided by rod-lens systems still exceeds that provided by all other forms of indirect laryngoscopy (mirror laryngoscopy and flexible fiberoptic laryngoscopy), including modern distal chip flexible systems. Clinicians concerned with extreme vocal fold detail, as can be observed when the system is combined with a stroboscopic light source, have chosen to employ it routinely.

At the same time as the rod-lens endoscope was being developed, both the power of artificial light sources and fiberoptic technology were improving. By the middle of the 1960s, researchers in Japan, working with newer halogen light sources, had developed fiberoptic technology sufficiently to allow adequate transmission of an image. Sawashima and Hirose found that by placing the clad fibers in parallel, images could be transmitted from the distal end to the proximal end of a flexible endoscope. They packaged clad fibers designed to carry the halogen light and those used to transmit the image into a single sheath small enough to be passed through the nasal cavity, and demonstrated that the laryngopharynx could be illuminated and an image transferred back to the observer.[4] The transnasal approach reduced the stimulation of the patient's gag reflex and permitted observations of complex laryngeal and pharyngeal behaviors in a more physiologic posture than that required for transoral examination. Although these flexible fiberoptic endoscopes did not provide the same image resolution as the rod-lens system, this was of little importance to clinicians who were principally interested in visualizing vocal fold structure and gross motion of abduction and adduction rather than details of mucosal vibration. In 1975, Williams, Farquharson, and Anthony demonstrated that flexible endoscopic examination with these endoscopes was at least as sensitive in the evaluation of laryngeal motion and gross disease as indirect laryngoscopy with a mirror. Due to patient tolerance and the technical ease of the examination, transnasal flexible indirect endoscopy of the laryngopharynx (also know as transnasal flexible laryngoscopy) soon became a common method used to examine the larynx and hypopharynx.[5]

Developments in Endoscopic Illumination

The ability to see or resolve an image is at least as dependent on the illumination of the object to be visualized as it is on the lens system used to transmit the image to the endoscopist. Over the 160 years since the inception of indirect laryngopharyngoscopy, light sources for all forms of endoscopy continuously evolved. Garcia's technique depended on reflected sunlight. Czermak used candles, and later physicians adopted incandescent bulbs. Advances in flexible fiberoptic technology for clinical application would not have been possible unless the sources of light used for illumination had improved as well. Halogen lighting is a form of incandescent lighting in which the tungsten filament is enclosed in a container filled with halogen and bromide gas. This allows the filament to burn hotter and provide greater light intensity than available through standard incandescent bulbs. Due to heat production, halogen lighting is not appropriate for internal use, but can be combined with fiberoptic technology for use in laryngopharyngeal endoscopy. Without halogen lighting, illumination for standard flexible fiberoptic light transmission would not be intense enough to permit visualization.

Stroboscopic illumination is distinct from the regular continuous light illumination of routine clinical examination, and uniquely suited to clinical observation of vocal fold vibration during phonation. Vocal fold vibration during phonation occurs at 80 to 1,000 cycles per second, a rate that readily overwhelms the input capacity of the retina, which can only resolve about five images per second. In the latter part of the 19th century, Oertel discovered that he could shutter a constant light source used to view the larynx at a rate just slightly different from that of the vibration of the vocal folds to select slightly different images from different vibratory cycles of the vocal fold for presentation to the human visual system. Because an image presented to the eye is held on the visual cortex for 0.2 seconds, a phenomenon known as persistence of an image, the visual cortex fuses these images, actually a montage, into a slow-motion, apparently continuous sequence of vibration.

Oertel used a spinning disk to shutter the light source, which was cumbersome and difficult to synchronize correctly. By the 1950s, the xenon arc lamp lighting system had been developed expressly for the purpose of creating a very bright short pulse of light to illuminate an object. The inherent properties of the xenon gas permit rapid ignition and production of a bright short flash of light in the range of 1 μs (1 millionth of a second). The application of quickly pulsed xenon light, timed to vocal fold vibration by means of a microphone, permitted laryngoscopic examination under stroboscopic light to become clinically practicable.

It is important to note that illumination and examination technique are two completely independent factors. Both stroboscopic and continuous light examination may be performed through flexible or rod-lens systems. Stroboscopy was initially best performed with rod-lens examination techniques, because the relatively large and stable fibers for light transmission present in such systems were far more effective than light-carrying

fiber bundles in early flexible endoscopes. Because both light-carrying fiber bundles and the image-carrying bundles need to be small enough to pass through the nasal cavity, developers of fiberoptic instruments reduced the overall number of light-carrying fibers, compared to the number built into rigid transoral endoscopes. This reduction in light compromised the utility of fiberoptic flexible endoscopes for stroboscopy. For image transmission to equal that of a rod-lens system, the clad fibers need to be 5 μm in diameter and placed in parallel, a technology which may never be feasible because of cost and fragility.

Distal Chip Endoscopy

In laryngology, fiberoptic image transmission is being replaced by computer chip technology, a transition that has already occurred in pulmonary and gastro-enterological endoscopy. This couples fiberoptic light transmission with digital image acquisition and transmission. Although the laryngopharynx remains illuminated with the fiberoptic light system (constant or stroboscopic), the image is captured distally by the miniaturized camera chip at the scope tip and transmitted electronically by wire. Minimal degradation occurs and image quality/resolution is dependent primarily on the characteristics of the distal chip camera, and the quality of light through the flexible fiberoptic bundles. The image quality of such endoscopes is markedly superior to most fiberoptic systems, and significantly more stable, as the electrical systems hold up better on repeated use than fiberoptic bundles. In addition, due to the reduced size of the chip camera as compared to the fiberoptic bundle, relatively greater numbers of fibers can be used to transmit light in distal chip flexible endoscopes. Distal chip endoscopy, or "chip-tip" endoscopy, provides a reliable image nearly as good as rod-lens technology and makes possible detailed clinical observations, including stroboscopy, via a transnasal approach.[6]

High-Speed Cinematography

High-speed cinematography has recently become available for office use, although it remains expensive. High-speed filming developed concurrently with xenon light technology, and was initially designed to study jet engine performance. It was adapted to visualize laryngeal vibration during the middle of the 20th century, but its true clinical value in the study of laryngeal vibration remains undefined. Therefore, the technology has yet to be widely applied in clinical practice, a situation that may change as companies commercialize the technology.

In high-speed cinematography, between 2,000 and 6,000 separate images can be captured each second. It is the first imaging technology with a capture rate faster than vocal fold vibration. This allows the evaluation of vocal fold vibration without the problem of missing aspects of the vocal fold vibratory activity, particularly when vibrations are aperiodic, as is often the case with vocal fold scar (Fig. 1). Because stroboscopy depends on aliasing, or producing a representation of vibration from

a montage of images across multiple vibratory cycles, it is virtually blind in the latter situation. Original high-speed cinematography units actually used 35 mm film, which was exposed with a xenon arc lamp so rapidly that the exposed film could not be spooled rapidly enough by any available winder, and had to be allowed to roll out onto the floor. Video technology now allows images to be captured and digitized for instant playback. The few commercially available units allow the user to select the rate of image capture. At present, only rod-lens technology transfers light from the xenon light source efficiently enough to allow adequate resolution, and thus high-speed imaging via flexible laryngoscopy is not presently possible.

The obvious advantage of the higher capture rate is greater detail in mucosal movement during voicing. The disadvantage is that the sheer amount of data requires a substantial amount of time to analyze. If we assume that most video technology plays images back at rate of 30 frames per second, then viewing 4,000 frames captured in 1 second of voice production just once will require over 2 minutes at the standard playback rate. Commercially available units allow the examiner to choose 2-second segments of voice production to image. Practically, it is often difficult to determine which 2 seconds of voicing are clinically important, and then equally challenging to analyze those 2 seconds. Several researchers have focused on vibratory patterns at onset of phonation, in vocal folds with lesions, and after periods of extended voice use.[7–9] These studies, although well done, have not yet resulted in information that has impacted clinical practice. In contrast, even though stroboscopy only provides a representation of mucosal vibration, it does allow/encourage extended observation across multiple pitches and intensities. From this information, clinicians have been able to identify altered vibratory patterns that are associated with clinically relevant disease states. As we learn more with clinical study, we may find that high-speed cinematography provides useful data at certain points during voice production, such as vocal onset or offset, so that the information achieves clinical relevance.

Kymography

Kymography is an outgrowth of high-speed cinematography with video capture. In kymography, the examiner selects one horizontal plane (essentially one raster line of the video image) of the glottis for detailed visualization. The vibratory motion of the vocal fold in that plane, as it moves toward and away from the midline, is then plotted in the vertical axis. This allows the examiner to study the movement of the most medial aspect of the vocal fold toward and away from the midline. In this manner, provided that the endoscope is oriented exactly perpendicular to the long axis of the glottis, the movement of the medial edges should appear symmetric during normal voice production. In patients with altered voice, vocal fold edges may be plotted to show asymmetrical movement or movement at different speeds (Fig. 2).[10] Again, as with any examination technique,
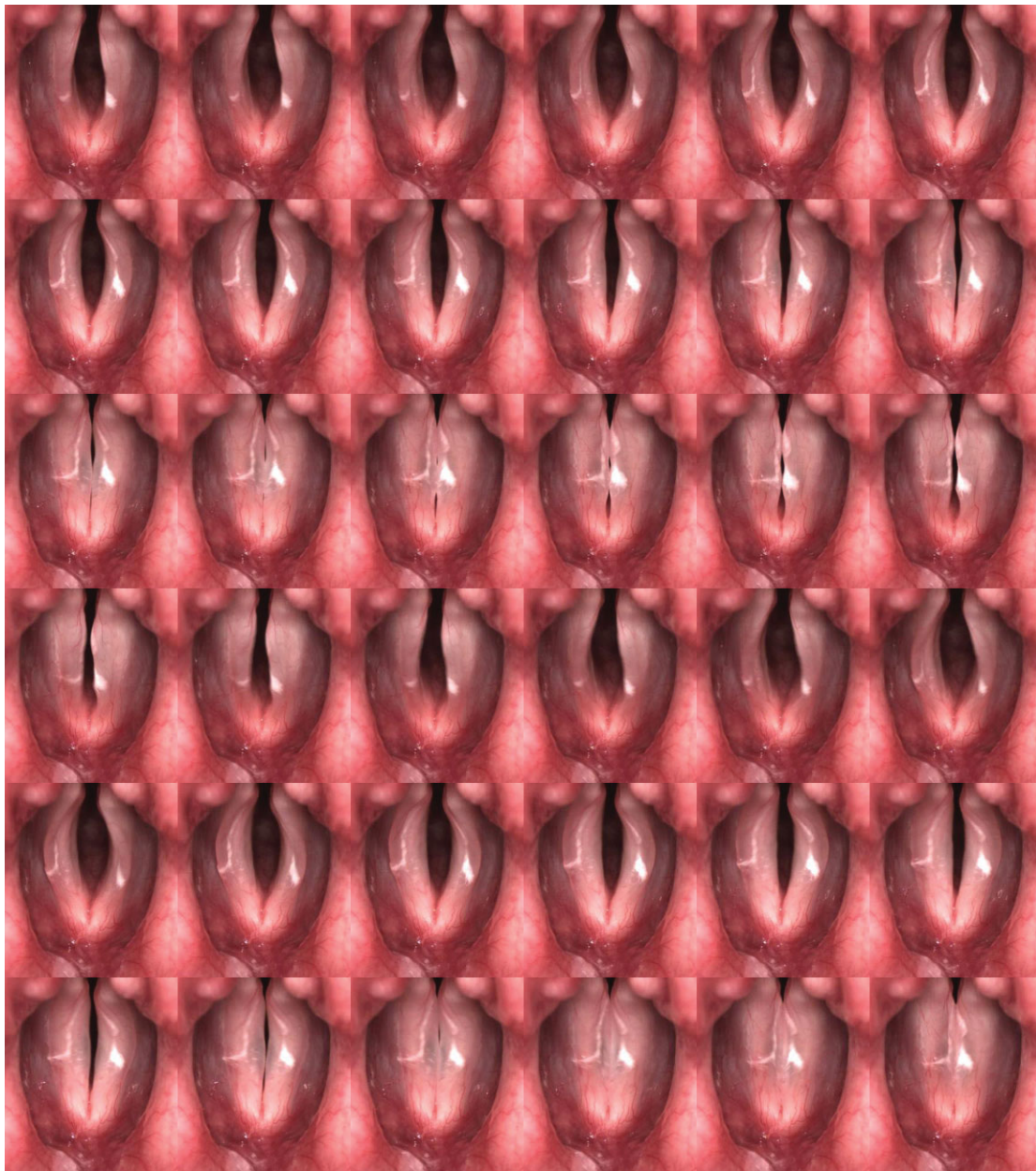
Fig. 1. Montage of high-speed imaging from two vibratory cycles. These 36 frames actually represent consecutive images captured during phonation. These were captured at a frame rate of 2,000 images per second. Therefore, these 36 images represent less than 0.002 seconds of phonation. (Image courtesy of Kay Pentax, Lincoln Park, NJ; color high-speed camera, model 9710).

there are many variables, ranging from the placement of the endoscope to choosing the correct plane of vibration for study and the correct voice segment. With further study, videokymographic observations may help improve our ability to diagnose altered laryngeal vibratory patterns.[11]

