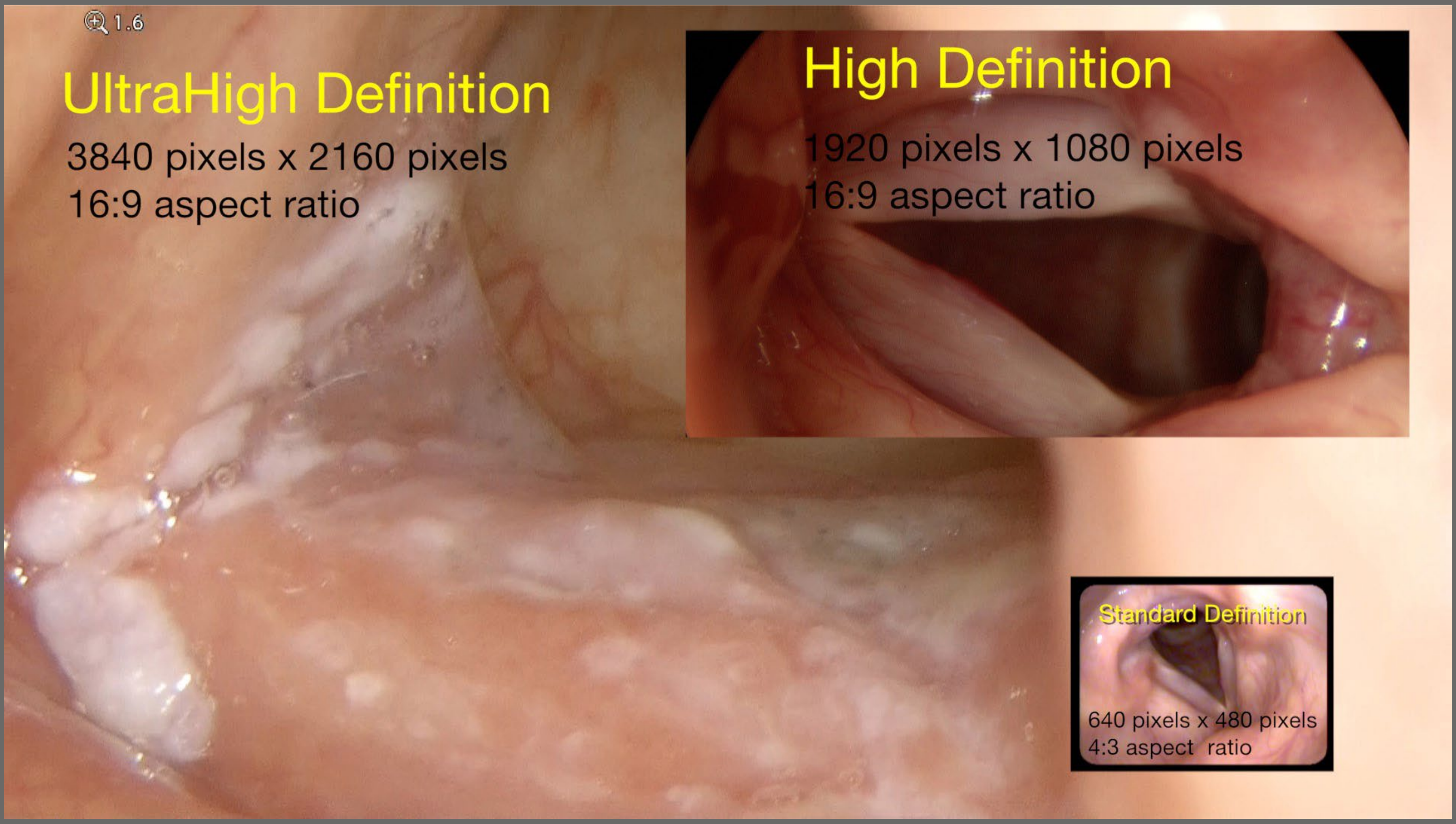
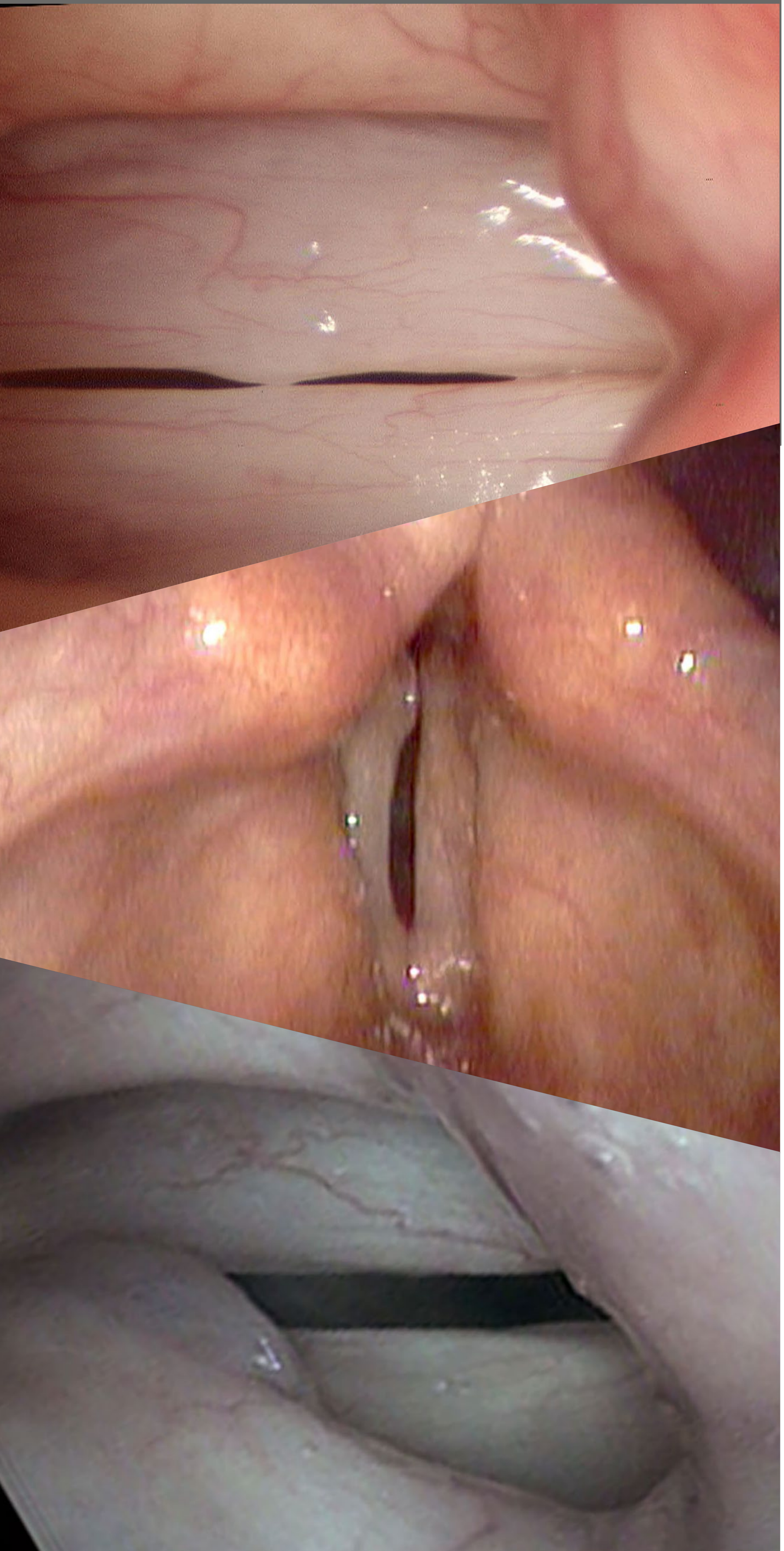
HIGH DEFINITION LARYNGOLOGY

CHOOSING YOUR EQUIPMENT
USING YOUR EQUIPMENT

JAMES P. THOMAS, M.D.





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HIGH DEFINITION LARYNGOLOGY

is

the **combination** of

equipment and **expertise**

leading to a precise diagnostic view of functioning vocal cords.

Equipment: High technology vocal cord imaging includes:

- **stroboscopic lighting**
- **chip-on-tip endoscopes**
- **high-definition cameras**
- **digital recording**
- **high definition monitors**
- **selective color filters**
- **high speed cameras**

Expertise: High definition techniques allow the examiner to **optimize images**, regardless if they are obtained with high or low technology or even lower quality equipment.

An optimum combination of equipment and technique leads to a cost-effective, high yield and accurate diagnosis for laryngeal problems. It also leads to an improved understanding of how the larynx actually functions normally, producing clear sound both for speaking and for singing. This is high-definition laryngology.

This lecture may help you decide what equipment to utilize or purchase. It will provide you with ideas for new techniques to image the vocal cords, perhaps with equipment you already own and how to think about laryngeal function more precisely.

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INTRODUCTION

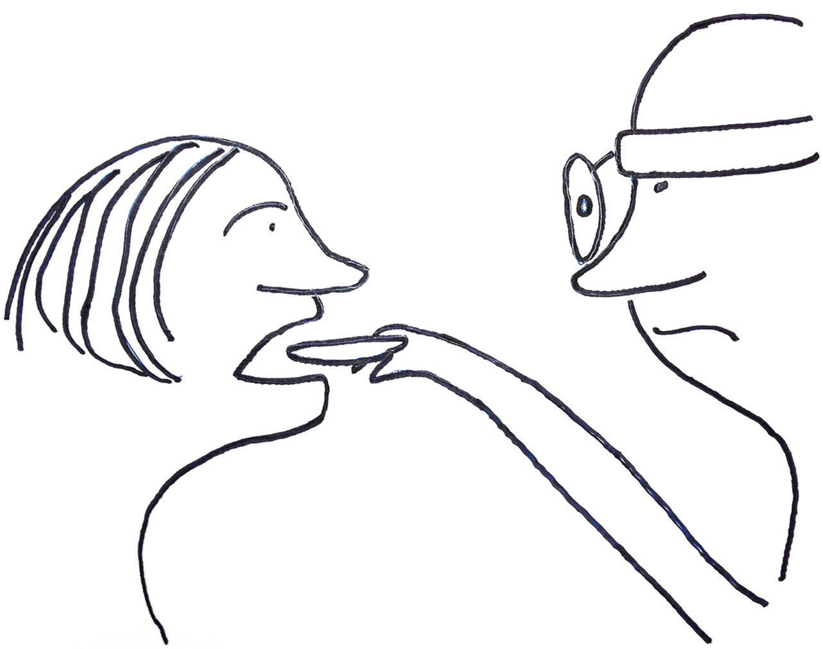
Voice Laboratory

A voice laboratory contains equipment essential for functional visualization of the vocal cords. Admittedly this is an expensive proposition to set up, but once in use, a dedicated laryngologist will find this equipment essential to diagnosis, to monitoring progress and results, and to learning about new conditions.

This initial capital expense has some hidden advantages. Because voice equipment is expensive, it needs to be used. Using it frequently leads to proficiency and further learning. Because it's expensive, few others will purchase it. You will have tools that almost no other health care provider will have. Because it is expensive, you will have the incentive to fully learn the capabilities of the equipment, extracting the most information from what you have. Because it is expensive, your colleagues will feel comfortable refering patients to you. They can tell their patient that you have equipment that no one else has. While this is indeed true, it contains the hidden face-saving gesture that the referring provider does not have to acknowledge incomplete medical knowledge, merely they lack equipment.

The lab might contain some or all of the following:

1. Endoscopes (rigid &/or flexible)(fiberoptic or chip-on-tip)
2. Camera & Processor (integrated or external)
3. Bright light source
4. Stroboscope
5. Hardware and software for recording and reviewing video with audio.
6. High definition monitors
7. High Speed camera



Low technology - High Definition

We often think of high definition as video equipment with large numbers. Historically 480 vertical pixels gave way to 720, then 1080, then 2K, 4K . I hear rumors of 10K and who knows where it will go. The larger the number, the higher the definition. Many times though, large areas of an image (and consequently many pixels) go unused for infomation in a medical endoscopic image. We will learn to use them.

Low technology, high definition laryngology is using inexpensive techniques to put pathology onto more pixels of any endoscope, no matter which endoscope the examiner already is using. Knowledge and skill improve upon the equipment at hand.

"Low definition laryngology" isn't spoken of, but you can see it all too frequently. It is where examiners may have high technology equipment, even a high technology education but;

1. they don't realize where to aim the endoscope, or
2. don't take the time to record quality images of the pathology or
3. do not understand the need for using low technology wisely to bring the pathology into focus
4. and/or do not review for mistakes to learn from them.

Upon completion, we should be able to...

understand various video standards

- **standard definition to ultrahigh-definition**
- **selective color imaging**
- **endoscopy orientation**
- **how to utilize consumer video equipment for laryngeal imaging**
- **innate value of recording**

implement cost effective video use

- **utilize low technology techniques to create high-definition images with lower cost equipment.**
- **substitute consumer products where possible**

interpret video findings

- **understand video and stroboscopy artifacts and make reasonable diagnoses even with the artifact present.**

Author & goals

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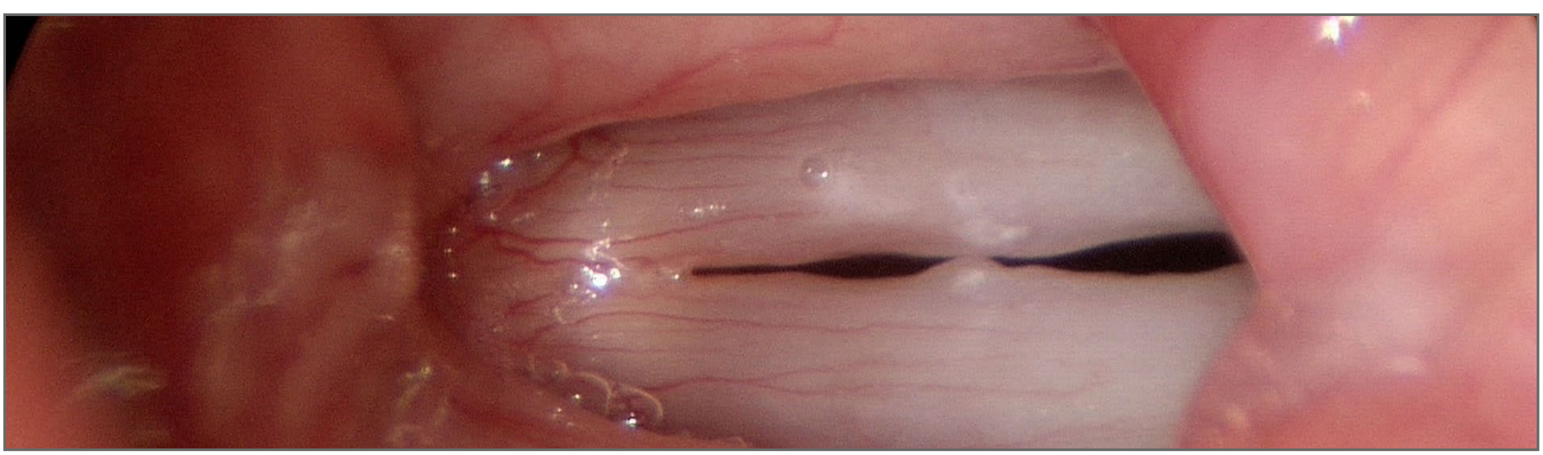
I specialized in laryngology after realizing there was too much for me to knowledge needed to keep up in general otolaryngology. I bought voice equipment, traveled and visited a number of laryngeal professionals around the world — physicians, voice therapists, voice teachers — corralling and questioning anyone who seemed to love working with voice. I observed both office work as well as surgical work. By 1999, my practice became entirely laryngology. One laryngologist, Robert Bastian, taught me how to listen to the voice and that set the foundation for the self-learning that continues to this day in my practice.

GOALS FOR YOU:

1. Understand the importance of video recording the vocal cords. The capacity to review an image several times reveals many additional details not initially perceived. Using a high resolution computer screen along with software which allows the easy ability to move frame by frame, backwards and forwards or at variable speed aids the examiner in visualizing microscopic vibratory impairments otherwise occurring faster than the examiner's perception is able to digest the information.
2. Understand how the correlation of sound with video, augments the diagnostic value of the image. Variation in vowels, changes in pitch and changes in vocal intensity all alter the visual endoscopic appearance of vocal cords.
3. Understand how the most commonly used endoscope, the very cost-effective flexible fiber-optic endoscope, artificially alters our perception of the larynx. If the examiner keeps this visual alteration in mind, a better diagnosis can be made, even with these blurred and honeycombed images. There is also wisdom in knowing what you may not be seeing.
4. Understand how variations in lighting alter our perceptions of what we see and specifically how even standard definition rigid and flexible endoscopes can offer complementary views of the larynx, the combination resulting in essentially a high-definition perception of the larynx.
5. Understand how topical anesthesia - at very little cost and only a small addition of exam time - can turn a standard definition (SD) image into essentially a high definition (HD) image by navigating the endoscope closer to a lesion. Closeness yields a recording with more pixels on the pathology and consequently is equivalent to a higher resolution image. Even with minimal but appropriate equipment, the astute examiner can learn to obtain essentially high definition images of pathology with relatively low-budget equipment.
6. Understand the capabilities of the highest resolution images that can be obtained with high definition endoscopic cameras for both rigid and digital chip-on-tip endoscopes. Whether or not you can afford the most current HD endoscope, you will gain an understanding of what you might be missing.
7. Understand how the added visual qualities of selective color imaging such as NBI (narrow band imaging) by Olympus or iScan by Pentax, highlight vasculature. Neovascularization and capillary patterns readily identifies the borders of many lesions, some malignant and some benign.



Case Study

A 72-year-old female underwent mitral valve surgery, waking up hoarse afterwards. She came into my office with a hoarse voice and difficulty breathing six months after her problem began. Here is her story.

"I had my heart valve replaced and became very ill. My daughter says that I had a tube in my throat to breathe for me for 10 days. The first I can recall, I had a very weak voice. My doctor said, 'Just wait, the voice almost always gets better with time'."

"About six weeks after surgery, I developed difficulty breathing and went to the emergency room. My voice was actually stronger at that time. They ran quite a few tests and told me that I did not have anything serious, at least I did not have a blood clot in my lungs. They sent me to a lung doctor."

They treated her with inhaled racemic epinephrine and bronchodilators. She had a chest x-ray, CT scan of the lungs, and a VQ (ventilation-perfustion) scan. Physicians concluded in the record that she did not have a pulmonary embolism and discharged her with a diagnosis of probable emphysema. She was referred to a pulmonologist for further care.

She continued, "The lung doctor examined my lungs with a scope. He told me that I had a vocal cord problem and referred me to an ENT doctor. Then the ENT doctor also put a scope in and told me that my vocal cords were paralyzed. She sent me to a specialist for vocal cords. He then told me that both vocal cords were paralyzed and that I needed a test called an EMG and he put me on a pill to stop stomach acid."

He had placed her on pantoprazole twice a day and referred her to a neurolaryngologist.

She added, "The next specialist told me that the EMG was abnormal and he recommended injecting Botox into my vocal cord. I let him inject it last week and now I make more noise breathing. Really, my breathing is worse. Even just getting up from a chair to walk makes me short of breath and causes a lot of noise."

EXAMINATION

All of these medical visits and tests occurred over the period between two and six months after her surgery, starting when she first became short of breath.

On exam, she makes obvious noise when she breathes inward and inspiration appears effortful. When I place a flexible endoscope into her pharynx, her vocal cords are resting near the mid-line. When she breathes in, she makes a high pitched noise and the right vocal cord draws inward, vibrating and generating sound. When she breathes out, the vocal cords shorten in length and the mid-membranous portion of the right vocal cord moves laterally. The upper portion of the arytenoids do not appear to move laterally very far during inspiration and they are also tipped forward, hiding the posterior, cartilaginous portion of the true vocal cords.

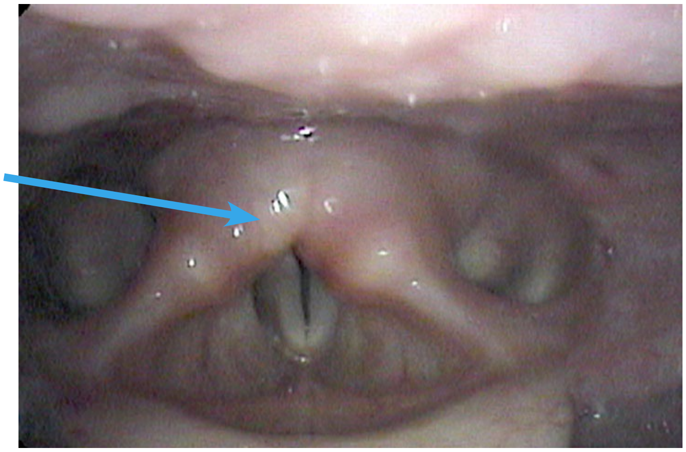
Since I cannot see all of the vocal cords nor can I see beneath her vocal cords, I ask her for permission to topically anesthetize her larynx with lidocaine. After anesthesia, I can touch the arytenoids and place the endoscope adjacent to the vocal cords for close imaging. With the scope, I lift the forward-leaning arytenoids for a view of the vocal processes and even pass the endoscope between the vocal cords, viewing the subglottis and trachea all the way to the carina and beyond.

Significantly, a band of scar tissue beneath the vocal processes bridges the vocal processes. The arytenoids are fixed about 2 mm apart at the tip of the vocal processes.

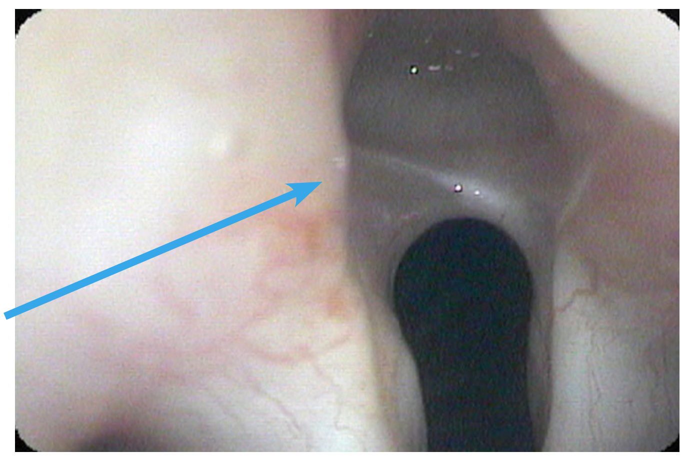
The right vocal cord, which had been injected with OnabotulinumtoxinA (Botox™) about one week earlier, is atrophic. With any increase in her rate of inspiration, the right membranous vocal cord passively flutters and draws medially from Bernoulli effect, narrowing the airway and generating a high pitched stridor.

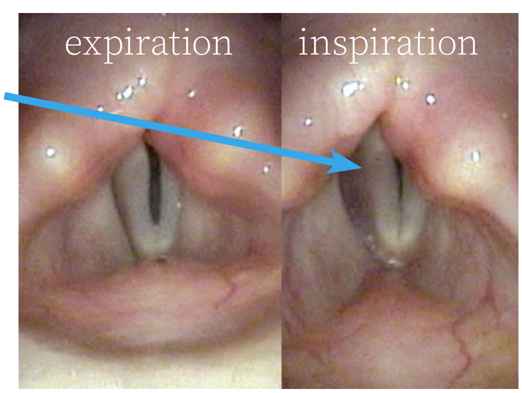
During phonation the upper portion of the arytenoids move closer together and touch, while the left vocal process appears to move about 1 mm closer to the right vocal process. The rest of her trachea, carina, left and right mainstem bronchi are normal anatomically and functionally during breathing.