Narrow Band Imaging

Narrow band imaging (NBI) is a technique of visualizing mucosal surfaces using selected portions of the light spectrum, or "narrow bands." Visible light, perceived as white light, is energy from the electromagnetic spectrum of wavelengths between 400 and 700 nm. Different wavelengths are perceived as different colors. The shorter wave lengths are blue in hue, whereas the longer wavelengths are red. Color is perceived from the wavelength that is reflected back from the object. For example, an apple appears red because the surface absorbs the blue/green wavelengths and reflects back the red. As light encounters tissue, it is absorbed and scattered. The long wavelengths (red) diffuse deeply, whereas the shorter wavelengths (blue) diffuse more superficially. Because some cancers arise in the superficial epithelium of tissue, and are associated with the abnormal proliferation of blood vessels due to
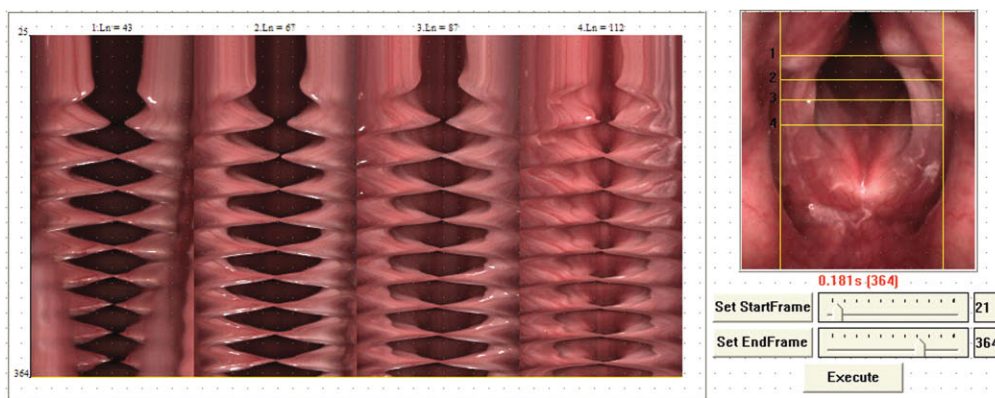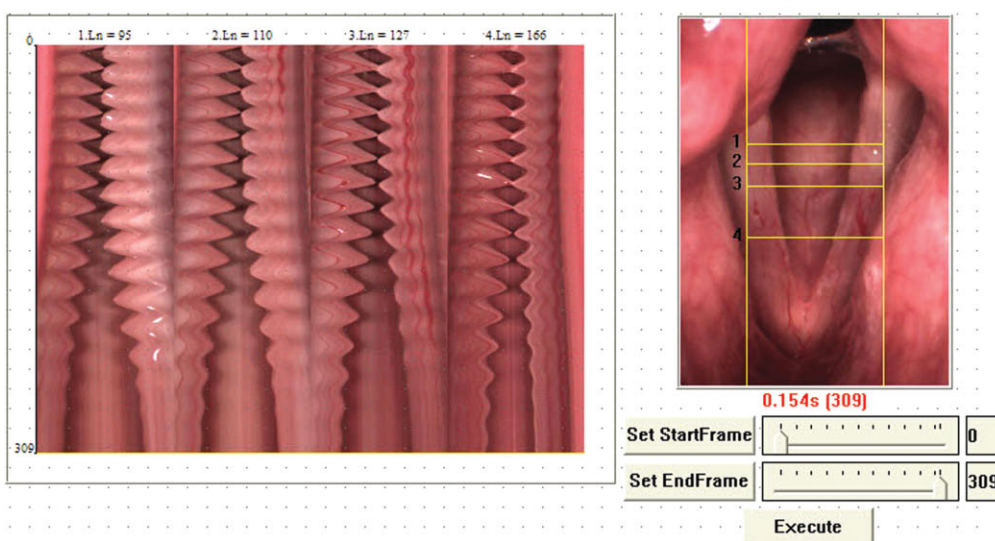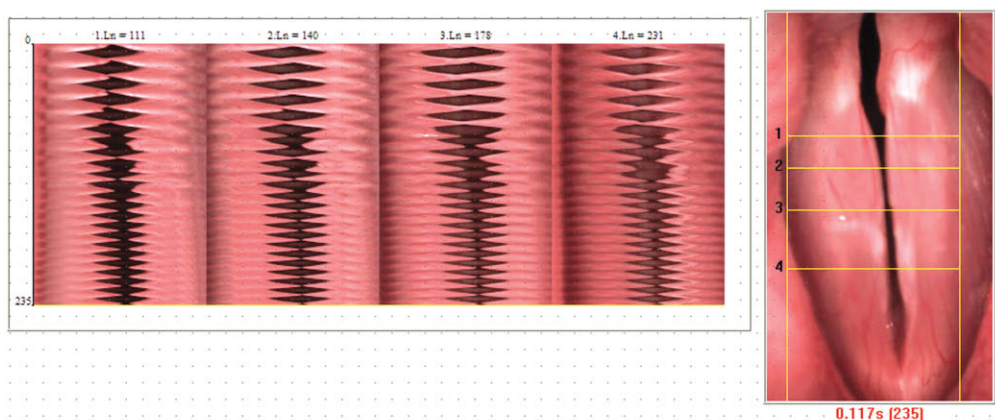
Fig. 2. Examples of kymography obtained from high-speed video examination of the larynx. Right hand image shows from where along the anterior-posterior aspect of the membranous vocal fold the kymography is being recorded. (A) Kymography during voice onset using a loud, breathy voice. Note large amplitude of the vocal fold and symmetry. (B) Kymography during voice offset with marked asymmetry. (C) Kymography during a break in the voice. Note the irregular amplitude and loss of periodicity in the middle of each kymography recording. (Image courtesy of Kay Pentax, Lincoln Park, NJ; color high-speed camera, model 9710.)

Fig. 3. (A) During transnasal esophagoscopy an irregular area of the squamocolumnar junction is seen above the gastroesophageal junction. (B) Narrow band imaging of the same individual clearly shows the area of 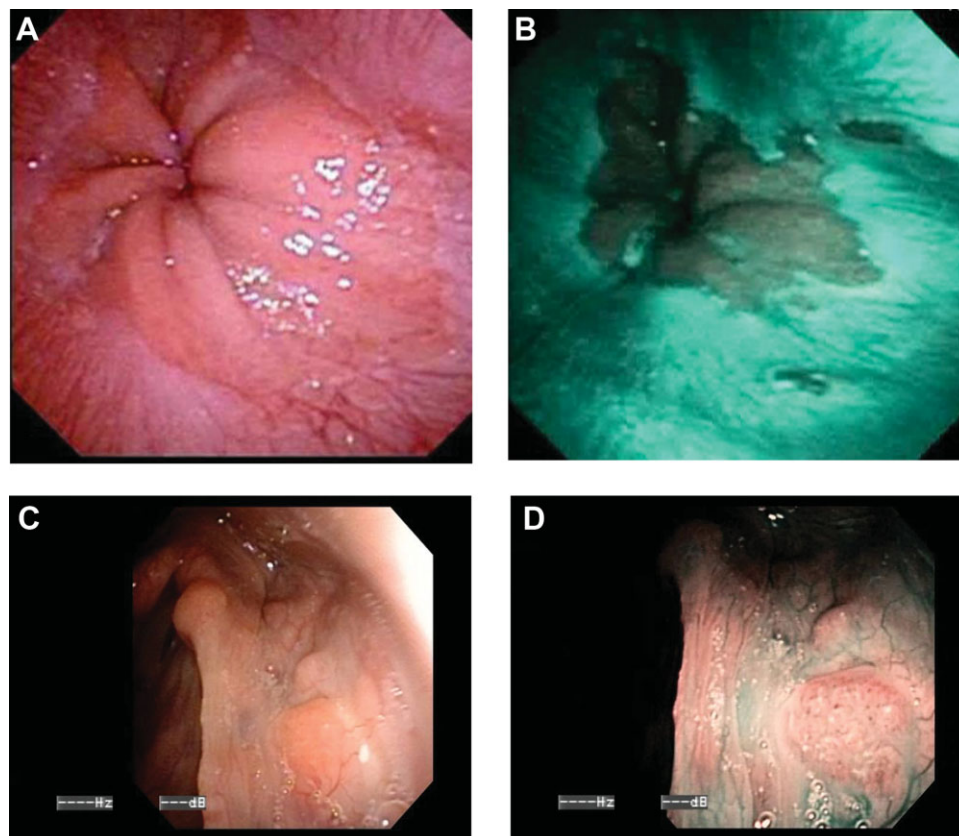abnormal epithelium along with 2 small "islands" of abnormal mucosa. (Olympus 280 K 001, Olympus America, Center Valley, PA) (C) View of slight mucosal irregularity in left pyriform sinus when viewed with a halogen light source. (D) View of same left pyriform sinus lesion with narrow band light filter. Punctate vascular pattern is present. On biopsy this was an invasive squamous lesion. (Olympus ENF-V2; Olympus America, Center Valley, PA)

angiogenesis, NBI technologies select only the shorter wavelengths of light to view tissue.[12] By filtering light to limit it to bands in the 400 nm (blue spectrum) and 540 nm (green spectrum) range, which are preferentially absorbed by the hemoglobin pigment in the superficial vasculature,[13] abnormal superficial blood vessels can be made to appear dark, and thus more obvious to the examiner. In esophageal neoplasia, NBI imaging is being studied to determine if routine surveillance can pick up these abnormal vascular patterns in individuals with Barrett's esophagus before they can be identified with standard visible light endoscopy (Fig. 3). Similar studies are being carried out for cancers in the head and neck area.[14,15] This work has not yet been conclusive, but for cancers not associated with keratosis, NBI screening may provide an advantage for early detection (Fig. 4). In lesions that are keratinized, such as many laryngeal lesions, the technology may be less useful, as keratosis reflects all of the visible light and appears white. This has been the case in autofluorescence, in which the oxidized flavin mononucleotide emission of a green fluorescence is hidden by the presence of keratosis.[16]

Conclusion

Contemporary office indirect endoscopy depends on high-quality images of the laryngopharynx, achievable with an array of readily available technology. Continuous light sources, such as halogen light, can be paired with standard flexible endoscopic technology to examine the hypopharynx for the condition of the mucosa, pooling in the pyriform sinus, vallecula and esophageal inlet, motion in the lateral pharyngeal walls, motion in the tongue base, and motion in the larynx. Motion in the larynx is evaluated at the level of the vocal fold proper and in the supraglottic tissues during phonation and other vegetative laryngeal tasks, such as coughing and throat clearing. Some debate exists as to whether using a Hopkins rod-lens endoscope provides equivalent information as a flexible transnasal endoscope, especially with respect to vocal fold motion (adductory and abductory range of motion). The argument has many variables, especially since the introduction of distal chip technology, and is in some part an artificial one, because there is usually nothing to prevent both examinations from being performed in the same patient if there is a need. In any case, no empirical equivalence study that specifically compares the two tests has been performed. The examiner should use whichever technique obtains the required information, and many clinical situations may require both a flexible and rigid scope approach.

In cases in which detailed examination of vocal fold mucosa and its vibratory characteristic are indicated, stroboscopic examination may be undertaken using either rigid or flexible instrumentation. The best combination of light carriers and image transmission for this examination technique remain the rigid Hopkins rod-lens endoscopes, but rigid instruments should in no way be considered the only means by which stroboscopic examination may be performed. Stroboscopy is possible
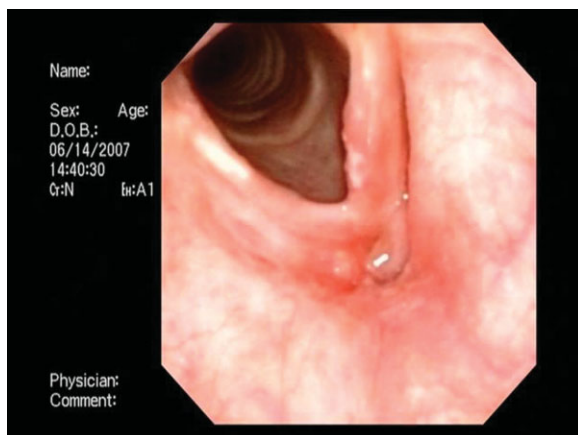
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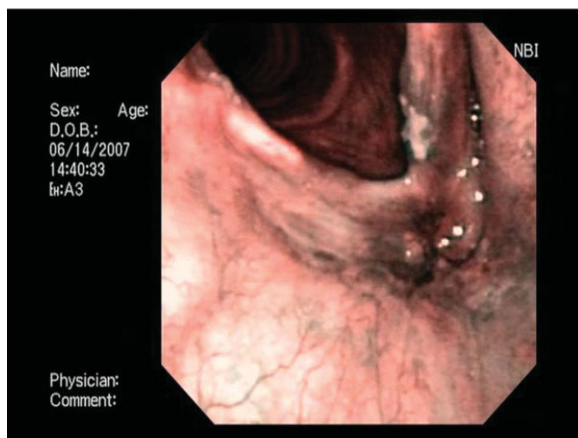
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Fig. 4. (A) Microinvasive squamous cell cancer of the left vocal fold viewed with halogen light through a distal chip endoscope. (B) Microinvasive laryngeal carcinoma visualized with narrow band light filter. Keratosis of primary lesion site that reflects all light, thus the image does not change with narrow band imaging. (Olympus ENVF-2, Olympus America, Center Valley, PA.)

with fiberoptic endoscopes, particularly now that distal chip technology has greatly improved image transmission compared to all-fiberoptic instruments, although the image still falls somewhat short of that obtained by rigid rod-lens examination.

At this time, high-speed cinematography, kymography, and narrow band imaging remain experimental means of imaging laryngeal and hypopharyngeal anatomy and function.