Typical diagnostic view



High-definition diagnostic view





INTERPRETATION

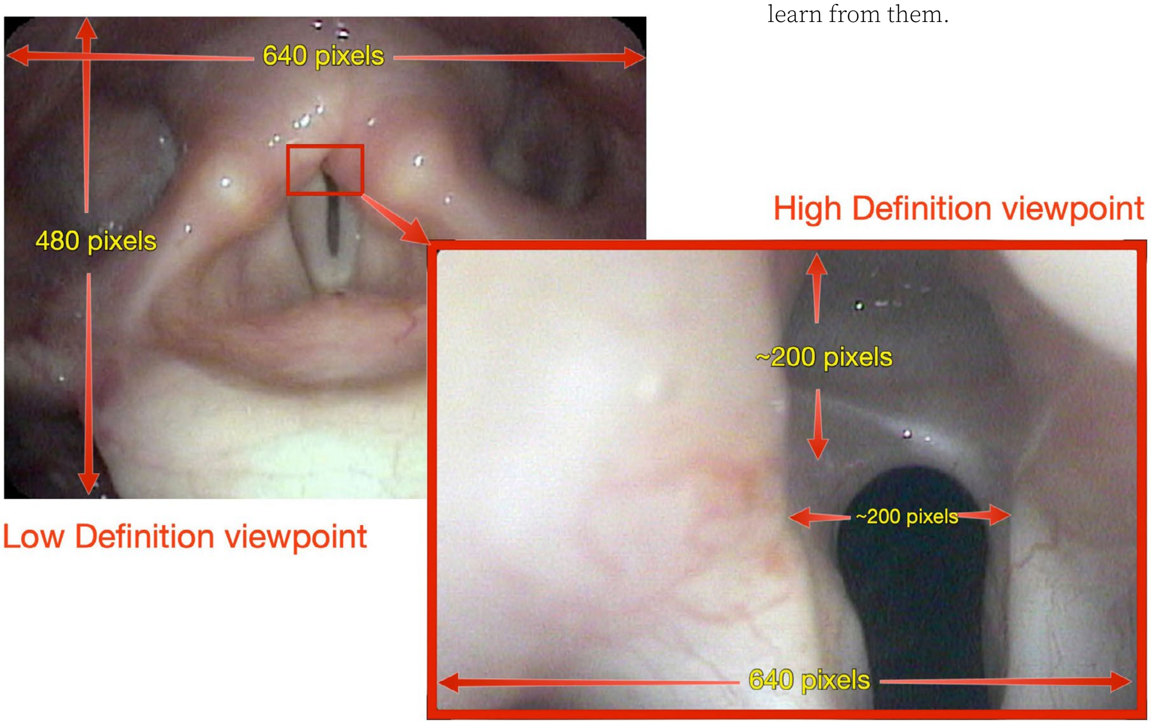
After an intubation, there are two principle conditions to be considered in the differential diagnosis for limited arytenoid rotational movement. Has there been a neurologic injury to the laryngeal nerve supply or is this motion limitation secondary to a traumatic mucosal injury? An endotracheal tube cuff which ends up located in the immediate subglottic area and is perhaps inflated too tightly can put pressure on the anterior branches of the recurrent laryngeal nerves as they pass beneath the thyroid cartilage and partially or completely paralyze one or both of them, typically limiting adduction of the vocal cords. This injury will also typically lead to atrophy of the injured thyroarytenoid muscle(s).

In the case of surgery along the pathway of the main trunk of the recurrent laryngeal nerve, a nerve injury may leave both the abductor and adductor muscles impaired. Initially after this type of injury, there may be limitation of both adduction and abduction. The vocal cord may rest in a very medial position, a mid position or a lateral position, but typically there is a larger than normal glottic gap during attempted phonation and a breathy voice.

When the nerve fibers regenerate back to the muscles (over several months), they often cross pathways and end up misdirected in terms of stimulating abduction and abduction. Consequently, delayed findings after reinnervation begins include vocal cords positioned near the midline or vocal cords that move in an inappropriate direction at an inappropriate time, such as medially during inspiration.

In terms of injury to the lining of the larynx, even after as little as a two hour intubation, pressure ulcers frequently develop on or near the vocal processes. With longer intubations, larger ulcerations, followed by granuloma formation and fibrin deposition may create a bridge between the ulcers, which ultimately epithelializes and contracts, pulling the vocal processes towards each other.

Both synkinetic reinnervation and scar contracture, ultimately bring the vocal cords closer together in the midline. In my experience, scar contracture ends up restoring the voice and limiting breathing sooner (often about 2 months) than neurologic synkinetic reinnervation (often about 4 months).



Consequently, after an intubation combined with surgery near the nerve both diagnoses need to be considered whenever there is a limitation of vocal cord motion.

In our example case, when the larynx is visualized with an endoscope, with the tip of the endoscope at a level above the tip of the epiglottis, only the lack of abduction is perceived and this frequently leads to the premature, simplistic diagnosis of "paralysis". After we topically anesthetized her vocal cords and passed the endoscope beneath the arytenoids, we viewed the limited movement of the vocal processes duing inspiration, expiration and attempted phonation. We viewed the mass of both vocal cords, effectively assessing the thyroarytenoid muscles. We viewed the posterior subglottis where scar tissue typically forms. We passed the endoscope into the trachea where there can be a secondary injury from the endotracheal tube cuff pressing the walls of the trachea and creating a second stenosis. In other words, we performed a complete and detailed examination.

We also performed a high definition examination. In moving the standard definition endoscope immediately adjacent to the posterior glottis, we effectively filled about 200 by 200 pixels of the endoscope's 640 by 480 pixels with the scar tissue creating her glottic stenosis.

If we compare this close view (where ~ 200 x 200 pixel area of the image is filled with the pathology) to a typical endoscopic overview image of the entire larynx from above the epiglottis, where the pathology is effectively hidden by the upper portion of the arytenoids, we can appreciate that moving the endoscope close to the pathology creates a high definition viewpoint for the pathology. In fact, we initially had effectively a 0 x 0 pixel view or one could say, a zero-definition view of the pathology, when the vocal cords were viewed from the level of the epiglottis.

The harm of using up 6 months of someone's life before obtaining an accurate diagnosis; the financial expense of all the non-essential tests performed on her; the reliance on a difficult to interpret test - a laryngeal EMG - for clinical decision making; the harm done when the unilateral injection of botulinum toxin led to the right thyroarytenoid muscle no longer remaining tense during inspiration and Bernoulli effect inducing further functional obstruction of the airway which increases with air hunger; the unnecessary expense and side-effects of a proton-pump inhibitor; all of this makes me appreciate the value proposition of an additional 15 minutes required to topically anesthetize her larynx and pass the endoscope between the vocal cords, to the carina. Additionally, when performed at the initial visit this exam is an incredibly valuable, low technology, high definition laryngology maneuver. This is putting more pixels on the pathology.

SUMMARY

Low technology, high definition laryngology is using inexpensive techniques to put pathology onto more pixels of the endoscope, no matter what endoscope the examiner already has. Low definition laryngology is where examiners may have high technology equipment, even a high technology education but;

1. they don't realize where to aim the endoscope, or
2. don't take the time to record quality images of the pathology or
3. do not understand the need for using low technology wisely to bring the pathology into focus
4. and/or do not review for mistakes to learn from them.

Rigid endoscopes

Rigid transoral endoscopes (Hopkins rod) tend to come in two configurations based on the angle of view; 70° and 90°. Sometimes a quick focus ring is added. In general, the glass transmitting the image in a rigid endoscope, carries more light than flexible endoscopes. Thinner rods reduce gagging, thicker rods improve light transmission and clarity. I use a thin 70° rigid scope and then if I need even better clarity, I switched to the larger diameter scope.

Although there is an eyepiece, I'll admit to never having looked through it directly. I have always attached a camera, a C-mount style camera. A recording which can be viewed mutiple times catches what the naked eye misses.

Because of the C-mount lens, higher resolution chip cameras are available for attached cameras when compared to chip-on-tip cameras on flexible endoscopes.

BENEFITS

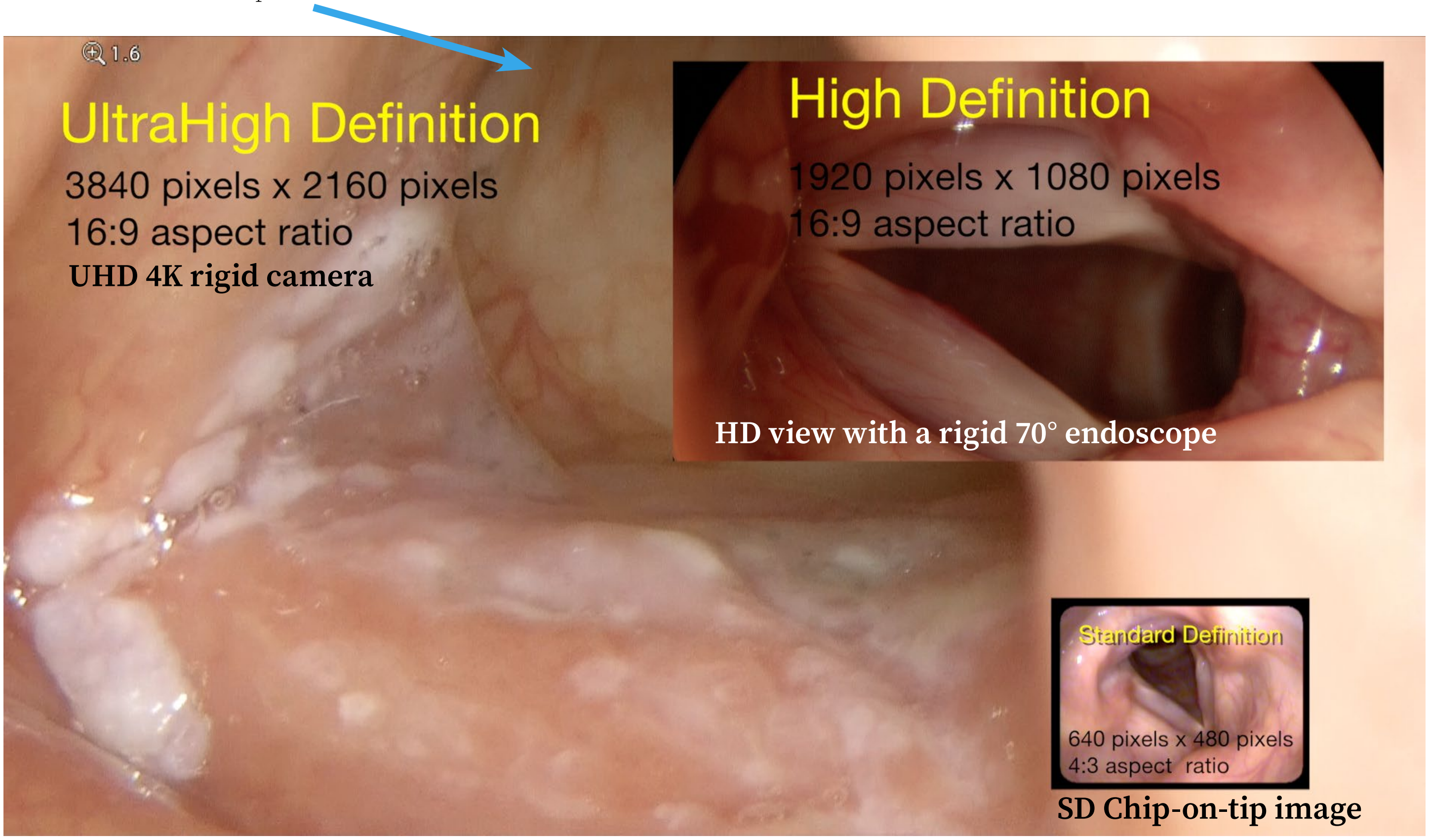
Benefits of a rigid endoscope include:

1. a high clarity image.
2. the endoscope can be attached to a standard definition camera which may be upgraded with a high-definition camera later.
3. The perpendicular view of the true cord vibrating margin highlights mucosal edge lesions. Especially when attached to a stroboscope, mucosal lesions on the margin of the membranous vocal cord stand out in high contrast against the background of the dark trachea.
4. With a cooperative patient and extreme depression of the tongue, a rigid scope can sometimes be tilted nearly into the laryngeal entrance and the cords examined extremely close up.