ANESTHESIA FOR OFFICE-BASED LARYNGOLOGY PROCEDURES

The success or failure of office-based procedures of the larynx hinge on patient comfort. An inadequately anesthetized patient is apt to be uncomfortable, anxious, hyper-responsive, and unlikely to tolerate office-based procedure; conversely, a patient who is well informed, well prepared on what to expect, reassured, and thor-

oughly anesthetized can undergo most any office laryngeal procedure.

When one begins to incorporate these techniques into their practice, a steep learning curve can be expected for some procedures, especially injection augmentation and laser procedures. It is best to choose "ideal" candidates for these first five to 10 procedures while a level of comfort is achieved. An ideal candidate has minimal to no gag reflex, reasonable pain tolerance, low level of anxiety, and is able to remain still and cooperative for a 20- to 30-minute period. Most patients are reasonable candidates for office-based laryngeal procedures. The following criteria are used:

Indications and Contraindications

- The patient must tolerate a flexible laryngoscopic exam without an excessive gag response. Monitoring with a flexible endoscope is key to maintaining visualization, and a hyper-responsive gag may render any procedure impossible. However, it should be noted that gagging with a mirror or rigid transoral endoscope is not a contraindication.

- The patient must have a patent nasal airway, at least unilaterally, to pass the flexible examination scope (around 3–4 mm for standard flexible laryngoscope, and approximately 5 mm for transnasal esophagoscopy and working channel flexible laryngoscope.) This rarely presents a problem.

- The patient must be able to remain reasonably still and upright in the exam chair for the duration of the procedure (typically 5–15 minutes). Patients with severe torticollis or head tremor (from essential tremor) are sometimes difficult to treat.

Relative contraindications for performing office-based laryngoesophageal procedures are as follows:

- Use of anticoagulants (acetylsalicylic acid, nonsteroidal anti-inflammatory drugs, Plavix, Coumadin). Ideally, the patient should be taken off of these prior to any planned biopsy or injection; however, clinical experience has shown that almost all of these patients seem to do well despite being on these medications at the time of their procedure.[17] A theoretical risk of hematoma and airway swelling is always possible with biopsies and injection augmentation, and the patient should be informed of this if the anticoagulants cannot be discontinued.

- Anxiety disorder/overly anxious patient. Obviously the patient's anxiety level comes into play, and must be taken into account when determining the patient's suitability for a clinic-based procedure. In some patients, a 2- to 5-mg diazepam tablet taken perorally 30 minutes before the procedure seems to help. However, this may necessitate monitoring the patient

with pulse oximetry during the procedure, and requires that someone else drive the patient home, thereby negating some of the prime benefits of unsedated, office-based procedures.

A methodical approach where the patient is informed of each upcoming step before it occurs is very helpful in alleviating patient anxieties. When manipulation of the larynx (injection/biopsy) is performed, the patient should be instructed to concentrate on (their) breathing during this portion of the procedure. This can be quite successful in patients with hyper-responsive gag reflex. Slow, shallow breathing is best to minimize the abductive effects of deep inspiration. In some patients, increased participation in their procedure seems to help. For example, some patients prefer to hold their own tongue with a gauze (as opposed to the surgeon) during the procedure. Forcing the patient to focus on a task such as this may act as a useful distraction. Last, some patients benefit from viewing the monitor as the procedure takes place, something akin to biofeedback.

Anatomy of Laryngotracheal/Esophageal Sensory Innervation

The sensory nerves of the larynx, trachea, and esophagus are derived from the vagus nerve. The internal branch of the superior laryngeal nerve supplies sensation to the glottic and supraglottic structures, whereas the subglottic sensory innervation is from the recurrent laryngeal nerves. The trachea and esophagus have sensory innervation from branches of the vagus nerve distally. The internal branch of the superior laryngeal nerve (SNL) pierces the thyrohyoid membrane at a point halfway between the hyoid bone and the superior border of the thyroid cartilage, and roughly halfway between the thyroid notch and the superior cornu of the thyroid cartilage. This entry point of the SLN through the thyrohyoid membrane can be located for SLN nerve blocks in certain cases[18]; however the vast majority of patients achieve excellent results via topical anesthesia only, as described in the following section.

Anesthesia Techniques of the Larynx and Trachea

Topical anesthesia for laryngeal procedures, such as injection, laser and biopsy, require the following sequential application[19]:

• Topical oxymetazoline/tetracaine 2% spray to nasal cavities

• Topical Cetacaine spray to oral cavity (palate/posterior pharynx)

• Lidocaine 4% drip on tongue base and larynx under flexible laryngoscope guidance (3–5 cc)

To achieve step 3, a flexible laryngoscope with a video monitor is used. The assistant can be a physician; however, paramedical office personnel can be trained to

Fig. 5. Sniffing position to maximize laryngeal exposure.

manipulate the endoscope. The endoscope is generally maintained slightly below the palate so that the tongue base and larynx can be easily viewed on a video monitor. The patient is bent forward at the waist with the neck extended in a "sniffing" position to maximize laryngeal exposure (Fig. 5). The tongue is grasped with a 4 inch × 4 inch gauze with the surgeon's left hand. A 3-cc syringe of 4% lidocaine attached to an Abraham cannula (Pilling; Teleflex Medical, Research Triangle Park, NC) is advanced into the oropharynx. Approximately 1 cc is deposited over the tongue base, and 2 to 4 cc are dripped onto the vocal folds during phonation, producing the characteristic "laryngeal gargle" described by Hogikyan.[20] It is optimal to deposit the 4% lidocaine in several 0.5- to 1-cc aliquots, instead of one large dose. The initial dose is usually followed by a brisk cough, as the anesthetic is aspirated and then distributed over the laryngotracheal mucosa. Absence of the laryngeal gargle and cough may indicate that the patient has swallowed the anesthetic, and additional topical applications may be indicated until the desired effect is obtained.

The preceding description is also adequate for achieving tracheal anesthesia; however, an alternate method is to perform a puncture of the cricothyroid membrane with a 27-gauge needle and instill 2 to 4 cc of 4% lidocaine transtracheally. Aspiration for air to confirm intraluminal needle position is essential prior to injecting transtracheal lidocaine. If the patient has a

tracheostomy tube, then this is removed and lidocaine is administered through the stoma. After instillation, the stoma is occluded to insure that the anesthetic is distributed proximal to the stoma as well. This technique is especially helpful when evaluating patients with subglottic/tracheal stenosis.

Another administration option is to deliver the lidocaine via a syringe attached to the working channel of a flexible scope. The only disadvantage of this method is that this tends to result in a sudden release of 2 to 3 cc of anesthetic through the channel, which is often poorly tolerated and results in waste, as a large portion of the anesthetic is swallowed. A much more efficient and better-tolerated method to deliver lidocaine is through a special catheter (PW-6P-1; Olympus America, Center Valley, PA) placed through the working channel of the flexible endoscope (Fig. 6). This catheter allows the physician to drip the lidocaine in a more controlled and well-tolerated fashion. Also, lidocaine delivered through an inhalation nebulizer is another efficient way to achieve local anesthesia of the upper aerodigestive tract. Typically 3 to 4 cc of 4% lidocaine are used. Often, a small amount of supplemental lidocaine must be used to achieve complete anesthesia of the larynx with this method.

Within 90 seconds of topical administration, the laryngopharynx and trachea are adequately anesthetized to perform any number of office-based procedures. The lidocaine results in 45 to 60 minutes of anesthesia theoretically; however 20 minutes is often the maximum window of time that the patient can tolerate the procedure before discomfort and/or gagging occur. For this reason, the surgeon must work very efficiently to complete some of the more time-consuming procedures, such as laser treatment of laryngeal lesions, or they may need to reapply anesthesia. In some cases of longer duration, additional 2 to 3 cc of 4% lidocaine can be used if adequate time has elapsed since the commencement of the anesthesia.

Anesthesia for Transnasal Esophagoscopy

Topical anesthesia for transnasal esophagoscopy (TNE) can be achieved quite effectively with the following protocol involving only nasal anesthesia: The patient's more patent nasal cavity is sprayed with a 1:1 oxymetazoline 0.05% and lidocaine 4% solution, and then packed with cotton pledgets soaked in the same solution. If any oropharyngeal anesthesia is required (it is usually not needed), one spray of 20% benzocaine (Hurricaine) is administered to the oropharynx. No additional anesthesia is needed for esophageal biopsies.

Precautions/Adverse Effects of Local Anesthesia

Drug reactions to local anesthetics are always a concern, although quite uncommon if some basic safety guidelines are followed. The following maximal dosage guidelines are recommended: 4% lidocaine (40 mg/cc), 7 to 8 cc (4.5 mg/kg; approx 300 mg in 70 kg pt); 2% Pontocaine (20 mg/cc), 0.9 cc (Pontocaine is administered for nasal anesthesia only, via an atomizer, therefore only 0.1–0.2 cc is typically used.); Cetacaine spray, spray for 2 seconds; Tessalon Perles, 100 mg, two 100-mg perles.[21,22]

Excessive use of any of the above anesthetic agents can lead to systemic toxicity involving cardiovascular depression, convulsions, and respiratory/cardiovascular arrest. Caution should be exercised when using combinations of different local anesthetics, because the toxic side effects may be additive. Toxicity can also be potentiated in patients with renal or hepatic compromise, heart block, and certain cardiac conditions. Allergic reactions are uncommon with lidocaine, but may be more prevalent with the amino esters (Pontocaine/Cetacaine). The allergic response is typically limited to urticaria and rash formation; anaphylaxis is very rare. Another rare complication related to local anesthetics (especially Cetacaine) is methemoglobinemia. This condition results in impaired oxygen delivery to tissues and presents with
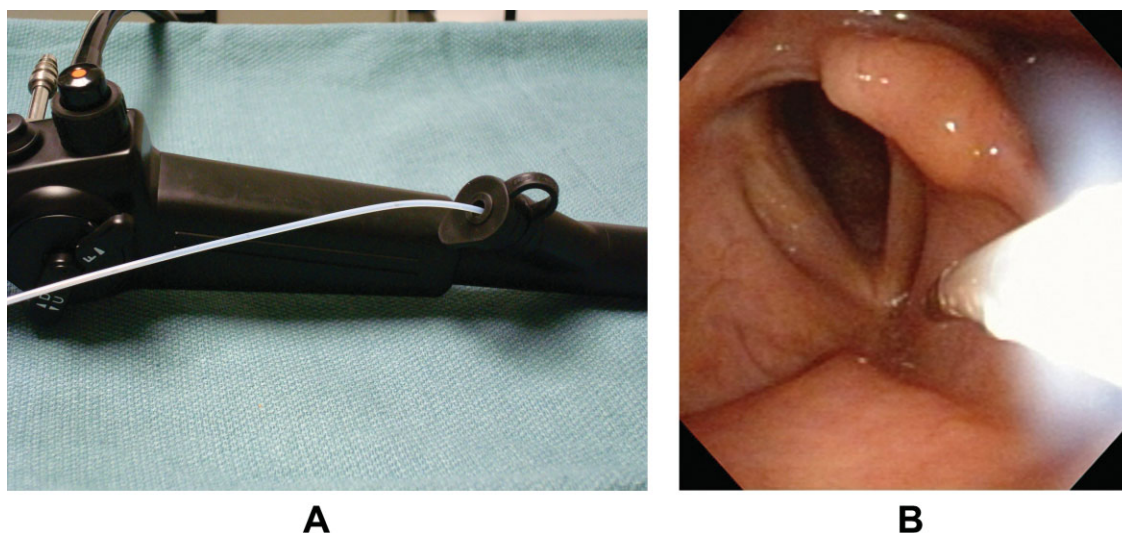

Fig. 6. Drip catheter for application of anesthesia. (A) Drip catheter inserted into working channel of flexible endoscope for anesthesia delivery. (B) Drip catheter coming out of working channel of flexible endoscope to deliver anesthetic to the endolarynx.

"chocolate cyanosis" of the mucous membranes—a brown discoloration of the lips and oral cavity mucosa. This may progress to more serious cardiac/central nervous system damage if methemoglobin levels rise above 70%. Treatment is IV methylene blue (1–2 mg/kg).

Rarely during laryngotracheal and esophageal office procedures vasovagal syncope can occur.[23] Precipitating factors may include patient anxiety, diffusion of anesthetic to the sympathetic trunk, or strong vagal stimulation from the procedure itself. The patient often has prodromal nausea, sweating, light-headedness, and paresthesia seconds to minutes before syncope occurs. Therefore, the procedure should be discontinued if the patient reports these symptoms. They should be placed in a reclining or supine position (an alternative is to have the patient place their head between their legs), and vital signs should be monitored. If syncope does occur, maintain the patient in a supine position and continue to monitor vital signs until the patient recovers consciousness (typically seconds later).

Monitoring Requirements

Because sedation is not employed, no monitoring equipment or intravenous lines are needed as a general rule. However, common sense will dictate that certain particularly ill or medically fragile patients with severe underlying pulmonary disease and/or supplemental oxygen requirements should be monitored with pulse oximetry at the very least. These patients may be better suited for the operating room under monitored anesthesia care or a hospital-based endoscopy suite with nursing and monitoring capabilities.

Postprocedure Patient Instructions

Because of the profound anesthesia of the upper aerodigestive tract, the patient is at risk for aspiration. We routinely instruct the patients to remain nil per os (NPO) for 60 minutes following the procedure, until full sensation in the throat returns. Postoperative pain is unusual, and acetaminophen is usually all that is necessary.

Conclusion

Topical anesthesia can be successfully achieved for almost all endoscopic procedures of the larynx, trachea, and esophagus. If strict guidelines for anesthetic dosing are followed, there is no need for pulse oximetry monitoring, and the risk of an adverse reaction is extremely low.[24]

UPPER AIRWAY EVALUATION AND TREATMENT

Most patients with airway complaints related to the upper aerodigestive tract can be assessed under topical anesthesia during a routine clinic visit. Furthermore, intervention for disorders affecting the laryngotracheal airway can also be accomplished in the awake setting in many cases. In this section, the indications, advantages, and disadvantages related to these practices are outlined. As with all patient-care discussions, the procedures and techniques reviewed here require a mature degree of clinical sensibility: What can the patient tolerate? What is appropriate in an awake patient? Is this evaluation/treatment safe in this setting? What are the diagnostic and therapeutic alternatives? These are decisions that otolaryngologists make every day; this discussion is particularly cogent in the area of in-office airway assessment and treatment.

With a few exceptions, flexible endoscopic examination is advantageous over transoral rigid examination for most patients with airway complaints. This approach allows for assessment of dynamic and fixed airway obstruction and facilitates topical anesthesia (by way of the channeled laryngoscope) if desired. A few exceptions are noted in the following sections. The clinician must also be aware of the potential for varying impressions of the airway depending on the modality used to assess it. This has been documented for inflammation around the glottis, for example, with a higher likelihood of abnormalities being described on flexible laryngoscopy than transoral rigid endoscopic exam of the larynx.[25] In a prospective study comparing flexible airway endoscopy to rigid airway endoscopy and radiographic imaging (computed tomography), Carretta et al. noted that there was some variation between clinic and operative airway endoscopy in predicting presence and characteristics of subglottic stenosis, for example.[26] Radiographic imaging was not ideal in assessing the length of stenosis, although it is particularly useful when investigating the airway distal to a tight stenosis that cannot safely be examined in clinic. With these caveats in mind, the sections below review several clinical entities and their evaluation in the office setting.

Cricoarytenoid Joint Fixation

Cricoarytenoid (CA) joint fixation may occur following prolonged or even routine intubation. CA ankylosis or arthritis may be present in as many as 25% of patients with generalized rheumatoid arthritis (RA), but there are no existing reports of the diagnosis of RA having been made with the initial presentation of CA arthritis in the absence of generalized or previously diagnosed RA.[27,28] Two basic findings can help the clinician distinguish between neurologic and mechanical motion impairment in the awake patient. One is the "jostle" sign, in which the denervated but mechanically mobile arytenoid is moved, or jostled, by the working vocal fold-arytenoid complex in neurologic impairment; in contrast, the CA joint with fixation will not be moved by the impact from adduction of the other side. Thus absence of a jostle sign suggests possible CA joint fixation.[29,30]

Palpation of the CA joint as an awake evaluation to determine its function has been described.[31,32] When mechanical impairment of CA joint function is suspected, the larynx is anesthetized topically (as presented in the previous section). Once anesthetized, the patient grasps their own tongue with a gauze, as the otolaryngologist
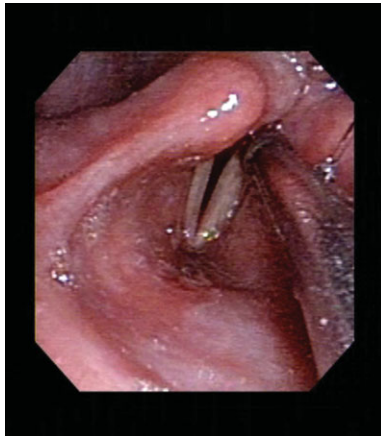
Fig. 7. Laryngeal cannula palpating arytenoid vocal process.

examines the larynx with a rigid telescope (70°) in one hand (the laryngeal visualization can alternatively be provided by flexible laryngoscopy) while manipulating the CA joint with a curved laryngeal forceps (or Abraham cannula) placed transorally with the other hand. The instrument is placed next to the immobile vocal process and gentle pressure is applied laterally and posteriorly to determine its passive mobility (Fig. 7). The contralateral arytenoid can also be manipulated during this exam, and with bimanual retractions of the arytenoids (patient holds own tongue), an excellent assessment of the posterior commissure can be done looking for posterior glottic stenosis.

Bilateral Vocal Fold Immobility Assessment

The importance of distinguishing the varying types of posterior glottic stenosis, as described by Bogdasarian,[33] can also be accomplished in the office setting. Retrograde subglottoscopy is very valuable and can be performed under local anesthesia via a tracheostomy. For this procedure, topical lidocaine is sprayed into the tracheotomy tube, after which the patient is asked to cough, thus distributing lidocaine to the subglottis and trachea. Decongestants, especially Neosynephrine, are not used in the airway due to concerns regarding systemic uptake and cardiovascular effects. The tracheostomy tube is removed briefly as the flexible endoscopy is passed distal to visualize the entire trachea and mainstream bronchi. The scope can then be retroflexed into the subglottis for evaluation of the subglottis, posterior commissure, and infraglottic aspect of the vocal folds.

Paradoxical Vocal Fold Motion Disorder

One of the most vexing conditions faced by otolaryngologists, speech-language pathologists (SLP), pulmonologists, and many other clinicians is paradoxical vocal fold motion disorder (PVFMD). Referred to in the general medical literature as vocal cord dysfunction, this disorder is characterized by inappropriate adduction of the vocal folds during respiration (inspiration and/or expiration). Although the etiology and pathophysiology of this disorder continues to be debated, its treatment with experienced speech-language pathologists is the mainstay of management.[34,35]

Flexible laryngoscopic examination of these patients is helpful in establishing the diagnosis in many cases, and in ruling out other laryngeal abnormalities.[36] Anecdotally, the patient's ability to understand the upper airway and participate in their respiratory retraining is significantly enhanced by their experience viewing their own larynx during the clinic examination, including the use of biofeedback during therapy sessions in severe cases.

When evaluating a suspected case of PVFMD, several options are available to the otolaryngologist. In patients with exercise-related dyspnea, one may have the patient run up and down stairs; once the patient is short of breath or otherwise experiencing symptoms, laryngoscopy is performed immediately to evaluate for inappropriate closure of the larynx during inspiration (Fig. 8). This exam is compared to the baseline flexible laryngoscopy. If the patient is not able to do so, or it is not otherwise convenient for the clinic setup, asking the patient to perform rapid counting serves as a reasonable surrogate to exert the patient.[37] In this task, the patient is asked to count from one to 100, for example, in one breath without stopping. If necessary, this is repeated until the patient experiences some shortness of breath. The larynx is closely scrutinized during the patient's recovery period and the images are reviewed following the exam. Ideally, an expert SLP is available to intervene with the scope in place to demonstrate the patient's own ability to positively impact their laryngeal airway. In more elusive cases, for example with elite athletes or patients in whom there has been no response to therapy, exercise laryngoscopy[38] can also be performed in a more formal manner. Although the impact of detecting paradoxical motion during any exam on the patient's overall outcome is not known, it may help to avoid other evaluations and to reassure the patient and family that the problem has been localized to the upper airway.

In a similar approach, patients with dyspnea symptoms related to environmental stimuli (such as odors) can be evaluated by flexible laryngoscopy with and without odor provocation.[39]

Subglottic and Tracheal Stenosis

In-office evaluation of the airway can be highly useful in ruling out distal or secondary stenoses and characterizing the nature of the obstruction. As outlined in the anesthesia section, the complete tracheobronchial tree can be evaluated in the clinic setting, although sound judgment is necessary to anticipate which patients may be too fragile or intolerant of the exam. Once anesthesia of the trachea is established (as discussed earlier), the airway may be assessed by passing a standard flexible laryngoscope; this will easily reach the carina and will often allow visualization into the principal bronchi. The transnasal esophagoscope or pediatric bronchoscope can easily proceed distally and instill topical anesthetic if required. Furthermore, without direct

Fig. 8. Collegiate athlete with paradoxical vocal fold motion disorder on portable rowing machine being examined in clinic during exercise.

topical anesthesia to the bronchi, such as administered through the working channel of a flexible scope, this exam is not well tolerated. For most otolaryngology evaluations, the standard scope and anesthetic will suffice. In-office airway examination is also safe and feasible in children.[40]

This examination is most useful in characterizing subglottic and tracheal stenosis. If the airway is not much larger than the scope, the exam is still possible but must be done quickly, as the patient will rapidly sense airway obstruction. If the area is notably inflamed or friable, routine or elective examination is best delayed so as to not exacerbate the condition. Tracheomalacia is particularly well suited to the awake examination, as dynamic collapse of the thoracic trachea leading to cough or airway obstruction is seen in this setting more easily than under general anesthesia.

In terms of intervention in the subglottis and trachea, the advent of fiber-delivered laser energy and balloon dilation has expanded the scope of in-office practice for otolaryngologists.

For the treatment of airway stenosis, balloon dilation has not been studied to the same extent as esophageal dilation, but this technique does appear to be a promising method to endoscopically open the narrowed airway.[41] With appropriate anesthesia, several laryngologists have pioneered the use of balloon dilation in the awake patient, even in nontracheotomized patients.

In this approach, a multidiameter hydrostatic radial expansion balloon (CRE Pulmonary Balloon Dilation Catheter and Guidewire; Boston Scientific, Boston, MA) is used to dilate the narrowed airway. In a series of 12 patients, no serious complications were encountered.[42] The authors explicitly outline the steps for this procedure as follows: following topical anesthesia, flexible airway endoscopy is performed and a guidewire is placed across the stenotic segment. The guidewire is left in place with the tip at the carina as the scope is withdrawn. Great care should be taken to prevent the distal advancement of the guidewire. The scope is reintroduced alongside the guidewire, and a balloon dilator is positioned across the stenosis. The authors make the explicit point that "the patient is asked to take a deep breath, then expire, and hold his/her breath for the length of dilation (usually 30 seconds)." The authors also highlight the importance of establishing signals and communication between the patient and clinicians prior to the procedure.

Following intervention, the airway is examined again; as many as 50% of patients will have notable lacerations, but these have not proved clinical significant.[43] The patient is then closely monitored for chest pain and dyspnea after the dilation. Treatment of the airway can also be accompanied by fiber-delivered lasers (CO_2, potassium titanyl phosphate [KTP], gold) that may be placed in the working channel of a laryngoscope. This is

further outlined in the section on in-office laser treatment of the larynx.

USE OF THE LASER FOR TREATMENT OF LARYNGEAL CONDITIONS IN THE OFFICE SETTING

Since the introduction of the CO_2 laser to operative laryngoscopy, surgeons have been testing and using a variety of different lasers on laryngeal tissues. Each laser has a unique absorption spectrum that, when coupled to a specific tissue type, yields a specific response. It should be noted that lasers in otolaryngic surgery are generally used for their photothermal effects. In this capacity, lasers target a specific chromophore and cause heating of the tissue in this region. The laser settings, including the spot size, power, pulse width, and pulse interval all alter the effect of the laser-tissue interaction. In addition, the specific tissue characteristics, including the presence and location of chromophores and heat dissipation capabilities of the tissue will also govern the response of the tissue to the laser energy delivery.

The CO_2 laser has remained popular due to its unique absorption characteristics with respect to laryngeal tissues. The ideal laser for vocal fold surgery should have fairly superficial penetration (effect within the superficial lamina propria layer), produce little collateral thermal injury, be adjustable to allow for both coagulation and precise cutting, and allow for deflection of the beam path while inside a rigid or flexible laryngoscope (i.e., flexible delivery system). Although traditionally the CO_2 laser has had most of these characteristics, until recently it has lacked an adequate flexible delivery system. Because of this, surgeons have continued to test fiber-based lasers on the larynx, in the hopes of discovering a laser that has ideal tissue effects in the larynx, yet has the capability of traveling along a flexible fiber.

The recent interest regarding in-office laryngeal surgery has redoubled the interest of surgeons to have a flexible laser delivery system to allow lasers to be used through flexible laryngoscopes. In the late 1990s, the pulsed dye laser (PDL) was adapted for laryngeal surgery.[44] Since then, other groups have adapted fiber-based lasers, such as the PDL, pulsed KTP laser, thulium laser, neodymium yttrium aluminum garnet (Nd:YAG laser), and gold laser.[45–47] Additionally, fiber-based systems have been developed in recent years to allow for transmission of the CO_2 through a flexible laryngoscope.

Patient/Laser Selection

As with any office-based procedure, patient selection is critical to procedural and outcome success. Although intolerance to routine laryngoscopy is not a contraindication, patient comfort levels with unsedated surgery must be assessed and considered. Oftentimes, inability to tolerate the procedure may not be known until it is initiated. It is notable that although patients are anesthetized, they may feel burning and gagging from the use of the laser. There is some variability depending on the type of laser and settings used and the laryngeal subsite being targeted.
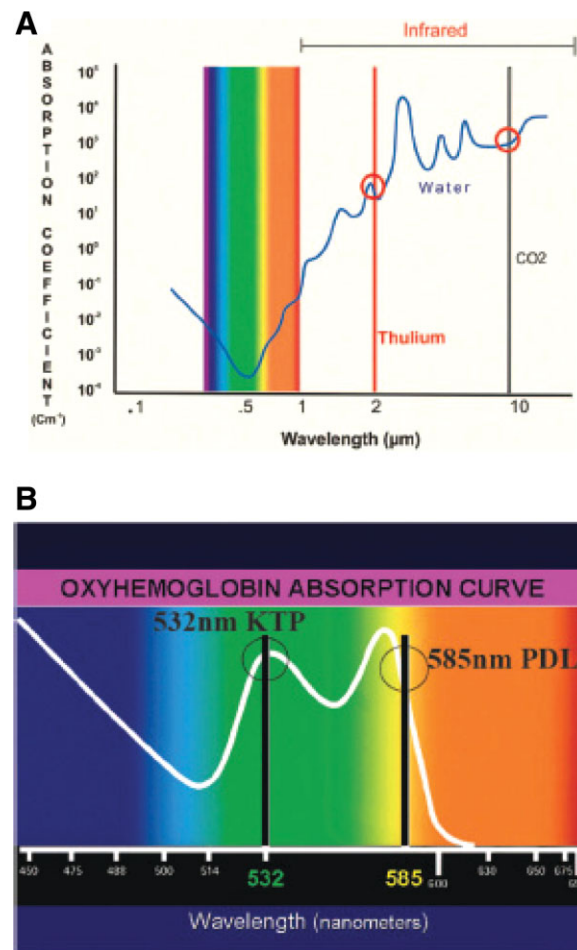

Fig. 9. Laser absorption. (A) Water absorption spectrum. (B) Oxyhemoglobin absorption spectrum. (From Burns, et. al. from Laryngoscope 118:1109-1124, 2008).