DISADVANTAGES

The potential pitfalls of the rigid endoscope are that:

1. It usually provides only a single perspective view - straight down from above.
2. Various anatomic structures can obstruct the image (uvula, base of tongue, epiglottis, posterior pharyngeal masses, supraglottic squeeze).
3. Gagging may preclude an examination altogether.
4. Depending on the amount of light, there is a relatively narrow depth of field. It can be difficult to put and keep the desired pathology in sharp focus.
5. Functional evaluation is limited, because the tongue is often stabilized by the examiner's hand.



Flexible fiberoptic endoscopes

There are a number of variations in the equipment available for flexible laryngoscopy. The main differentiation is between fiber-optic technology and chip-on-tip technology.

Typically flexible fiberoptic endoscopes are attached to a separate camera via a C-mount. The chip endoscopes are integrated with a large, shelf mounted processor.

BENEFITS OF FIBER

This can be the same camera used on the rigid transoral endoscope. One camera attaches to two different endoscopes yielding relatively lower initial capital cost.

The flexible aspect of this technology allows the endoscope to be passed through the nose, typically reducing the gag reflex during the examination.

Most laryngeal function is retained during a flexible examination. Palate function, pharyngeal function and laryngeal function may all be observed at different points in the examination.

Flexible endoscopes have a wider angle lens than rigid endoscopes and a wider angle perspective than the human eye. Consequently close objects appear relatively larger than objects farther away. There is a relatively higher depth of field compared to rigid scopes so more of the image is in focus at a given time.

Endoscopes have an articulation for bending close to the tip of the endoscope. When there is an even curve near the tip, they are easy to maneuver, especially within the confines of the false cords or the trachea.

The angle of view of the structures of the larynx can be modified to provide various perspectives on the same pathology. For example vocal cords may be viewed from above (the same perspective as the rigid), or the flexible tip may be bent so that the camera lies parallel to the vocal cords, looking along the length.

It has a wide angle lens, so much of the field of view will be in focus. Most of the pharynx can be viewed at once, yet the endoscope can also be positioned close to the vocal cords and even passed beyond the structures of the larynx. The esophagus and trachea may be entered.

One significant appeal for this equipment is that fiber-optic technology is relatively inexpensive compared to chip-on-tip technology.

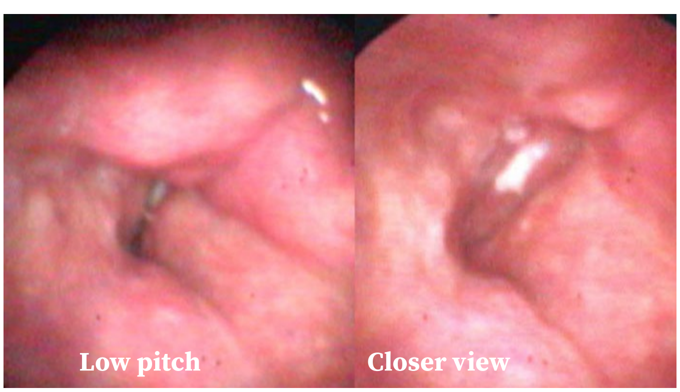
DISADVANTAGES

On the downside, although an attached camera can be updated from standard definition to high definition, the images provided by this technology are inherently quality-limited by the flexible glass fibers carrying both light to the interior of the larynx as well as transmitting the image of the larynx back to the camera to which it is attached. These relatively large glass fibers are visible in any image produced. When the image is recorded, the pixelation of the glass fibers interact with the pixels on the recording device and create a moiré effect. Attempts to diminish the honeycomb image and moiré effect produced by this technology involve a loss of resolution by blurring the image either physically or electronically.

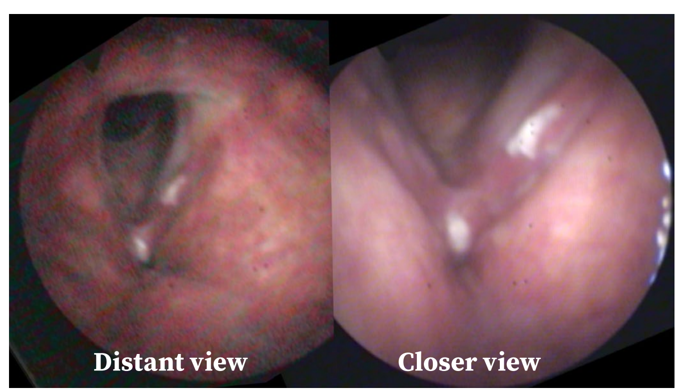
Fiberoptic glass fibers absorb light reducing image resolution. When they break over time, the absorption becomes complete and leads to a black spot in the image.

Loss of light through the glass fibers is compensated by the auto gain features of the cameras but leads to artifact. Digital noise produced by increasing video gain alters both the color and clarity of the images. Reflected light decreases greatly with distance.

Digital noise is particularly evident when the endoscope is relatively far away from the pathology. For example, with the endoscope at the level of the tip of the epiglottis, there is significant loss of light at the level of the vocal cords several centimeters away. Since most users have the auto-gain function turned on, electronic amplification of the image occurs without the examiner even sensing the degradation of the image. As electronic gain increases to maintain even lighting, more pixels in the image are assigned colors that don't actually exist. The image becomes more pixelated. Additionally, as capillaries become blurred, the image becomes more apparently red.



Increasing pitch contracts cricothryoid muscle, reducing supraglottic compensation. More true cord is visible.



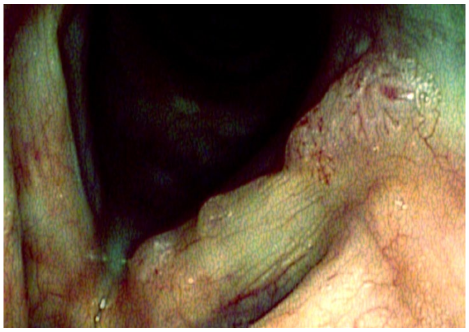
Moving endoscope closer increases reflected light, automatic gain reduced with reduction of digital noise.

Chip-on-tip endoscopes

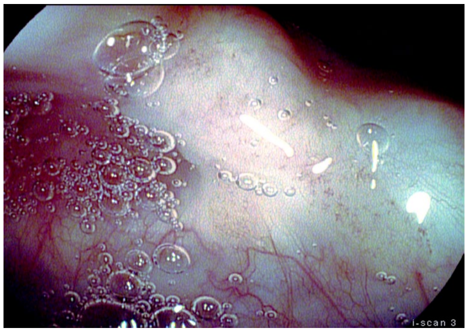
Chip-on-tip technology derives its name from miniaturizing the electronic sensor or chip and then moving it from the camera (which was typically attached to the endoscope eyepiece) onto the tip of the endoscope. Images are transmitted electronically through the flexible scope to an external processor. Since the image no longer passes through light fibers, moiré effect is eliminated and the images are much clearer.

As chips become smaller, higher resolution chips lead to higher definition images and/or smaller endoscopes. When topical anesthesia of the larynx is not utilized, smaller endoscopes can generally be moved closer to the laryngeal structures before gagging or laryngeal irritation occurs. This dipping maneuver may be employed during inspiration when the vocal cords are far apart. A small endoscope can approach the vocal cords without touching the arytenoids or false cords.

Additional processing of the image such as selective color adjustments, can alter the images before or after they are recorded. The most common use of color alteration is to amplify the visibility of the red of hemoglobin. Capillary architecture readily differentiates tumors and papilloma from normal, irradiated or scar tissue.



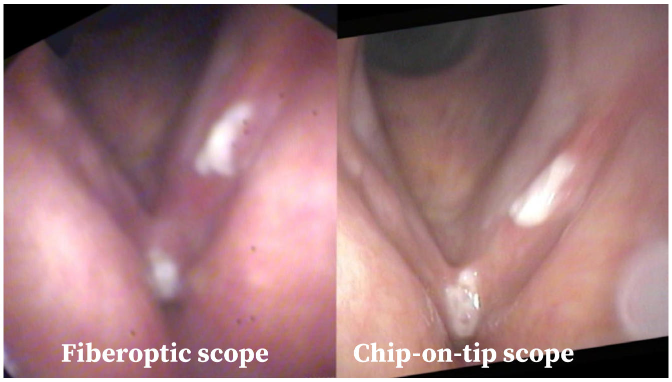
Papilloma capillary architecture



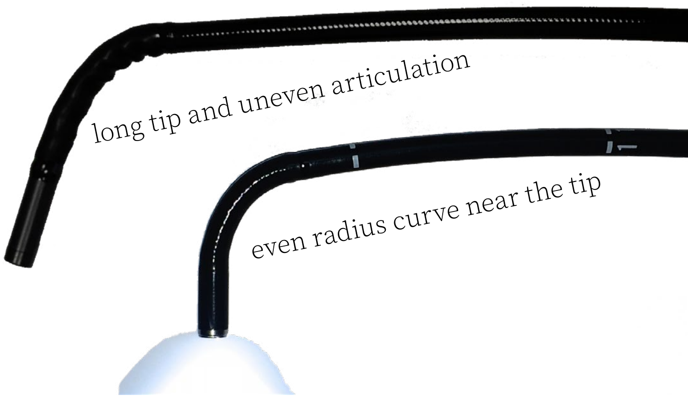
Squamous cell carcinoma capillary architecture

FLEXIBLE ENDOSCOPES

Resolution
Diameter of scope
Curvature of tip
Distance of curvature from tip



Chip-on-tip endoscope yields clearer image with less digital noise (less speckled red appearance)



Fiberoptic scope tip flexibility and distance from tip matter when maneuvering within the larynx. An even radius curve near the tip allows close insertion into the larynx parallel to the true vocal cords

What is meant by "definition?"

Although any combination of x by y dimensions could be utilized, the video industry has settled on a relatively few standardized sizes and ratios. The most popular, based originally on TV formatting, has become labeled standard definition. When televisions were still analog, the standard called NTSC consisted of 525 lines, the aspect ratio was 4:3 and the images were recorded at 30 frames per second. Each frame consisted of two frames, which were interlaced.

As digital technology took over this standard, the 4:3 aspect ratio, turned into 640 x 480 pixels utilized to record the same image (some of the additional vertical lines were used for other things during the analog era).

60 frames per second may be recorded with only 1 field per frame, which eliminates interlacing artifact. Many other compromises have been made over time for technical reasons as well as commercial reasons and Wikipedia has a nice overview if you desire further information. Technology has not remained still and silicon means more and more pixels can be processed and stored.

Various compromises have led to high definition video recording standard resolution and settling on a 16:9 aspect ratio. Some of the shorthand utilized to express video recording is listed below.

VIDEO FORMAT

Video format = resolution + frequency + frame rate

SD - 525i - 640 horizontal by 480 vertical pixels + 59.94 Hz + 59.94 Interlaced Fields

HD - 720p - 1280 x 720 pixels + 59.94 Hz + 59.94 Interlaced Fields

HD - 1080i - 1920 x 1080 pixels + 59.94 Hz + 59.94 Interlaced Fields

4K UHD - 4096 x 3072 pixels

GRAPHIC FORMAT

Highly variable, almost any x:y variation of pixels is available on different computers.

Determining the video output of the processor affects the resolution that should be captured by the user. Capturing at a higher resolution than the video output results in wasted hard disk storage. Capturing at a lower resolution than the video output results in loss of video resolution.

Although high definition carries a variable meaning, the variations are fairly well accepted and when the terminology HD is accompanied by a number, such as HD 1080i, you have a fairly good idea what you are getting. The term "high resolution" has no standard meaning in terms of video and I have frequently heard medical marketing representatives use the term loosely to mean this current endoscope is better than our previous endoscope and sometimes the buyer's brain misinterprets the words "high resolution" as "high definition". The marketing representatives don't seem to object to this confusion.

LIGHT

Camera and processor are typically integrated into one proprietary package. Often the light source is also integrated into the processor. However, for laryngology, separating the light cable from the camera allows for changing the connection from a constant light to a stroboscope. Constant light has even illumination and brightness going for it. Stroboscopic light loses illumination but yields apparent slow motion.

Xenon, halogen and LED lights are being used for laryngeal endoscopy. Each colors the image in a slightly different way. Even the camera used for recording and the screen used for viewing the video recording alters the perceived color of the laryngeal tissues.