In addition to tolerance issues, medical condition should be assessed. Although there are no specific guidelines regarding patient selection for in-office laryngeal surgery, poor pulmonary and cardiac status are risk factors for medical complications related to this type of procedure. Caution should therefore be taken when considering in-office laser procedures on these patients, and monitoring may be considered by doing the procedures in a hospital-based endoscopy setting or in an operating room. This being said, there is little evidence to show major cardiopulmonary effects from this type of procedure. In fact, the safety profile of in-office laryngeal surgery is excellent.[48–50]

The choice of laser is largely theoretical. There are no good studies to date comparing the various lasers on a variety of different pathology types or for patient-related issues. Technically, the currently used lasers can be divided based on their targeted chromophores. The CO_2 and thulium lasers primarily target water, whereas the PDL and KTP primarily target oxyhemoglobin (Fig. 9). The gold laser and Nd:YAG target other chromophores, such as melanin and carbon, and are only partially absorbed by water and oxyhemoglobin. However, depending on power settings, spot size, and other parameters, each of the

described lasers can have a range of effects from cutting to coagulation. Generally, though, lasers that target water tend to cut more precisely with less surrounding thermal injury, and those that target oxyhemoglobin tend to coagulate better. Other lasers that target other chromophores may provide a mixture of coagulation and cutting.

Indications

In-office laser treatment is indicated for a variety of epithelial lesions of the larynx, including papilloma, granuloma, leukoplakia, dysplasia, Reinke's edema, and vocal fold polyps.[46,48,51,52] It has also been used in selected other lesions, such as vascular ectasias and stenosis.[47,48,53] It is not indicated for certain specific subepithelial lesions, such as intracordal cysts and rheumatoid nodules. Use in scar has been reported,[54] but is experimental and unsubstantiated.

During clinical use, it is evident that there is a variable tissue response when treating different lesions with the various commonly used laryngeal lasers. Although there are claims of superiority of one laser type over others for a variety of laryngeal lesions, such statements are not borne out by careful study on laryngeal tissues. In fact, as mentioned above, the tissue response to laser energy is dependent on a host of factors in addition to wavelength.

Other Laser Issues

In addition to the matters mentioned above, there are a variety of issues related to in-office laser surgery, including laser safety, endoscope maintenance, cost, and reimbursement. Prior to considering use of this technology, all these issues must be considered.

As with laser surgery done in the operating room, laser safety and standardized reporting protocols should be adhered to. While the risk of laser fires is significantly reduced, due to the absence of an endotracheal tube and lack of high-concentration oxygen, many other safety issues remain the same. Additionally, lasers must be maintained to ensure consistency of energy delivery and safety of function.

The fibers used to convey the laser energy are generally small and will fit through small side channels on flexible laryngoscopes (<2 mm). There has been recent concern over scope damage due to scratching of the side channel walls with the laser fibers and laser energy delivery to the endoscope. Unfortunately, the use of a sheath may not protect the endoscope channel,[55] leading to costly repairs.

The issue of cost is certainly a concern. Each of the laser systems are quite expensive and may be costly to maintain. Additionally, the very practice of in-office laser surgery may increase costs due to additional personnel, equipment (channel endoscopes, fibers, sheaths), and cleaning costs necessary for the procedures. These additional costs may be difficult to bear, given the lack of established billing codes for these procedures and the spotty reimbursement. However, these initial and "local" cost issues may be significantly counterbalanced by the

substantive overall healthcare cost savings afforded by providing care in an office setting versus the operating room.[56]

Individual Laser Characteristics

CO$_2$ laser (flexible). As mentioned above, the CO$_2$ laser has many ideal characteristics for laryngeal surgery. The wavelength of the laser is 10,600 nm, and it is highly absorbed by water. Because water is ubiquitous in laryngeal tissues, the laser energy is dissipated quickly in the superficial tissues without deep penetration.

With the recent introduction of a photonic bandgap fiber assembly (OmniGuide, Cambridge, MA), it is now possible to direct the CO$_2$ laser through thin flexible fibers capable of passing through the side channel of flexible laryngoscopes.[57] This ability has allowed the use of the CO$_2$ laser for in-office unsedated laryngeal surgery. The one ongoing concern has been the cost of the fiber, which is expensive to manufacture.

Used with the fiber, the CO$_2$ laser has almost all the capabilities previously enjoyed in the operating room. The most appealing feature is that it produces minimal surrounding thermal injury when used properly.[58] One technical difference with the flexible system is that the beam cannot be focused in the traditional manner with a micromanipulator. Instead, like other fiber-based lasers, spot size is related to distance from the target tissue. Additionally, unlike the CO$_2$ laser systems in the operating room, there is no associated aiming beam.

Generally, the CO$_2$ laser is excellent for purely epithelial-based vocal fold lesions, such as papilloma and granulomas, and for cutting tissue (such as with stenosis). It can also be used effectively for ablating lesions off the true vocal folds. Lesions such as vocal fold vascular ectasia and Reinke's edema require larger amounts of energy delivered to the true vocal folds that may lead to excessive heat delivery and surrounding tissue injury.

Thulium laser. The thulium laser has a wavelength of 2,013 nm and its target chromophore is water. Because of the strong absorption by water, the thulium laser behaves much like the CO$_2$ laser.[59] However, because of the shorter wavelength, the laser is capable of traveling through a thin glass fiber. Therefore, the thulium laser possesses much of the cutting capabilities of the CO$_2$ laser without the comparable expense of the specially made fiber. Additionally, the thulium laser, as currently configured, is fairly small and does not require a gas tank, making it somewhat more convenient than the CO$_2$ laser.

The thulium laser has been shown to be safe and effective in treating a variety of pathology related to the larynx.[45,48] Previous authors have suggested that its tissue effects are similar to those of CO$_2$, but that it has better coagulation capabilities and may produce more thermal injury.[45] The latter issue may be ameliorated with cooling of the tissues with use.[60]
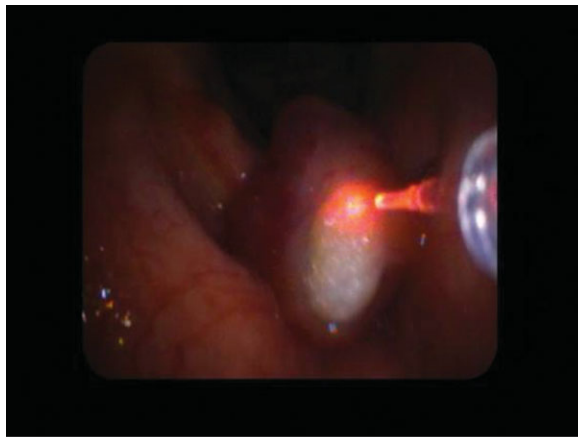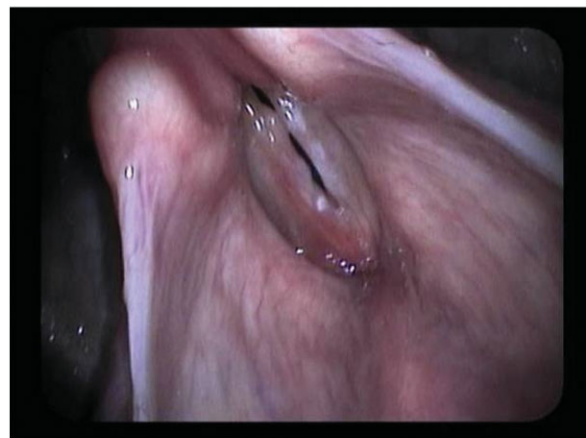
Fig. 10. Treatment of vocal fold polyp with pulsed potassium titanyl phosphate (KTP) laser (30-W, 30-ms pulse width, two pulses per second). (A) Vocal fold polyp receiving pulsed KTP treatment via a working channel of a flexible endoscope in an office setting with local anesthesia. (B) Vocal fold polyp during pulsed laser treatment. (C) Two weeks following treatment. (D) One month following treatment.

Pulse dye laser. The PDL was the first specifically adapted for laryngeal surgery in the late 1990s, and was quickly adopted for in-office laryngeal surgery. Because of its 585-nm wavelength (target chromophore is oxyhemoglobin), it has been suggested that its mechanism of action may be to destroy the blood supply of a lesion, leading to involution.[61] However, the laser's indications have been expanded to include relatively nonvascular lesions, such as Reinke's edema and leukoplakia, with considerable clinical success,[48,49] adding some uncertainty to the exact mechanism of action.

Only a single study could be found carefully examining the pathology of the PDL lesion on the vocal fold. This study showed coagulation of the vasculature and the development of a cleavage plane between the basement membrane and the superficial lamina propria.[62] However, deeper tissues were not examined, so effects within the entire lamina propria are not known.

Potassium titanyl phosphate laser. The KTP laser (532-nm wavelength) has been used in otolaryngology for a long time.[63] However, it has recently been adapted for use in office-based laryngeal surgery (Fig. 10).[46] Recent versions of the laser have allowed for millisecond pulse widths, which should lessen thermal injury compared to earlier versions of the laser. The KTP laser's target chromophore is oxyhemoglobin, and therefore it has excellent coagulation capabilities like the PDL. However, it does not possess the same cutting capabilities as CO_2 or thulium, and may create increased thermal injury when used to vaporize tissues.

Despite its extensive clinical use, little basic research has been done to study the effects of this laser on the vocal fold. Amin and colleagues have recently created an animal model for studying its effects on rat vocal fold epithelium.[64]

Other lasers. The gold laser and Nd:YAG have also been used for laryngeal surgery, but their use is

somewhat limited at this point in time. They have similar wavelengths (in the range of 1,000 nm) and, as mentioned above, primarily target melanin and carbon. The exact mechanism of action in laryngeal tissues is not known.

The depth of penetration has been a concern for Nd:YAG. Its use has been shown to result in longer healing times compared to CO_2, largely attributed to its increased zone of tissue necrosis at the base of the surgical site.[65] At the time of publication of this article, there is no clinical data regarding the use of the gold laser.[66]

Conclusion

The use of in-office laryngeal laser surgery has flourished in the last decade due to the availability of new flexible laser systems that are compatible with flexible endoscopic technology. There is increasing evidence in the literature that such surgical procedures are safe and effective for a variety of lesions. Although the various laser types vary in their physical properties, there is no consensus as to the overall advantage of one laser type versus another for the various pathologies encountered in the larynx. This may be due to the difficulties inherent in doing such case controlled studies or due to the almost unlimited variables present when dealing with laser tissue interactions. Hopefully, with time and careful study, specific indications and contraindications for this type of surgery will be developed.

VOCAL FOLD INJECTION

Of all the techniques described in this article, in-office injection augmentation of the vocal fold may be the most therapeutically useful in routine, day-to-day clinical practice. Described for use in the awake patient almost a century ago,[67] in-office injection augmentation is in fact not new, but a tried technique that fell out of use principally because of problems with injectable materials—specifically polytetrafluoroethylene paste (Teflon)—rather than any intrinsic shortcomings of the procedure. Vocal fold injection remained well-established in the repertoire of procedures performed in the operating room, however, and now has only gained in scope and utility with its return to the office setting. Indications have expanded to uses that would not necessarily have merited exposing the patient to a general anesthetic, including even treatment trials when the potential for improvement is uncertain.[68] The convenience of the procedure readily appeals to many a patient who would otherwise turn down an operating room intervention as a treatment option. Its efficacy is satisfying for the otolaryngologist, as is the lack of financial or technical barriers to its adoption—the clinician may embark on in-office injection for little more than the cost of the injectable. All of this is not to make light of the technical demands and limitations, and the potential pitfalls of the procedure; recall that these have caused the procedure to be nearly abandoned once before. As in any surgery, insight, prudence, and practice are essential for safe, effective use.

Indications and Treatment Considerations

The majority of in-office injections are performed for vocal fold augmentation. The discussion in this section will restrict itself to this use, although the adaptability of the technique for injections of substances like steroids or cidofovir should be clear (superficial vocal fold injection is discussed later). The technique is not typically limited by anatomic considerations, given the variety of potential approaches to the larynx, each detailed below. On the other hand, it does depend on a calm and cooperative patient who is appropriately informed. In fact, the participation of the awake patient who can cough, phonate, and swallow during the procedure frequently provides useful feedback to guide injection amount and placement, and constitutes a substantive advantage over injection under general anesthesia. Patient anxiety and a nonsuppressible gag reflex are relative contraindications; techniques for anesthesia have been discussed earlier and are reviewed below as well.

Any material that can be injected in the operating room can be used in the office, with the obvious exception of autologous fat. In general, control of the injectable bolus is somewhat less precise than what can be achieved in the operating room, so some technical experience is strongly advised prior to the use of long-term materials, such as calcium hydroxylapatite in the awake patient. Inadvertent placement of durable injectable material into the subepithelial layers of the vocal fold will result in prolonged dysphonia, inflammation and scar, and constitutes one of the significant complications of the technique.[69]

The indications for in-office injection augmentation encompass those four conditions that cause glottic insufficiency: 1) vocal fold paralysis; 2) vocal fold paresis; 3) atrophy, age-related or otherwise; and 4) scar and its related conditions, such as sulcus vocalis and postsurgical defect.

In patients with vocal fold paralysis, in-office injection is particularly useful for prompt, temporary symptomatic relief shortly after onset. This may include bedside injections in the first postoperative days on inpatients with vocal fold paralysis *status post* skull-base procedures, esophagectomy, pneumonectomy, and other major thoracic procedures; in this population, vocal fold paralysis is a source of considerable morbidity. The in-office technique lowers the barriers to treatment of severely debilitated patients, such as those with late-stage malignant disease, by obviating the need for a general anesthetic. Ambulatory, otherwise healthy patients typically appreciate the prompt results and minimal downtime.

Paresis, or partial paralysis, is often challenging to identify because signs may be subtle and/or variable.[70] It is not rare for the physician to make the diagnosis tentatively. In such cases, in-office injection with a temporary material offers a means of testing a provisional diagnosis. Although it certainly does not yield conclusive proof of disease, it answers clinically important questions regarding the utility of augmentation or medialization as a treatment modality.[68]

Atrophy is typically a chronic condition that is relatively mild. Patients, either because of age or because they do not perceive the resulting vocal handicap to be grave, are often reluctant to pursue treatment if it involves general anesthesia. Typically, injection is bilateral and symmetric.

In cases of scar, glottic insufficiency is typically only part of the cause of hoarseness, the other being mucosal stiffness. Of the two, the glottic insufficiency is by far the easier to address, and may provide relief from the increased phonatory effort affected individuals are frequently obliged to exert. It may make their voice easier to understand in challenging acoustic situations as well. Paradoxically, placing damaged vocal folds in closer approximation may sometimes exacerbate the roughness of the voice quality. A trial injection offers a means of assessing the result of vocal fold augmentation in these cases, for both patient and physician.[68] In general, it is difficult to augment only the area of the deficit in the office, especially if the deficit is extremely focal. This task requires great precision and frequently some subepithelial dissection, both of which make direct laryngoscopy the preferred technique when such delicacy is called for.[71]

We have made much of the safety and convenience of the technique, particularly for patients in suboptimal medical condition. This should not create complacency regarding patient selection. Awake laryngeal injection is typically performed under local anesthesia without vital sign monitoring, in the manner of routine diagnostic endoscopy. Occasional vasovagal reactions are triggered, usually in young, fit patients in robust cardiovascular health, and these are of little consequence. Nevertheless, they do serve notice that awake laryngeal injection represents a stress that should not be underestimated in patients prone to significant arrhythmia.

Vocal Fold Injection Techniques

Visualization. The essential requirement for in-office injection of the larynx is adequate visualization. The larynx is visualized via flexible laryngoscopy performed by an assistant, with the image projected to a monitor viewed by the surgeon and assistant. As is true of every technique described in this report, the practicality of in-office injection has been enhanced in no small part by the advent of distal chip technologies for flexible laryngoscopy. In-office injection may certainly be performed with fiberoptic instrumentation, however, provided that illumination and resolution are adequate to place the injectable appropriately. Alternatively, the larynx may be visualized perorally with a Hopkins rod laryngoscope, although this requires the injector to occupy one hand with the scope, and the patient to hold his own tongue during the procedure.

Anesthesia. Because the procedure is likely to require the presence of the laryngoscope for a longer period than the typical diagnostic examination thorough nasal anesthesia is recommended, even including pre-procedure packing with lidocaine and decongestant soaked pledgets, as for transnasal esophagoscopy. For percutaneous approaches, the skin overlying the anticipated puncture site may be anesthetized in the normal manner. When the injection needle is not anticipated to breach mucosa, as in transthyroid cartilage or cricothyroid technique, no further anesthetic is necessary. For every technique in which the needle must cross the mucosal surface, anesthetic may be administered to the mucosa of the oropharynx, larynx, and hypopharynx in a variety of ways. Anesthesia options for these approaches have been discussed earlier. A formal superior laryngeal nerve block is virtually never necessary. Surgeons should avoid injecting epinephrine into the airway, and should bear in mind the toxicity threshold of lidocaine (as previously discussed). Mucosal anesthesia may be excessive in some cases, resulting in secretions overwhelming the larynx, making the patient uncomfortable and obscuring the injection site.

Injection location and amount. There is currently no injectable with appropriate rheologic properties for injection into the subepithelial plane. The role of such superficial injection is limited at present due to this, and the required precision renders it generally inappropriate for the office setting. Further, there is no material that does not cause some tissue reactivity. In transient injectables, this is probably of little consequence, as it disappears along with the material. In longer-lasting injectables, this may be significant, particularly when it occurs close to superficial structures. The more soft tissue between the injectable and membranous vocal fold, the less the chance that the injectable itself or the inflammatory reaction that it typically triggers will adversely affect vocal fold vibration. In all office-based injection augmentations, then, injected material should be placed within the vocal fold muscle, lateral to the superior arcuate line. Placement too far lateral, into the paraglottic space, will result in no harm to the patient, but typically yields little augmentation in proportion to the amount of material injected.

The placement of the material along the length of the vocal fold depends on the deficit to be corrected. In paralyzed vocal folds with a large posterior gap, the injection should be placed lateral to the vocal process of the arytenoid cartilage. For patients with membranous vocal fold glottic insufficiency as a result of atrophy or paresis, an injection at approximately the midpoint of the membranous vocal fold will address the problem most effectively. Injection in the anterior half of the membranous vocal fold is generally to be avoided, as inadvertent overmedialization with consequent mucosal wave dysfunction is easily induced, analogous to anterior overmedialization with a laryngoplasty implant.

The amount injected is determined primarily by the voice quality, and secondarily by the appearance of the vocal fold itself. Most injectables require some degree of overcorrection, as they contain an aqueous component that will resorb. The extent of overcorrection varies from material to material, but a very gentle convexity of the vibratory margin of the vocal fold usually suffices. Most vocal folds are adequately medialized with 0.5 mL or less of injectable; the exception is an extremely
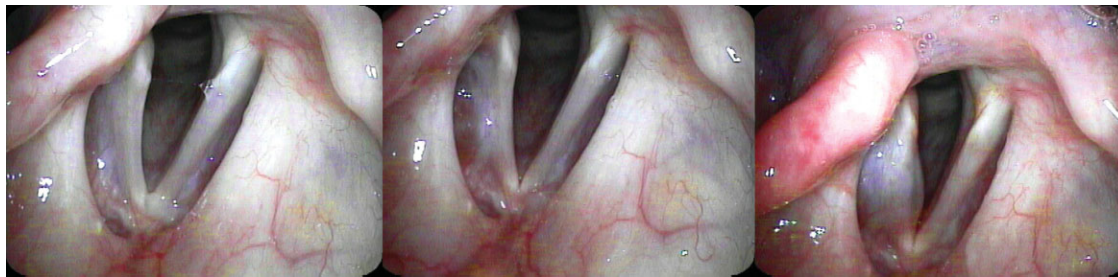
Fig. 11. In-office injection of a paralyzed right vocal fold via the cricothyroid space. (Left) Preoperative examination reveals an atrophic right vocal fold. (Center) After identification of transmitted motion from the needle tip (not visible in this still image), gentle injection produces the beginnings of a mass effect in the floor of the ventricle. Compare with image to the left. (Right) At endpoint, the vocal fold is overmedialized some 20%. The voice sounds pressed, but will improve over 1 to 4 days. There is no blood visible, as the entire injection is performed submucosally.

hypotonic and/or atrophic denervated vocal fold in a large male larynx. It is important to understand that injection augmentation is not a stereotyped procedure, and the amount and placement of the injectable is determined in each case by a number of individual factors, including degree of glottic insufficiency, anatomy and the patient's vocal requirements and expectations. In fact, one significant advantage of awake injection augmentation is that voice quality and glottic closure can be monitored throughout the procedure.

In the event that the injectable is unevenly distributed, yielding an irregular or "lumpy" vocal fold contour, a throat clear or sharp cough by the patient may help distribute it more evenly.

Peroral approach. Peroral injection is probably the most technically demanding approach, requiring the surgeon to guide the needle past sensitive structures including base of tongue, epiglottis, and ventricular folds. Because of this, it requires that the oropharyngeal mucosa be well anesthetized. This approach offers unparalleled precision, because the surgeon can visualize the needle down the entire path to the larynx.

Fig. 12. Transthyrohyoid membrane vocal fold injection in an office setting. The surgeon passes the needle into the larynx via the thyroid cartilage notch and the assistant positions the distal chip endoscope for optimal visualization. Both are monitoring the injection on the display to the right of the patient.

Typically, the patient is placed in the same position as for peroral stroboscopy, leaning forward with the chin thrust forward. The tongue is grasped by the patient or the surgeon, and an appropriately curved needle is guided just past the faucial arches under direct visualization. The needle typically is bent 90°, but the proper curve to navigate the path to the glottis varies from patient to patient, and may only be determined by experience. The surgeon may gain valuable information regarding this curve for delivery of topical anesthesia with an Abraham cannula. Once in the oropharynx, the needle is identified on the monitor (view from assistant using the flexible laryngoscope) and guided to the injection site. The shaft of the needle may be used to nudge the medial edge of the ventricular fold aside as the needle is inserted into the lateral aspect of the vocal fold to the required depth.

Long needles (220–250 mm) are available with the Brünings syringe (18 gauge), the Medtronic Oro-Tracheal Injector (27 gauge), or are supplied free (25 gauge) with the purchase of an injectable by some manufacturers (BioForm, San Mateo, CA; CoApt, Palo Alto, CA). Some of these are marked 5 mm from the tip to aid in gauging depth of injection. It is important to prime the needle with injectable material prior to insertion, as injection of air into the vocal fold may cause unpredictable swelling.

Transcricothyroid membrane approach. The transcricothyroid approach has evolved out of the technique used to inject botulinum toxin. The skin overlying the cricothyroid space is anesthetized. With the patient's head in the neutral position, a 25-gauge needle, bent about 45° about 1 cm behind its tip, is inserted at the inferior border of the thyroid cartilage, some 3 to 7 mm off of the midline towards the side to be injected. The goal is to keep the entire path of injection submucosal, and to prevent the needle from entering the airway; if this is possible, no intralumenal or laryngeal anesthetic is required at all. Once the tip of the needle passes the inferior lip of the thyroid cartilage, it is angled cephalad and laterally, in approximately a 1 o'clock direction on the patient's left and 11 o'clock on the right. The cephalad angle may need to be sharper in women, as the anterior-posterior length of the vocal folds is less. The glottis is visualized on the monitor via a flexible

laryngoscope, and signs of transmitted motion are sought. The needle may be rocked left and right slightly to make the transmitted motion easier to perceive. Once identified, the injection is performed (Fig. 11).

Occasionally it is not possible to identify the needle. No injection should ever be performed unless the surgeon is sure where the needle is, and thus, where the material will be deposited. When needle visualization is problematic, the trachea may be anesthetized, and the needle may be inserted in the midline. This will allow it to be identified in the airway via flexible laryngoscopy, and it can then be guided into the appropriate site. If the mucosa is inadvertently breached in the unanesthetized trachea, the patient will frequently cough or swallow to the extent that the procedure may need to be aborted.

Transthyroid cartilage approach. The skin overlying the thyroid cartilage on the side to be injected is anesthetized. With the patient's head in the neutral position, an unbent 23- or 25-gauge needle is inserted approximately perpendicular to the ala of the thyroid cartilage at the point that the surgeon estimates corresponds to the midpoint of the membranous vocal fold. The vocal fold lies substantially closer to the lower border of the thyroid cartilage than to its superior border, contrary to some descriptions, so the needle should enter the thyroid cartilage at no more than 3 to 5 mm above its inferior border. Gentle pressure will usually allow the needle to pass through the cartilage; care should be taken to avoid a sudden advance of the needle (pastpointing) with consequent mucosal puncture once it passes through the cartilage. Transmitted motion should be identified on the view from the flexible laryngoscope prior to injection. The injector should also be aware that a cartilage plug may initially obstruct the needle; gentle pressure on the plunger usually suffices to clear it. If applied too forcefully, plunger pressure may cause uncontrolled expulsion of the injectant, resulting in gross overmedialization. Medtronic ENT makes an injection device specifically designed for this approach, which is able to overcome the cartilage plugging problem (Casiano needle; Medtronic ENT, Jacksonville, FL).

The transthyroid cartilage approach is best for younger patients without extensive calcification of laryngeal cartilage. In the event that extensive cartilage calcification prevents needle entry, it can be converted to the transcricothyroid membrane approach with little difficulty.

Transthyrohyoid membrane approach. The skin overlying the thyroid notch is anesthetized. The laryngeal mucosa must also be topically anesthetized as previously described. The patient's head may need to be extended or turned slightly to expose the thyrohyoid notch. A straight 25-gauge needle is inserted into the notch and guided sharply downward; its tip should enter the laryngeal lumen near the petiole of the epiglottis (Fig. 12). Once identified on the view from the flexible laryngoscope, it is guided to the injection site. Both vocal folds may be injected via the same puncture by redirecting the needle as necessary. This approach shares with the peroral approach good visualization of needle place-

Fig. 13. Transthyrohyoid membrane vocal fold injection, endoscopic view. Needle has been introduced via the thyrohyoid membrane and enters the laryngeal lumen below the petiole. It is then directed into the posterolateral aspect of the vocal fold.

ment in the vocal fold, which may offer an advantage in injection placement[72] (Fig. 13).