On the voicedoctor.net blog I have detailed my thoughts on two major producers of laryngeal endoscopes, Olympus and Pentax. Even when the resolution of the cameras is identical, videos of an individual larynx appear different depending on the camera used to obtain the images.

TRANSMISSION

Carrying audio and video signals along a cable requires different types of connections. Some of the terms that you might run into include:

1. DVI - Digital Video interface (carries analog or digital signals, SD or HD, but no audio)
2. HDMI - High Definition Multimedia Interface (SD, HD, video, audio)
3. SDI - Serial Digital Interface (single cable)
4. HD-SDI - High Definition Serial Digital Interface
5. Thunderbolt (Apple)
6. USB (Universal Serial Bus)

CONVERSION

Basically, what comes out of the camera may not be what a computer wants to digest. So unless one manufacturer designs your entire system, you may need to do a conversion between the output on your camera and the input on your computer. Also, since high definition video consists of so much data, most conversion processes require hardware in order to do a conversion quickly enough not to lose frames on the video. Quite typically, the cable comes out of the camera processor carrying video to a hardware converter which may combine the audio with video, convert the video to a different format and then plug into a computer.

CAPTURE

I have been capturing video on Apple laptop computers for some time. There are various software programs that can grab live video. The one I currently use is designed to go with the hardware conversion box which encodes the video for Apple's QuickTime video format. QuickTime seems to have remained a stable standard "wrapper" over the past 15 years. The codecs within QuickTime have changed over time but I can still view all of the video I have recorded with this program.

After capture, I organize and review the video in Apple's Final Cut Pro video program. Another common program is Adobe's Premiere video editing program. I appreciate these programs for their ability to slow video, move frame by frame, view in forward or reverse and render a given frame completely removing the interlacing. I can view the still images on high resolution monitors and make annotations on interesting frames.

Conveniently, video files can be viewed directly on the laptop. This is quick, but lacks many of the abilities mentioned above.

STORAGE

No one wants to store every pixel that comes out of your endoscope. Consequently there are various compression and storage formats for video called codecs. Some of the more common ones are listed.

VIDEO CODECS

Compression algorithms

- MPEG-4
- MPEG-2
- H.264
- H.265
- WMV (Windows Media Video)
- Apple ProRes 422
- DV
- .mov (quicktime)
- H.265 HEVC

In 2018, I recorded from my high-definition cameras through a converter box to Apple ProRes 422. These were moderate sized files with a resolution fairly optimized for the highest resolution endoscopic cameras I currently had.

Hospital operating room cameras and endoscopes seem to favor PC formats and variously capture video in MPEG-4 and WMV formats. Since these are not native formats for Apple computers, they are slower to load on Apple software.

In 2021, I switched to direct capture on a card with a BlackMagic Design HyperDeck Studio recorder which captures directly in H.264. This is fast and yields small files. The deck shuttle can be used to review video while the patient is still in the room.

With files from hospital recorders, my own files and emailed files, I end up with a mix of formats on my hard drive. My oldest files were formatted in DV. With the introduction of H.265, I run all recordings through videoconverter ff·Works compressing all my files to a very small size. I now store 20 years of video on a small solid state hard drive. When I do want to view them, they load rapidly. There is some loss of resolution from H.264 to H.265, but the convenience of small files outweighs the image loss in my experience.

For data safety, immediately after a patient examination, I transfer the video files to a networked RAID hard drive which makes two copies of each video so that when a hard drive dies, the video still exists elsewhere on the RAID drives. Every evening, a program — CrashPlan Pro — backs that RAID drive up to another one in a different physical location.

Every few weeks, I also store another copy of all the video files on a separate hard drive which is not connected to the internet and which I store at a different physical location. Redundancy is a key word for managing video data files and preventing data loss.

Slow motion

Since video is typically captured at about 60 images per second and almost all vocal cord vibratory movement occurs at more than about 80 cycles per second and interlaced video is the most common format, almost all images of vibrating vocal cords will appear blurred on standard video recordings played on video monitors. After one has seen enough slow-motion video recordings, one can often infer from these blurred images what is might be happening to the vocal cords in real time.

However, there are several ways to capture images of moving vocal cords: each method has trade-offs in terms of data collected and time spent viewing the video.

The method I utilize and a significant improvement on standard video occurs with a stroboscope. An audio sensor detects the pitch of the voice and triggers a strobe light to flash at one or two beats more per second than the vibration of the vocal cords. The video then records slow, apparent motion of the vocal cords. The video is a compilation of many cycles of movement and to the extent that vocal cord vibration is regular, this apparent motion mirrors real motion. When a single pitch is heard, vocal cord vibration is constant and regular and this supposition holds.

The trade-off with stroboscopy is that when there is irregular vocal cord vibration, the strobe light cannot track irregularity well. The recorded image is in some respects an illusion.

For example, in the case of diplophonia, where there are two separate pitches simultaneously, the strobe may track the source of one of the pitches. The source of the other pitch will appear to be highly irregular, perhaps like a flag flapping in the wind. This artifact may create a false impression of the actual physical movement of the vocal cords.

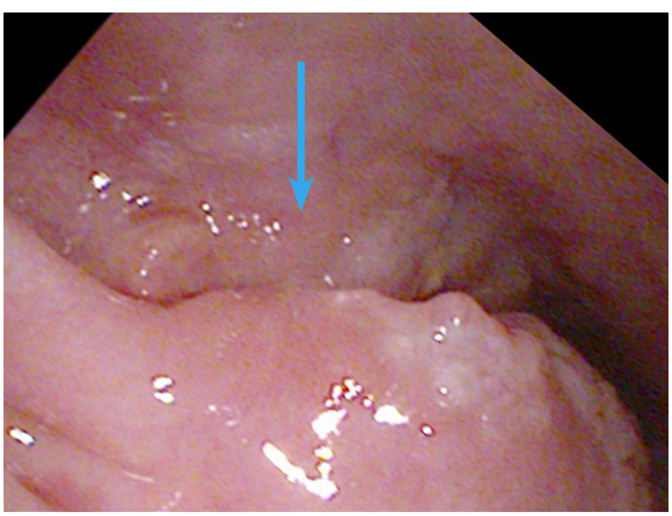
High-speed video records several thousand frames per second, thus recording actual vocal cord motion. Some of the trade-offs with this technique are that it requires a large amount of data storage, it can be difficult to capture actual pathologic movement of the vocal cords since you have to record in short bursts. It can take a long time to review this video to find the pathologic motion. As a newer technology, it is also relatively more expensive than stroboscopy.

There is also kymography, which I have never used. It is high speed video of a single line on the camera, then compiled into a timeline. I understand how it can help to understand the apparent movement visualized with stroboscopy. I just find it easy enough to understand the principles of stroboscopy to use it clinically.

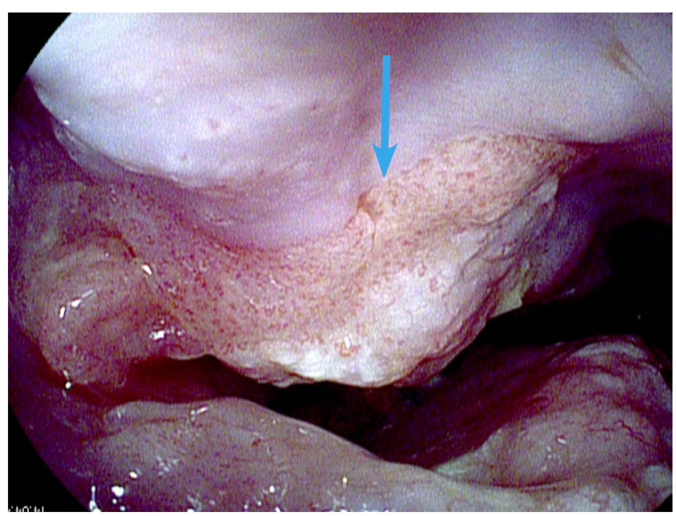
Selective color imaging

Since video images consist of red, green and blue channels, it is possible to selectively filter some of the light on the individual color channels. Both Olympus and Pentax have made use of this and electronically filter certain bands of light in the blue and green wavelengths, which are absorbed by hemoglobin. Blood, normally viewed as red in video images, then appears dark or black in the video recordings, adding additional contrast with the surrounding tissue.

This makes the capillary vasculature of the larynx pop out in the images. While the capillaries are visible using the normal lighting algorithms, emphasizing capillaries tends to lead the eye to various laryngeal conditions. In particular, hemorrhage and dilated capillaries occur with trauma and infections, but most notably capillaries are dilated and generate specific patterns as tumors grow and require or induce an increased vascular supply for their metabolic needs. Additionally, very thin films on the vocal cords can be more readily visually identified because the films obscure the expected normal capillary architecture beneath them. See photos below.



With normal lighting, it is difficult to separate the tumor from normal tissue (arrow points to tumor margin).



Selective color imaging of the same area (and the trumpet maneuver to insufflate the piriform sinus) highlights the vascularity of this tumor and differentiates easily the tumor margin (arrow points to tumor margin).

Recording & Reviewing Video

Motion happens in the larynx very quickly. Sometimes pathology is large and the impairment easily recognized. Other times, a vibratory impairment may be recognizable on as little as only a single frame of a video recording. This means that during live recording, the problem might be present, but not be visually recognized. Even during the quick review of the recording that I perform while the patient is in the examination room and during my explanation of the problem to the patient, I slip through the video to the pertinent pictures in order to describe the problem I perceived. On a regular basis though, I later review the video again as I am developing a report on a patient. I search for optimal individual frames of the video that demonstrate the pathology. During this detailed review, as I sometimes play the video frame by frame, I often notice additional detail.

Sometimes after surgery or some type of intervention or even just the passage of time, when something doesn't turn out as expected, I return to prior videos and review them in light of the new information and I will discover details that I missed on prior reviews. Consequently, I find that the recording of a video is valuable not only for finding the immediate problem, but is equally valuable for teaching myself about the significance of audio and visual findings that I might have initially missed.

LOW TECHNOLOGY

Low technology is really the most valuable part of a High Definition endoscopic examination. The quality of the image obtained does not depend directly on money. Rather it depends heavily on the examiner's knowledge, skill and patience. In our example patient at the beginning of this book, no matter what definition the endoscope recorded, the pathology occupied zero pixels of the endoscope when it was placed at the level of the epiglottis, a common location for many endoscopic laryngeal recordings. By applying topical anesthesia and maneuvering the endoscope beneath the upper portion of the arytenoids, the pathology could be seen just inferior to the vocal processes. By the time the tip of the scope was close to the vocal processes, I estimate that about 200 x 200 square pixels of Low Technology, High Definition imaging were exposed to the lesion, merely by supplementing a typical laryngeal examination with an additional 10 minutes and topical lidocaine.

Here are some selected ways that low technology can be utilized to obtain a high definition laryngeal exam.

CLOSENESS

Occasionally the endoscope can be maneuvered close to the larynx just because a patient can tolerate it, or because a sensory nerve injury allows the endoscope to actually touch the larynx without triggering a gag or initiating a laryngospasm. Sometimes it is possible to maneuver the endoscope close to or in between the vocal cords during inspiration and back it up during expiration as the vocal cords tend to abduct during inspiration.

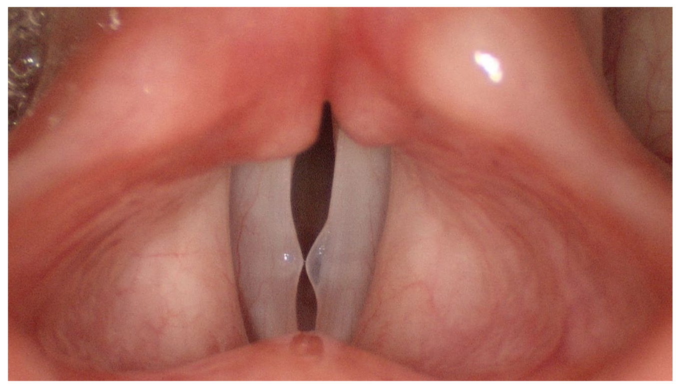
More typically though, topical anesthesia is the laryngologist's best friend.

In the nose I use a mixture of phenylephrine, 4% lidocaine, stevia and peppermint oil for a somewhat user friendly approach to removing the nasal discomfort of passing an endoscope through the nose.

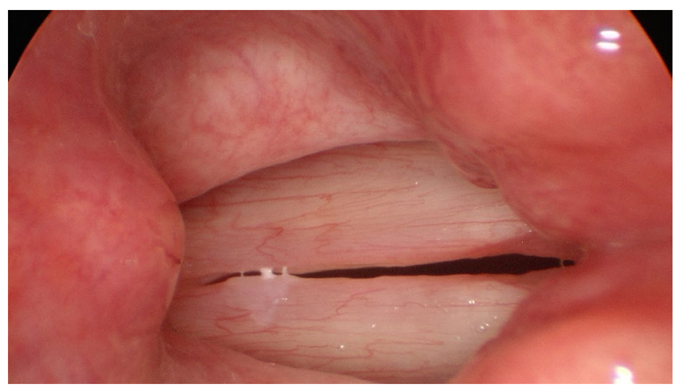
For super close views, I somewhat frequently utilize 4 mL of topical 4% lidocaine, typically dripped on the vocal cords in 1 mL aliquots over a minutes or more. The larynx can be completely anesthetized and an endoscope can usually be maneuvered anywhere in the larynx or trachea. The first aliquot of anesthetic makes the patient cough and distributes medication around the entire larynx, pharynx and subglottis. I ask the patient to phonate while I add additional topical lidocaine and this generates a laryngeal gargle, the lidocaine drops dancing on the surface of the vibrating cords. After the fourth milliliter is dripped and gargled and I wait for an additional 2 to 3 minutes when the topical anesthesia is complete.

Camera orientation - Rigid endoscope

While the image captured by endoscopes is typically round, there is enough transmission of light with rigid endoscopes to mechanically zoom some cameras with minor loss of light and resolution. When combined with the newer high definition ratio of 16:9, vibrating vocal cord anatomy nicely aligns with this horizontal visual field in terms of length: width ratio, utilizing more of the pixels available on the camera. Compared to my typical placement of the camera on a flexible fiber-optic endoscope or the orientation of the camera chip on integrated chip endoscopes, this rotation of the external camera attached to the rigid endoscope 90°, aligns the vibrating edges of the vocal cords horizontally on the stretched, high definition video monitor. It has the potential to place more pixels onto vocal cord pathology.



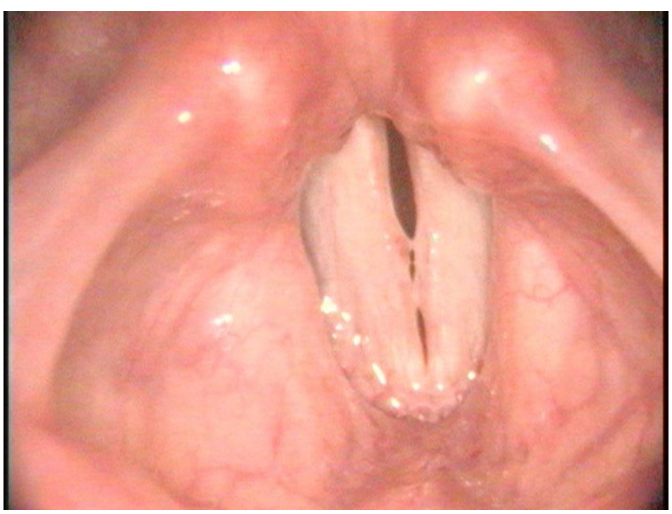
vertical orientation



horizontal orientation of the vocal cords

Choose a vowel

“Ahhhh” sound allow epiglottis to occlude some of the vocal cords

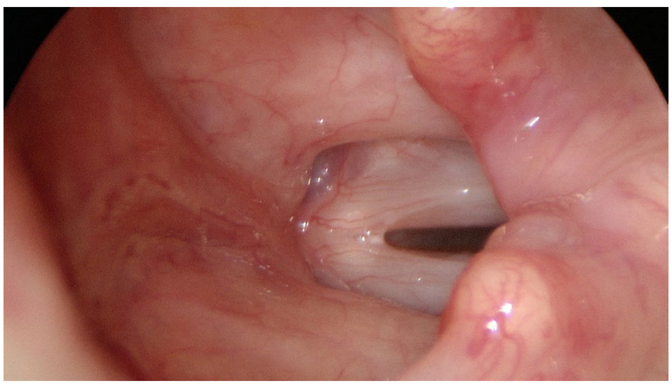


“eeeee” sound or /i/ opens up the pharynx for a better view of the vocal cords

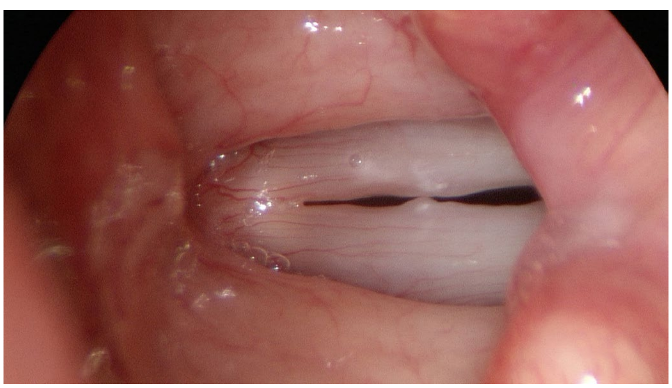
Since most consonants are produced at the level of the palate, tongue and lips, it is not necessary to visualize connected speech during a laryngeal examination. Vowels are produced in the pharynx. The vocal cords are primarily responsible for the production of sound. They primarily modulate frequency and volume. Consequently If we eliminate words during our examination, we reduce inadvertent movement of the flexible endoscope by palatal and tongue movement. We want to keep the pharynx as open as possible and the epiglottis as far forward as possible. The vowel /i/ provides for this maximal pharyngeal opening.

I find that /u/ is a helpful vowel in some situations where the individual is squeezing too hard on /i/.

Alter pitch - high



Low pitch, vocal cords short and loose - marginal lesions disappear into the vocal cord mucosa



High pitch, vocal cords long and tense - marginal lesions are pushed into the central glottic opening

We can record our examination at both low and high pitch. In fact, if we identify a particular pitch during the vocal capabilities pattern matching portion of our examination that triggers dysphonia, we should make an attempt to record that pitch during our endoscopic examination. In effect, we want to record the worst sound.

HIGH PITCH

Apart from finding a specific pitch that triggers dysphonia, high pitch activates the cricothyroid muscle to lengthen the vocal cord and the thyroarytenoid muscle to intrinsically tension the vocal cord. As the vocal cords lengthen, any lesion along the vibratory margin will tend to be pushed out into the field of view, particularly from the rigid endoscopes vertical viewpoint. At high pitch, the vocal cords are also reaching their maximum tension which will aggravate any pre-existing stiffness and make the vibratory impairment more visible.

In neurologic impairment, if there is an asymmetry between the superior laryngeal nerves, oscillations will be symmetric at low pitch and asymmetric tension at high pitch will move the cords out of phase.

Alter pitch - low

LOW PITCH

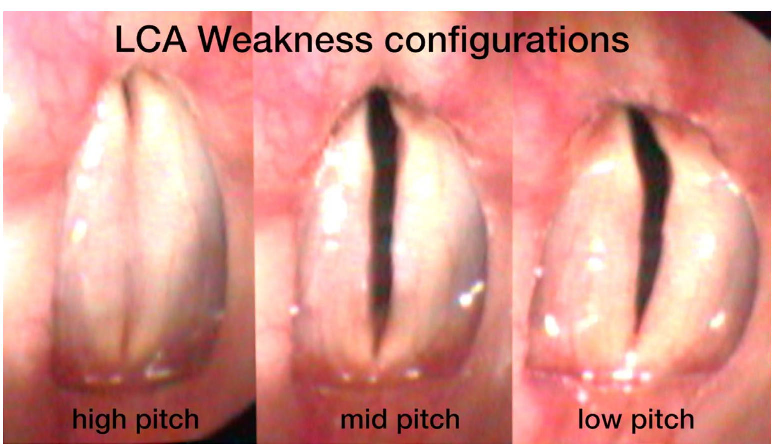
Recording at low pitch removes any inadvertent or obligate compensation by the cricothyroid muscle. Activation of the cricothyroid muscle may occur in nonorganic voice disorders. It almost always occurs in neurologic disorders involving paresis of the thyroarytenoid muscle, the lateral cricoarytenoid muscle or both.

As the patient reduces pitch, this natural or intrinsic compensation by the cricothyroid muscle is removed. The uncompensated thyroarytenoid muscle oscillates more laterally, and sometimes, with enough difference in tension, the vocal cords will break synchrony and the weak cord will flutter.

With the removal of intrinsic compensation by the cricothyroid muscle, a weakened lateral cricoarytenoid muscle will allow the vocal process to cant laterally, creating an obtuse angle between the vocal process and the membranous vocal cord.

At high pitch the weak right vocal cord is held tense and relatively straight by a contracted cricothyroid muscle.

At low pitch the weak right vocal cord is lax, oscillates far lateral to its axis, buckles and the thyroarytenoid muscle thinness is visually very apparent.



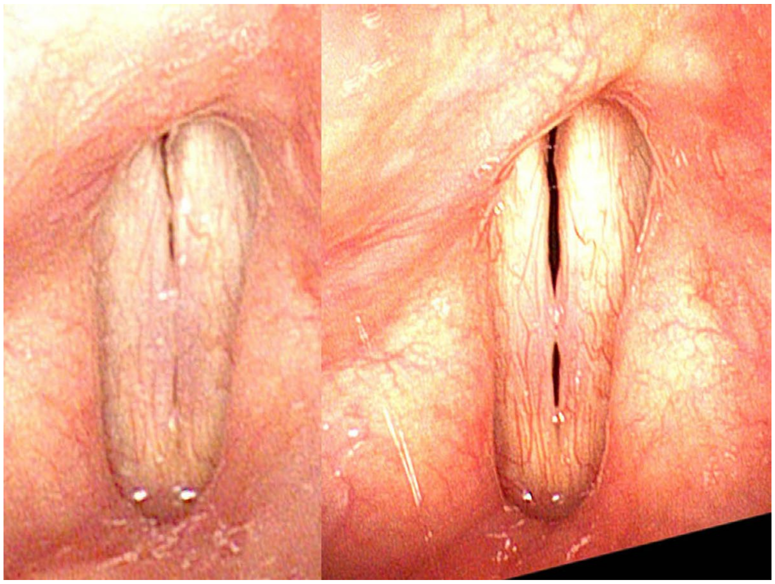
Left lateral cricoarytenoid muscle paresis visualized at three different pitches. At high pitch (left), the cricothryoid muscles lengthen and tighten the vocal cords, bringing the vocal processes close together at high pitch. Viewing the vocal cords during phonation at lower pitch removes this compensation and the effect of the weakness becomes more visible (right).

Alter volume

Patients may adjust volume quickly as unconscious compensation to avoid abnormal sound during an examination, even though abnormal voice is the raison d'être for their office visit. But if you can coax them to allow the abnormal sound during stroboscopy, it is possible to record the cause of the hoarseness. Increase and decrease volume to find the abnormality.

Low volume - swellings

This is particularly true for singers. They often convince themselves that abnormal vocal sounds are the results of poor technique. In order to avoid audible impairments they increase vocal cord tension and increase their subglottic pressure and volume. Small gaps, small elevations and minor stiffness can be completely overcome by the increased subglottic pressure. By eliciting from the patient, low-volume sound production, smaller vocal impairments can be visually discovered during the examination.

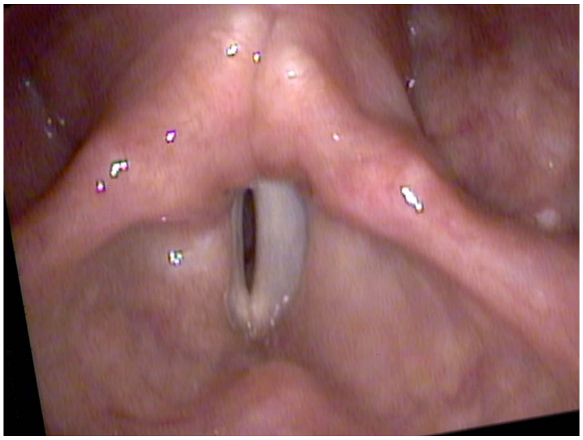


High volume left: Stroboscopy at pitch D4 with high airflow and the vocal cord margins close completely.