Perioperative Care and Complications

Antibiotics and steroids are not routinely used for in-office vocal fold injection. Patients are typically observed for 15 to 30 minutes postprocedure to ensure hemostasis and no dyspnea. They are discharged with instructions to take nothing by mouth for 2 to 3 hours if the larynx and pharynx have been topically anesthetized; otherwise they may eat sooner. Discomfort is sometimes quite sharp during the injection, and pain occasionally radiates to the ear on the side injected. Patients are no more than mildly uncomfortable at the time of discharge, and acetaminophen is usually adequate for postoperative pain. Patients should be advised that the immediate postprocedure voice is typically quite poor because of overcorrection and edema. Recommendations for voice rest are not uniform, but rarely extend beyond 1 to 3 days. The patient should be aware that it may take up to 2 weeks in some cases for the voice quality to stabilize; this will prevent many an anxious telephone call.

The most serious complication is airway obstruction. The potential for this should be significantly less in the awake patient than in the patient under general anesthesia, in whom the functional respiratory glottic aperture cannot be assessed during the procedure. Some bleeding is common during procedures in which the mucosa is breached, and is usually of little consequence. Vocal fold injection is probably best avoided in fully anticoagulated patients (but can be done when no other option is available), although aspirin and similar antiplatelet agents are no barrier to the procedure. Hematoma at the skin puncture site may occur, particularly when multiple passes are necessary. Inadvertent superficial injection may cause prolonged hoarseness. Under no circumstances should materials be injected unless the surgeon is precisely aware of the location of the tip of the needle.

As for many new procedures, there is no accepted CPT code for in-office vocal fold injection according to

the techniques presented above, and reimbursement for the material itself outside of the hospital setting is especially challenging. This is despite the obvious financial benefit in avoiding hospital and anesthesia expenses.[73] This, rather than any technical issue, may represent the most significant problem with in-office injection. Otolaryngologists should pursue a correction to this situation rather than pass an expense for an indicated medical procedure on to the patient, or, worse yet, deny the patient effective remediation for glottic insufficiency because of administrative obstruction. In settings where in-office injection is not reimbursable, awake injection in the hospital setting, such as a hospital endoscopy suite (gastroenterology or pulmonary), may be a viable alternative offering patients the benefits of awake injections.

Conclusion

In-office vocal fold injection is a useful adaptation of a familiar procedure that enhances its benefit to patients. Regardless of the evolution in injectable materials, the technique is likely to remain useful, and even provides a means of delivery of other therapeutic substances (cidofovir, Botox, steroids).

TRANSNASAL ESOPHAGOSCOPY

Office-based procedures have had an extraordinary impact in the evaluation of dysphagia, reflux, and head and neck cancer primarily via the introduction of TNE.

Since the pioneering work of Chevalier Jackson, esophagoscopy has undergone many changes.[74–76] With the use of distal video chip technology, ultrathin esophagoscopes with high-resolution images can now be inserted through the nose using topical anesthesia alone. This allows the otolaryngologist to perform esophagoscopy as a rapid, in-office procedure without sedation. The entire upper aerodigestive tract from the nose to the gastroesophageal junction (GEJ) and gastric cardia is readily examined.[77–79] In addition, biopsies and other procedures can easily be performed.

Since 2000, otolaryngologists have popularized TNE and expanded its diagnostic applications for head and neck cancer, dysphagia, globus, laryngopharyngeal reflux, and gastroesophageal reflux disease (GERD).[77–80]

Technique and Overview of TNE

The individual should be NPO for 3 hours prior to the procedure for optimal examination, but a recent meal is not a contraindicaton to TNE. The patient is seated in a standard ear, nose, and throat examining chair. No cardiac or oxygen saturation monitoring is necessary.

The patient's more patent nasal cavity is sprayed with a 1:1 oxymetazoline 0.05% and lidocaine 4% solution, and then packed with cotton pledgets using the same solution. (Other anesthetic and decongestant agents may be used.) If oropharyngeal anesthesia is required (it is usually not needed), one spray of 20% benzocaine (Hurricane) is administered to the oropharynx. The endoscope (VE-1530: KayPentax Precision
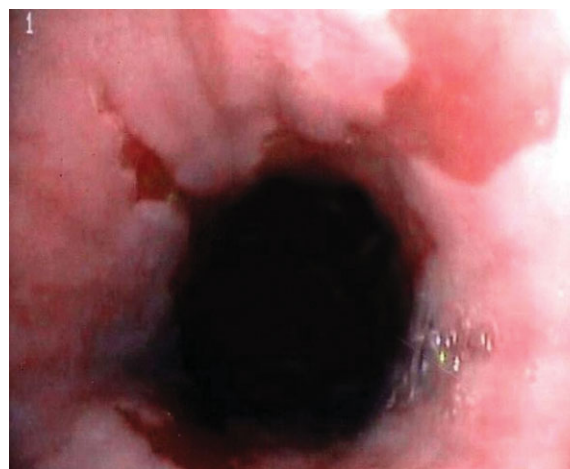

Fig. 14. Barrett's esophagus.

Instrument Corporation, Orangeburg, NJ; Olympus PEF-V: Olympus America Inc., Melville, NY; or Medtronic ENT Esophagoscope TNE-5000 with sheaths) is then lubricated and passed through the nasal cavity and into the pharynx. The patient's head is then flexed forward toward their chest as the endoscope is passed toward the esophageal inlet. The patient is asked to swallow or belch and the instrument is advanced into the esophagus. The scope is gently but rapidly advanced through the esophagus into the stomach for a retroflexed view of the gastric cardia and GEJ. This is done by rotating the entire scope 180° and maximally deflecting the endoscope's tip 210°. Commonly, extra air must be insufflated into the stomach to provide room for visualization. After the cardia and GEJ are examined, the air should be suctioned from the stomach (Fig. 14).

Using air insufflation, suction, and irrigation the mucosa of the entire esophagus is examined as the scope is withdrawn. This is performed carefully to insure that all mucosal surfaces are examined. Because the esophagus is collapsed at rest, air insufflation, drinking water with a straw, or voluntary swallows by the patient may be needed to allow for better visualization. If mucosal lesions or irregularities are noted, 1.8-mm biopsy forceps are passed through the working channel and multiple biopsies are obtained.

Difficulty in passing through the upper esophageal sphincter (UES) should alert the examiner to the possibility of a hypertonic UES, proximal esophageal stricture, or a Zenker's diverticulum, and a very careful examination should be performed or the procedure aborted.

Indications

The reasons for the transnasal evaluation of the esophagus include patients with esophageal and extraesophageal indications, and various procedures requiring TNE.[81,82]

Esophageal indications includes dysphagia, esophageal symptoms that persist despite an appropriate trial of antireflux therapy, odynophagia, screening, and

possibly surveillance of Barrett's esophagus, caustic ingestion evaluation, foreign body evaluation, visualization and biopsy of radiologic abnormalities, monitoring of esophageal varices, and longstanding (>5 years) GERD.

Extraesophageal indications for TNE include patients with chronic cough, cervical dysphagia, head and neck cancer (initial panendoscopy with biopsy and long-term follow-up), poorly controlled asthma, moderate to severe laryngopharyngeal reflux and globus pharyngeus.

Procedural indications include biopsies of the laryngopharynx and esophagus, esophageal, neopharyngeal, and nasopharyngeal stricture balloon dilation,[83–85] secondary tracheoesophageal puncture,[86,87] the delivery of flexible lasers, delivery of feeding tubes, injection of Botox into the esophagus,[88] and the insertion of wireless pH monitoring devices.[89]

Contraindications

There are no absolute contraindications to TNE. Concerns have been raised in reference to anticoagulation, but in the authors' experience, performing TNE and obtaining biopsies in patients taking Coumadin or Plavix has not been a problem. The presence of a known Zenker's diverticulum will make the procedure more challenging, but would not be considered a reason to refrain from TNE if otherwise indicated.

Complications

Most complications during sedated endoscopy are related to sedation. Cardiopulmonary complications account for more than 50% of all adverse events.[90] A recent survey of endoscopists reported that adverse cardiopulmonary events secondary to conscious sedation constitute the majority of endoscopic complications; in fact, 67% of complications and 72% of mortalities were cardiopulmonary related.[91] The unsedated aspect of TNE eliminates all sedation-related complications.

Esophageal perforation is a rare but catastrophic complication, and among the thousands of TNE and TNE-gastroduodenoscopy cases performed, there has been only a single case of esophageal perforation reported.[92] Minor complications are also uncommon. In the two largest series reported, involving 1,800 total patients, rates of epistaxis were between 0.85% to 2%, and vasovagal events were 0.3%.[81,93]

Coding and Billing

At this time, TNE uses the same coding procedures as conventional endoscopy. Diagnostic TNE (43200) and TNE with biopsy(s) (43202).

TNE Versus Conventional Esophagoscopy

Since the introduction of TNE, there have been many studies comparing TNE with the "gold standard" of conventional esophagoscopy (CE), which is performed transorally with sedation. Studies utilizing small-caliber video endoscopes have almost all concluded that TNE image quality and diagnostic capability is equivalent to CE, and that the majority of patients prefer TNE to CE.[94–102]

A summary review of these and other comparative studies was recently published as a portion of the American Academy of Otolaryngology position paper on TNE.[82]

TNE is also less expensive than CE. The increased direct costs of CE include longer procedure time, recovery room and recovery time, and the costs associated with medications, monitoring, and nursing.[103] The difference in cost has been found to be greater than $2,000 per procedure.[104] Indirect costs are also important but difficult to quantify. This includes loss of work time by both the patient and a driver or caretaker. In contrast, with TNE, most patients are able to return to work or home shortly after the completion of the examination and do not need a caretaker.

Studies have shown a very high patient satisfaction rate, often greater than with CE.[81,93] Crossover studies have shown that in patients who had both sedated and unsedated examinations, the unsedated transnasal endoscopy was better tolerated.[97]

The Future

We anticipate that the future will bring continued refinements, such as still smaller endoscopes and the development of novel instruments to be used in conjunction with them. In addition, new techniques in imaging have emerged showing promise for enhancement and better visualization of the microvascular patterns of mucosal surfaces. Of particular interest is NBI optical technology, as noted earlier.[105,106] NBI employs the filtering of light into three narrow bandwidths. This allows for optimal visualization of surface capillary and mucosa patterns, which the literature has suggested may allow for better evaluation and diagnosis of esophageal lesions. This may very well lead to improvement in the diagnosis of Barrett's metaplasia, adenocarcinoma, and head and neck squamous cell cancer.

Conclusion

In-office TNE has become an important part of the evaluation and management of patients with dysphagia, extraesophageal/gastroesophageal reflux disease, and head and neck cancer. TNE provides a number of advantages over conventional endoscopy with equivalent clinical results. These advantages are improved safety, decreased overall costs, and patient preference.

MISCELLANEOUS LARYNGEAL PROCEDURES IN THE OFFICE SETTING

Laryngeal Biopsy

The revival of interest in awake laryngeal techniques has led to the development of additional procedures that offer novel value in care of the laryngology patient. Perhaps the largest and most widely applicable is awake laryngopharyngeal biopsy. Although its roots are over

100 years old, awake laryngeal biopsy has seen a resurgence with the development of new endoscopes, endoscope sheaths, and instrumentation. Until approximately 15 years ago, the primary means for awake laryngopharyngeal biopsy was similar to the approach used by the fathers of laryngology in the mid 1850s: transoral passage of long curved biopsy forceps with indirect mirror laryngoscopy guidance. Although visualization is now achieved with rigid or flexible endoscopes with video display of the image rather than laryngeal mirrors, the technique remains largely unchanged. However, in addition to the peroral biopsy approach, laryngeal biopsy can be done via the working channel of a flexible endoscope.

After adequate laryngopharyngeal anesthesia (as described previously), the patient is positioned sitting upright in the sniffing position. When using a rigid endoscope transorally, the patient holds their tongue protruded. The otolaryngologist holds the rigid endoscope in one hand and the biopsy forceps in the other. The patient is asked to breathe comfortably through their mouth as the forceps are introduced into the laryngeal introitus. The forceps are directed to the biopsy site and a representative sample is taken. Today, this still remains a valuable tool for the otolaryngologist, but requires skill and patience on the part of the otolaryngologist and patient.

With the introduction of flexible channeled endoscopes or flexible endoscopes with a channeled sheath (Medtronic ENT, Jacksonville, FL), the procedure has become considerably better tolerated by patients and easier to perform. The patient is anesthetized and positioned similarly to the previous descriptions. The flexible laryngoscope is passed transnasally and held in position viewing the biopsy target. A 2.0-mm flexible cup forceps is introduced by an assistant through the channel of the endoscope or the endosheath until they appear several millimeters beyond the tip of the scope (Fig. 15) (Olympus Biopsy Forceps, SB-34C-1, 1.8 mm diameter, 1050 mm length. Olympus America, Center Valley, PA). The forceps are opened and then the endoscope is advanced onto the target. The assistant closes the forceps and the sample is taken. The specimen can be withdrawn via the forceps, leaving the endoscope in place most of the time, which facilitates a rapid additional biopsy if needed. If the biopsy tissue is very large, then the entire endoscope can be withdrawn, allowing the specimen to be placed in the collection cup without being withdrawn through the working channel.