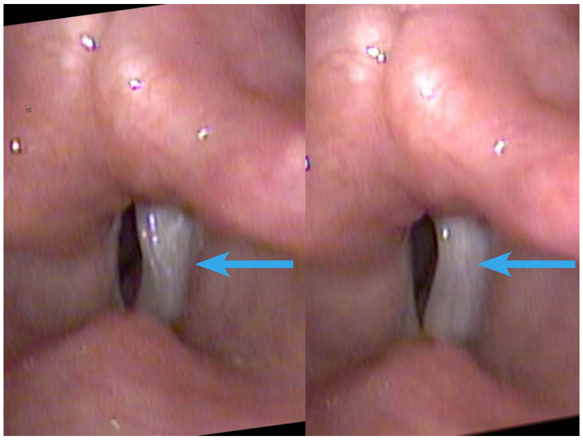
Low volume right: Stroboscopy at pitch D4 with low airflow and the vocal cord margins cannot close because of bilateral vocal margin swellings (polyps).

High volume - weakness

Higher volumes, especially at low pitch, can augment neurologic and muscular weakness visual findings by causing the weakened vocal cord to vibrate abnormally. A non-tense thyroarytenoid muscle may break up into two or more oscillatory segments, generating the appearance of flutter on stroboscopy and also oscillate lateral to its axis creating an infinite open phase on stroboscopy.



Low normal: Stroboscopy at pitch C4 with low airflow and both vocal cords entrain symmetrically, creating a clear tone.

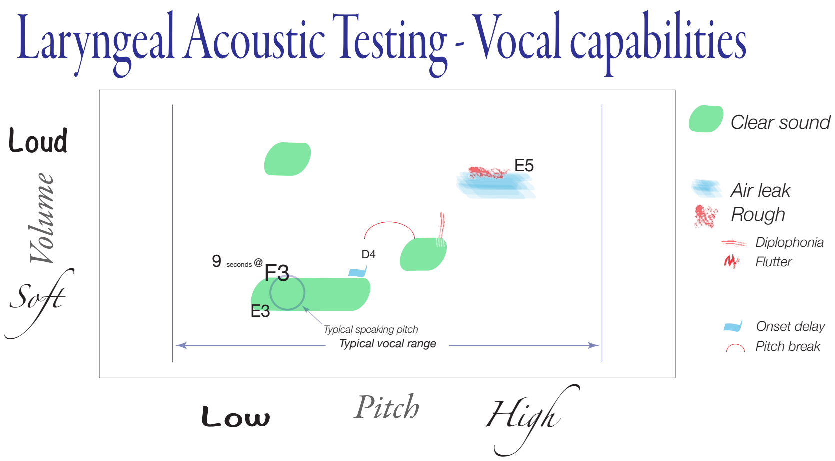


High abnormal: Stroboscopy at pitch C4 with high airflow and the left vocal cord osciallates as two standing waves around a sonic node (blue arrow).

Closeness

CLOSENESS

Roberta complains of a scratchy voice for several years, typically worse after yelling at football games. She finds it difficult to sing clearly.

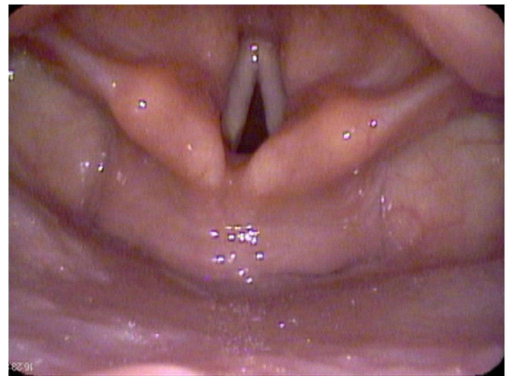


We know there is pathology. She is fairly clear at low pitch, but as she increases in pitch, she begins to have vocal onset delays, then pitch breaks. In her upper range at high volume she has both air leak and roughness.

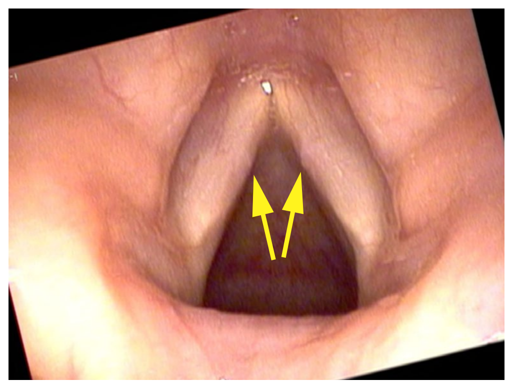
All of these abnormal findings: onset delays, diplophonia, roughness, air leak and pitch breaks compel us to look with our endoscope until we find the cause (especially if everything looks "normal" at first.)

A typical laryngeal exam is often performed with the camera above the epiglottis (presumably to avoid gagging). As the endoscope is moved closer, the pathology occupies more pixels on the screen and becomes more apparent.

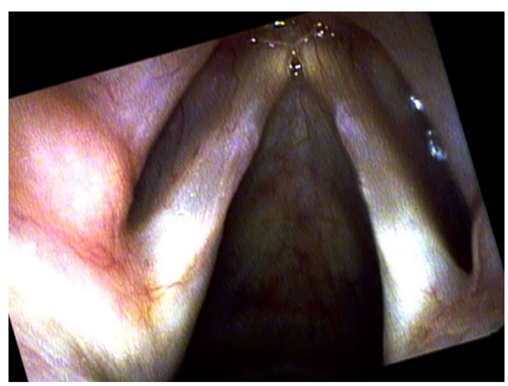
Some maneuvers in addition to closeness contributing to visualization: inspiration, parallel view of cords, selective lighting, high pitch phonation and, high definition cameras.



Typical viewpoint with standard definition chip scope above the top of the epiglottis. Epiglottic tip is visible in upper right of photo. The vocal cords look fairly smooth & normal.



Moderate close viewpoint with standard definition chip scope. There is a faint thickening on the vocal cord's central vibratory margin.



Moderate close viewpoint with standard definition chip scope, selective color and during inspiration. Central swellings stand out in terms of elevation from the margin as well as in color or opacity.

Parallel viewpoint & sniff

PARALLEL

It is sometimes possible to dip into the larynx with the flexible endoscope during inspiration while the vocal cords abduct. When that does not yield a close enough view, topical anesthesia can be added. Then the scope may be passed into the larynx and bent anteriorly, approaching a plane nearly parallel to the vocal cords. This perspective reveals where on the vibratory margin a lesion lies. The degree of elevation from the surround tissue may also be more obvious.

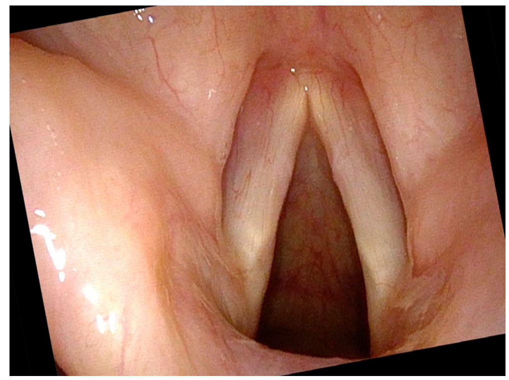
INVERSION

Passing an inverted endoscope through the nose requires a bit of upside down thinking, but the curvature in this direction is typically different in degree from the usual direction. It also places the light and any working channel at a different angle. I find it easier to visualize and work on the right vocal cord through an inverted endoscope.

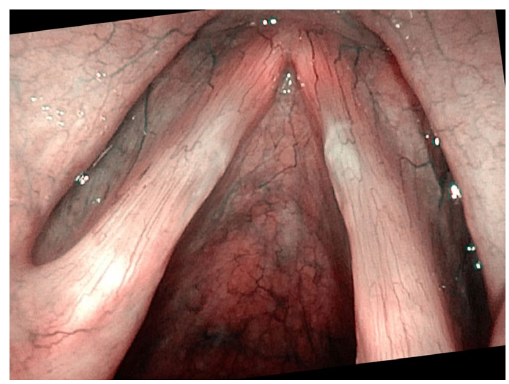
SNIFFING

Active abduction during sniffing stretches and thins the true vocal cords. It is very useful for comparing the bulk of the thyroarytenoid muscle which may be reduced on a neurologically impaired side.

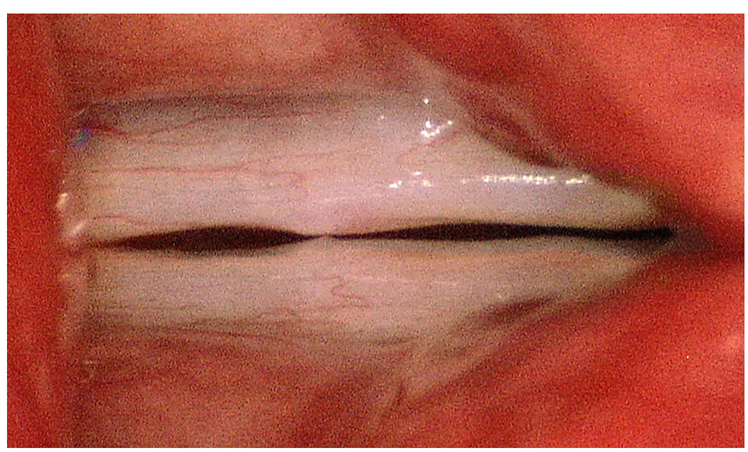
All of the photos on the these pages were taken in the same patient on the same day.



Moderate close viewpoint with high definition 1080i chip scope. Vessels & marginal swellings more obvious



Close viewpoint, high definition 1080i chip scope, selective color imaging, inspiration maneuver to thin cords. Vessels & marginal swellings increasingly obvious.



Rigid endoscope
turned 90 degrees to enlarge cord margins
stroboscopy
attempted pitch F5
pitch break to E6 in two segments
captured frame at phonatory onset

Both protrusion & length of medial, central vocal swellings are visible

Respiration

OBSERVATION

FASCICULATION

Monitoring the vocal cords closely during quiet respiration can detail subtle neurologic findings. Fasciculations are often noticed during quiet breathing when the larynx is relatively still. These can be seen on the arytenoids relatively easily. They are also visualized within the laryngeal ventricle on the superior surface of the vocal cord in a denervated thyroarytenoid muscle.

TIMING

The timing of abduction and adduction are also well assessed during quiet respiration. During expiration, partial adduction typically occurs, while during inspiration, partial abduction occurs. The degree of abduction and adduction should be symmetric.

RANGE OF MOTION

With acute denervation the angular range of motion is less on the injured side. Later, as varying amounts of synkinetic reinnervation occur, the timing of motion can become asymmetric. Additionally, with synkinetic reinnervation, the resting position of the vocal process may become more medial.

LEVEL

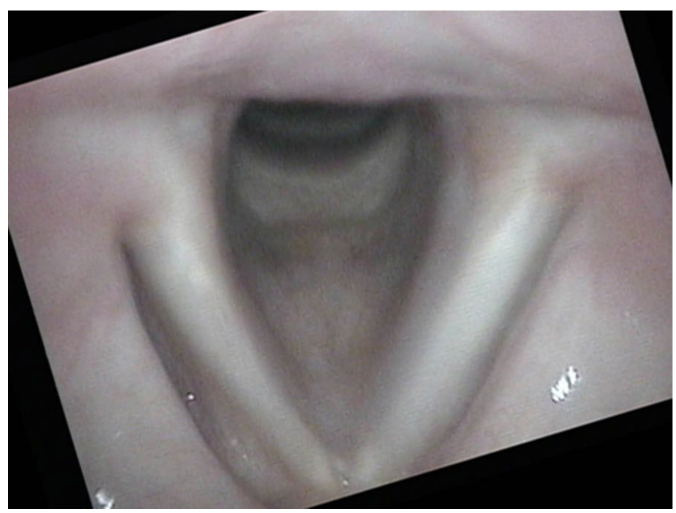
Height differences between the vocal processes can really only be appreciated well when the flexible endoscope is placed between the arytenoids, nearly parallel to the axis of vocal cords. From this posterior view, oriented along the axis of the vocal folds, the mass of each thyroarytenoid muscle can be compared.