When combined with transnasal esophagoscopy and bronchoscopy, awake panendoscopy, staging, and biopsy has become a reality. Awake laryngeal biopsy and tumor staging has been demonstrated to be equally as effective as operative staging.[83,107] Time from presentation to initiation of treatment is reduced by elimination of the traditional panendoscopy and biopsy under general anesthesia. Patients are spared from additional general anesthesia, physician efficiency is improved, and healthcare costs are reduced. Additional value of awake laryngeal biopsy lies in the evaluation and surveillance
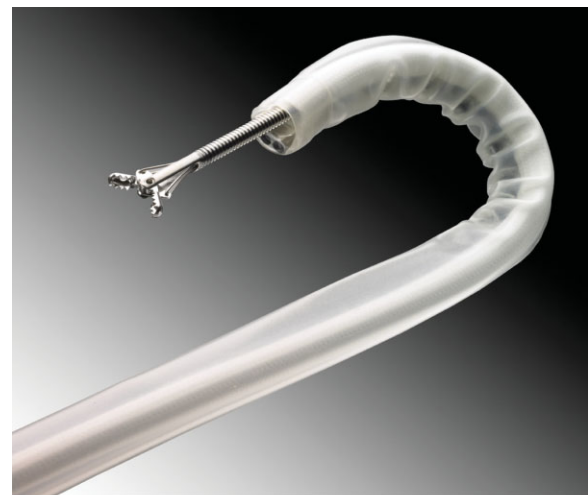
A

B

Fig. 15. (A) Cup forceps for biopsy of larynx, pharynx, or esophagus via a working channel endosheath. Note that this type of endosheath allows a flexible endoscope used for diagnostic purposes to become a useful instrument for therapeutic purposes. (B) Biopsy of vocal fold lesion with cup forceps passed through a working channel of a chip-tip flexible endoscope done under local anesthesia in an office-based setting.

of laryngeal lesions that do not warrant operative excision, and culturing of lesions suspicious for bacterial or fungal infection.

Secondary Tracheoesophageal Puncture

Additional value for the head and neck cancer patient rests in awake tracheoesophageal puncture (TEP).[87] The visualization that is achieved with the transnasal esophagoscope greatly facilitates placement of a secondary TEP. The procedure is performed with the patient sitting upright in the examination chair. After anesthesia of the nasal cavity and pharynx, the transnasal esophagoscope is passed into the cervical esophagus. Transillumination can be used to localize the scope at the level of the tracheostoma. The endoscope is withdrawn slightly and the position for the

tracheoesophageal puncture is chosen. Local anesthesia is injected into the chosen site and blunt instrumentation can be used to identify the internal position for the puncture on the esophagoscopy monitor. Air insufflation assists in expanding the esophagus at the puncture site. A small puncture is made with a #15 or #11 blade, taking care not to lacerate the posterior esophageal wall, which is directly visualized by the flexible scope in the esophagus. Blunt spreading with a curved hemostat dilates the puncture slightly. A soft rubber tube is then introduced into the esophagus with the hemostat and the tube is directed inferiorly. The tip of the endoscope can facilitate this. The puncture is cared for identically to a puncture performed intraoperatively.

Superficial Vocal Fold Injection

Superficial vocal fold injection can be done under local anesthesia in an office-based setting. This vocal fold injection technique involves the use of a fine-gauge needle to inject in a subepithelial plane a material such as a steroid or collagen substance. Given there is no present superficial lamina propria replacement material for patients with vocal fold scar or atrophy of this portion of the vocal fold, sometimes wound healing behavior following inflammation, trauma to the vocal folds, or surgery can be modified by superficial vocal fold injection with a steroid substance or placement of a collagen-based material.

The most common indication for superficial vocal fold injection in an office setting is to modify the wound healing response following phonomicrosurgical procedures. This is especially true for patients who have had extensive lamina propria dissection, such as is often the case with removal of ligamentous lesions or extensive fibrous mass lesions. Superficial injection of steroids in the immediate perioperative time period (2 weeks to 3 months) may improve the overall pliability of the vocal fold following phonomicrosurgery. It is also possible to inject collagen-based products (Cymetra, Zyplast, Cosmoplast) into the superficial aspect of the vocal fold for vocal fold scar or atrophy of the superficial aspect of the lamina propria. However, this procedure requires significant precision, and is thus not well suited for an office-based, local anesthesia procedure. This type of vocal fold injection is best suited for microlaryngoscopy using general anesthesia.[108]

A variety of different steroid substances can be injected superficially into the vocal fold. Only a relatively small volume of material can be injected into the superficial aspect of the vocal fold, and thus, a high-concentration steroid solution is usually selected. Examples of these solutions include dexamethazone, 10 mg/mL or Kenalog 40. There have been concerns raised regarding the use of Kenalog given that the solution has a carrier that has been reported to serve as a nidus for altered vocal fold vibration following superficial vocal fold injection.

Anesthesia required for superficial vocal fold injection is described in the Anesthesia for Office-Based Laryngology Procedures section. After adequate anesthesia has been achieved and confirmed by palpation of the

vocal folds with a blunt instrument (drip catheter for anesthesia or an Abraham cannula), then one can proceed with superficial injection of the vocal fold. This can be done using two different approaches, a peroral approach or a transnasal endoscopic approach. The peroral approach is identical to the previously described deep vocal fold injection (see the Vocal Fold Injection section), and differs only in the use of a fine gauge injection needle (Orotracheal injector, Medtronic ENT, Jacksonville, FL) and the location and depth of the injection. The transnasal endoscopic approach for superficial vocal fold injection involves passing a fine-gauge needle, which is sheathed through the working channel of the flexible endoscope or an endosheath with a working channel (Olympus injection needle and sheath, NM-101C-0427, 27 gauge, Working length 1050mm, Needle length 4 mm, Olympus America, Center Valley, PA). Once the sheathed needle has been passed all the way through the working channel and can be visualized in the pharynx, the needle can be unsheathed and then passed via advancement of the endoscope to within 1 to 2 mm of the intended vocal fold injection location. The endoscope is then held steady as the assistant advances the needle slowly into the tissue of the vocal fold, keeping the depth of the needle at a very superficial level of penetration. A small test injection is then performed, and if the needle is in the proper location, a visual confirmation of superficial placement of the material is seen with blanching and a small bleb formation on the vocal fold. The injection should be done relatively slowly to minimize disruption of superficial vocal fold vasculature and inducing a vocal fold hemorrhage. A relatively small volume is typically injected into a single vocal fold (approximately 0.1–0.2 cc).

A short period of postoperative voice rest is recommended to minimize leakage of the vocal fold injection material and trauma to the swollen vocal fold. The patient should be counseled that there will be a short period of onset dysphonia following the vocal fold injection lasting approximately 5 to 7 days. Steroid injection(s) placed superficially into the vocal fold are often done in a serial fashion: 3 injection treatments done with 2 to 4 weeks between each treatment.

Atypical Botox Injections to the Larynx (False Vocal Fold and Interarytenoid Muscle)

Recent office-based approaches have facilitated the expansion of the role of Botox to treat select individuals with movement disorders of the larynx. This includes Botox injection to the false vocal folds and the interarytenoid muscle. These two atypical Botox injection locations in the larynx have enhanced the ability of the otolaryngologist to care for the challenging/difficult patient with the rare movement disorders that does not respond to standard percutaneous, electromyography (EMG)-guided Botox injections to the larynx (thyroarytenoid-lateral cricoarytenoid, posterior cricoarytenoid, and/or cricothyroid muscle). There are two indications for a false vocal fold Botox injection: 1) adductor spasmodic dysphonia (SD), and 2) essential tremor of the voice.

The former involves a very small number of adductor SD patients that have a profound amount of postinjection dysphonia with a relatively short period of "good voice" with standard percutaneous, EMG-guided Botox injection approaches. For these individuals, often a Botox injection to the false vocal folds will result in a significant diminution of the post-Botox injection dysphonia and an overall "smoother" response to Botox. These patients, however, do have a slightly decreased overall duration of the Botox injection compared to the traditional percutaneous approach.[109] Botox injections of the false vocal folds can also help patients with severe essential tremor of the voice that is primarily focused in the supraglottic region.

Botox injection to the interarytenoid muscle can be effective for patients with severe essential tremor of the voice that appears to have a dominance at the level of the glottis arising from or including the interarytenoid muscle. A relative contraindication to either of these Botox-injection approaches include dysphagia. If the patients have significant dysphagia prior to the Botox injection, one should proceed with great caution given that these Botox injections may further enhance the patient's underlying difficulties with dysphagia. Possible complications of these injections include prolonged dysphonia and dysphagia, although this is quite uncommon with the false vocal fold injection approach. Selecting the dose carefully and starting with a low dose and working up will minimize the risk of these complications.

Both of these Botox-injection approaches require similar levels of local anesthesia applied to the endolarynx, similar to vocal fold injection of different materials in different locations as previously described (see the Anesthesia for Office-Based Laryngology Procedures and the Vocal Fold Injection sections).

Botox Injection to the False Vocal Fold

Botox injection to the false vocal fold can be done via a peroral approach (see the Vocal Fold Injection section) or via a transnasal endoscopic approach. The latter is preferred due to patient tolerance and has equal efficacy. The decision to proceed with either of these approaches is usually dependent on equipment available to the surgeon. If a flexible scope with a working channel or an endosheath (Channeled Slide-On Endosheath, 33-5401, Medtronic ENT, Jacksonville, FL) with a working channel is available, the transnasal endoscopic approach is preferred. The goal of Botox injection to the false vocal fold is to deposit a small volume and small dose of Botox submucosally into one or both of the false vocal folds. Anesthesia for this procedure can be done with nebulized lidocaine and/or a direct application of topical lidocaine onto the false vocal fold region as previously described. In the transnasal endoscopic approach, a fine-gauge needle with a sheath (as previously described) can be passed through the working channel of the flexible scope, and once the sheath is visualized in the pharynx, the sheath can be withdrawn exposing the fine gauge needle. The needle is positioned to a distance of 2 to 3 mm from the false vocal fold, and then the nee-
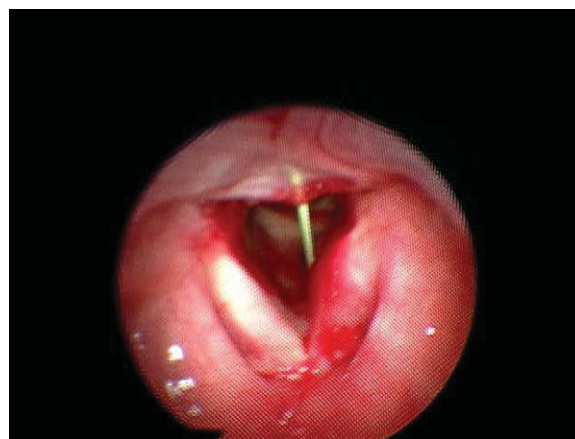

Fig. 16. Interarytenoid muscle Botox injection via a cricothyroid approach done with local anesthesia. Note the electromyography needle enters from the anterior subglottis and then is passed posterior and cephalad into the interarytenoid muscle, which is confirmed by electromyography prior to injection.

dle is advanced into the submucosal space of the false vocal fold to deposit the Botox, creating a characteristic bleb formation from the superficial plane of the injection. Ideal locations for false vocal fold Botox injections have not been elucidated, however, typically midfalse vocal fold from an anterior-posterior perspective and approximately 5 mm above the inferior aspect of the false vocal fold are good guidelines for injection location. Typical doses for false vocal fold Botox injection for adductor spasmodic dysphonia range from 2.5 to 5 U per side.

Botox injection into the interarytenoid muscle can be done via a transnasal endoscopic approach or a combined percutaneous and endoscopic visualization. The latter approach is superior, given that it allows for simultaneous EMG guidance. Anesthesia is achieved within the endolarynx via the approaches described above. After adequate anesthesia has been achieved, flexible laryngoscopy is performed and the endoscope is placed down into the endolarynx to visualize the infraglottic portion of the anterior larynx. An EMG needle (bipolar or concentric) is then passed percutaneously at the midline immediately under the inferior border of the thyroid cartilage directly into the lumen of the endolarynx. Once the needle has entered the lumen of the endolarynx, needle guidance can be switched to the endoscopic visualization from the flexible endoscope and the needle is then directed posteriorly and slightly cephalad to enter into the posterior commissure of the endolarynx. Once the EMG needle pierces the posterior commissure of the endolarynx, EMG guidance is used to identify the interarytenoid muscle prior to injecting Botox (Fig. 16).

After each of these procedures, the standard patient instructions, including avoiding eating and drinking until all the anesthesia has worn off, is advised (approximately 1–2 hours).

CONCLUSION

The dramatic and substantive changes that have occurred in office-based diagnosis and treatment in

laryngology in the last decade have been reviewed in this article. The significant benefits of the office-based approach include convenience for the patient and surgeon and the potential for improved voice outcomes due to the ability to monitor voice quality throughout the procedure. As noted throughout the article, there are still many aspects of office-based diagnosis and treatment in laryngology that require further critical review as the field moves forward. Some of these issues are patient selection, cost of technology, insurance and reimbursement problems, and the need for comparative studies. Despite these hurdles and unanswered questions, many of the procedures described in this article are rapidly becoming the preferred technique in most laryngologists' hands, and may in the future become the standard of care. As the area of office-based diagnosis and treatment in laryngology advances, improved patient care will be driven by scientific inquiry, innovation, and the delineation of what diagnostic and therapeutic interventions are provided in an office-based setting versus an operating-room–based setting will be clarified.

Acknowledgments

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