MUSCLE MASS

Sniffing augments abduction, lengthening the vocal cords while they are pulled further apart than during expiration or even quiet inspiration and an atrophic vocal cord will thin even further. This finding is most prominent when deep inspiration occurs immediately after phonation. See photos to right.

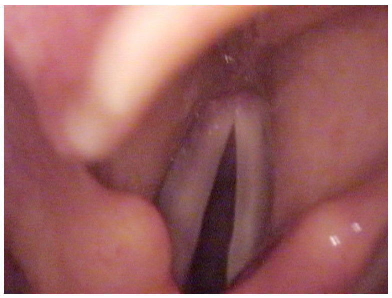
The same inference may be visualized in a negative way. During deep inspiration, the ventricle on the side of thyroarytenoid muscle atrophy, appears to enlarge relative to the other side. This may be easier to visualize in the sense that both thyroarytenoid muscle atrophy and false vocal cord atrophy contribute to the size of the laryngeal ventricle.

During quiet respiration, the vocal cords and ventricles appear similar in size.



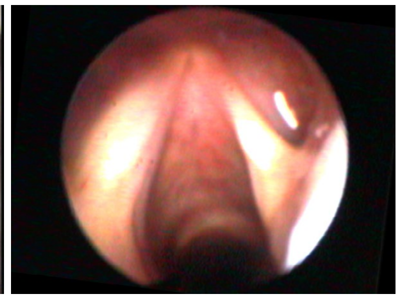
During deep inspiration (sniffing), the right vocal cord thins and the right ventricle appears to enlarge.

Multiple viewpoints

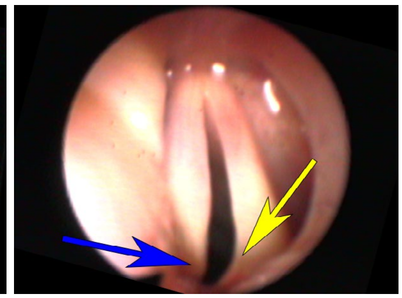


View from above of the vocal cords with a rigid 90 degree endoscope during mid respiration. This view suggests the vocal cords are similar even though the right one does not move during breathing or phonation.

View from above of the vocal cords with a rigid 90 degree endoscope during phonation at a high pitch. There appears to be little air leak based on how closely the vocal cord margins approximate each other during maximal adduction. This view doesn't explain her complaints of a fading voice and it does not explain any roughness the examiner hears.



View with flexible fiberoptic scope. Almost lined up with the cords, the right thyroarytenoid muscle is extremely atrophic relative to the left. This will explain her roughness because two sound sources of different massed will tend to vibrate at different pitches. This right TA muscle also probably cannot provide nearly as much tension as the left.



View with flexible fiberoptic scope positioned in the posterior commissure. The left LCA muscle is adducting the vocal process past the midline (blue arrow) and the right LCA muscle provides almost no rotation (yellow arrow). If the left LCA fatigues at the end of the day, the gap will widen and leak more air.

DUAL VIEWS

One method to improve resolution of a vocal cord problem is to probe multiple viewpoints. With both a rigid and a flexible fiberoptic endoscope, a more complete understanding of vocal impairment emerges.

These standard definition images, taken at a relatively low resolution, adequately tell the story behind the vocal complaint of a weak, poorly durable and rough voice. 20 years ago she lost her voice after a neck surgery. It recovered, but has not ever been normal. Her voice is rough and fades with use.

With a rigid endoscope the vocal cords are viewed from above, an excellent perspective for assessing the vocal cord margin and in this case to evaluate abduction and adduction. At the time of this exam I was recording with DV quality (720 x 480 pixels).

The right vocal cord, although it is not moving in this plane, is positioned near the midline and the left vocal cord is able to meet it. So the "paralysis" (and it is likely synkinesis rather than paralysis), viewed from the perspective of the rigid endoscope easily addresses abduction and adduction and air leak, but does little to visually explain her diplophonia. Indeed she was told that her vocal cords were "well compensated."

Adding a flexible fiberoptic endoscopic view to the rigid exam, especially after the addition of topical lidocaine adds significant information. The flexible fiberoptic endoscope, even though it records at an even lower resolution, visually explains the diplophonia based on the mass difference between the vocal cords. The right vocal cord thyroarytenoid muscle is extremely atrophic and will tend to vibrate at a different pitch based on mass asymmetry.

Additionally, even though compensation appears really good on rigid exam (at a high pitch), the left LCA muscle is working extremely hard to bring the left vocal process anywhere near the right. The gap is larger at low pitch and after vocal use and likely left LCA muscle fatigue, the gap is probably even larger.

We can think of the view from directly above as a satellite view that offers us a very nice overview, but misses topographical details. The flexible scope, appropriatly positioned adds those details in.

Anesthesia

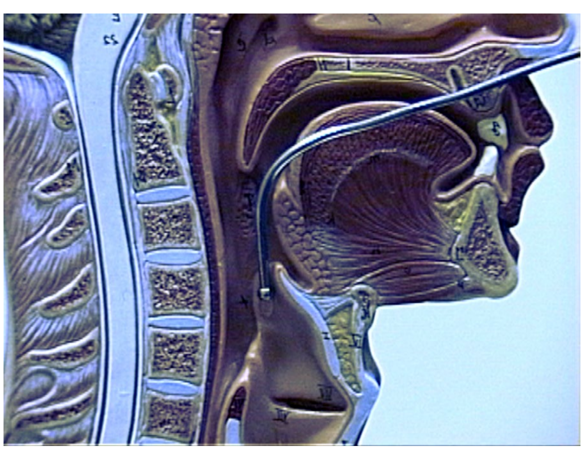
Topical anesthesia is your best friend. There are several ways to place topical 4% lidocaine onto the vocal cords. These maneuvers improve the quality of your vocal cord assessment.

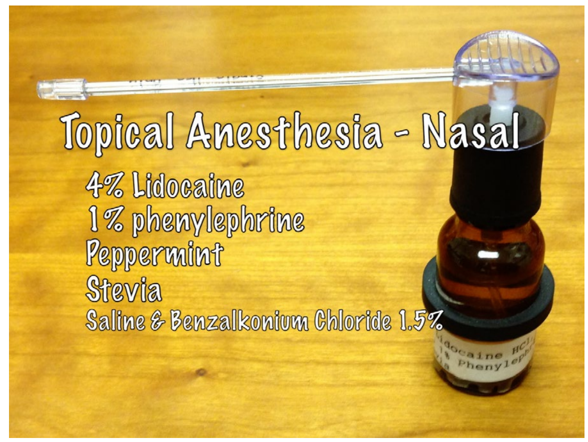
Generally the nose and posterior pharynx our first anesthetized. It Is important to wait 3 to 4 minutes for the anesthesia to have full effect. Then an atomizer, Abraham cannula,or endoscope with a channel can be utilized to drip lidocaine onto the vocal cords during phonation.

The initial aliquot of approximately one milliliter when applied generally triggers sudden coughing. After 30 seconds, a second application can more easily be applied while the patient makes the /i/ sound. This creates a gargle on the vocal cords and a deep anesthesia.

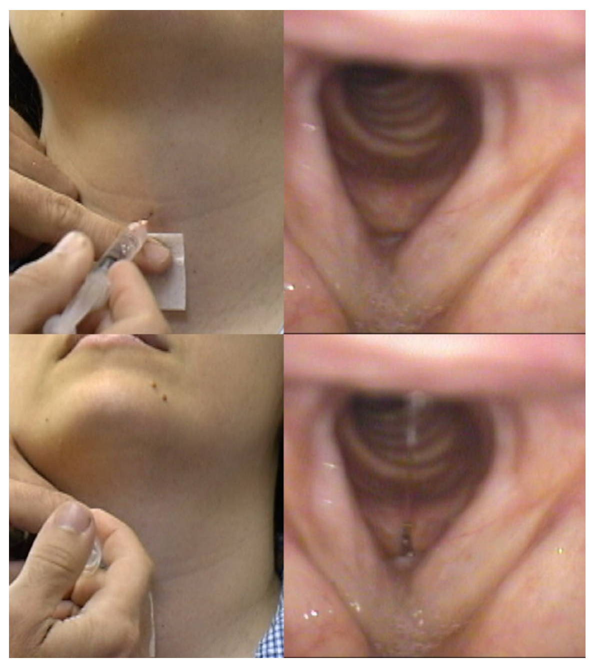
Quicker, but it involves a needle, 2% Injectable lidocaine can be applied through the cricothyroid space. It triggers a cough and generally quick anesthesia. Sometimes a few spots of blood appear in the image.

An Abraham cannula used ot drip lidocaine into the pharynx for a laryngeal gargle.





This atomizer gently places a flavored medication into the nose and posterior pharynx.



2% lidocaine is injected trans-cricothyroid space. This initiates a cough, which bathes the vocal cords in topical anesthesia

Equipment

TYPICAL VOICE LAB

For the well-equipped, standard voice lab, I would consider the following equipment essential to varying degrees:

1. Endoscopes
   Rigid endoscope coupled to a camera
   Flexible fiberoptic endoscope coupled to a camera
2. Light source
3. Recording device
   Computer with adequate memory for video recordings
   or videotape (digital)
4. Stroboscope
5. Consumer LCD screen

This is a budget conscious approach to laryngology. The equipment is sufficient to perform a reasonable examination.

HIGH-END VOICE LAB

As one can afford more…

1. Flexible videochip endoscope,
2. Flexible high-definition videochip endoscope,
3. Transoral rigid endoscope attached to a high definition camera,
4. Videochip endoscope with a working channel,
5. Stroboscope,
6. Digital recording device (computer with video capture software and a large RAID hard drive) and
7. Two high definition video screens – one for the patient to watch and one behind the patient for the examiner to watch during the exam.

I haven't felt that a UHD 2K endoscope is worth the cost just yet. Some available types cannot be used with a stroboscope, others can. With HD endoscopes and optimum technique we are getting close to an "optical biopsy" in the office. The resolution of endoscopic equipment is nearing the level where we can identify pathology in the office from the visible light examination alone.

BUDGET VOICE LAB

1. A flexible fiberoptic endoscope with a camera and
2. Any digital recorder.

I would give up a rigid endoscope and a stroboscope before giving up a video recorder in the voice lab. Without a recording, viewing the larynx with only the naked eye loses too much value in the way of documentation and review. In laryngology, much of what happens is so fast that inability to review a recording of movement several times (and slowly) misses valuable information. With this simple lab of endoscope and recorder, the very astute observer could even elucidate the pathologic process on video recording without a stroboscope, though it takes a great deal of effort and intuition.

In the high-end lab, I use the rigid endoscope primarily in the patient where I suspect there is a mucosal lesion otherwise I use the flexible chip endoscope on nearly every exam. In the mid-range lab, I would often use both the flexible and rigid scopes in many patients to fully define and characterize much vocal pathology.

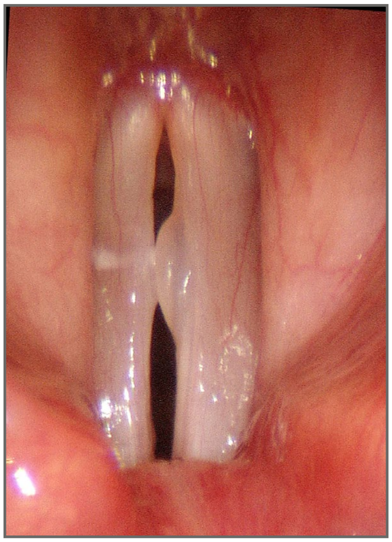
Further reading

Thomas, James P., "Why is there a frog in my throat?" 2012

Thomas, James P., "Clinical Evaluation in a patient with a voice disorder" in Textbook of Laryngology, Ed. Nerurkar, Nupur Kapoor. 2017, jaypeebrothers.com

https://www.voicedoctor.net/HighDef

Hearing & seeing



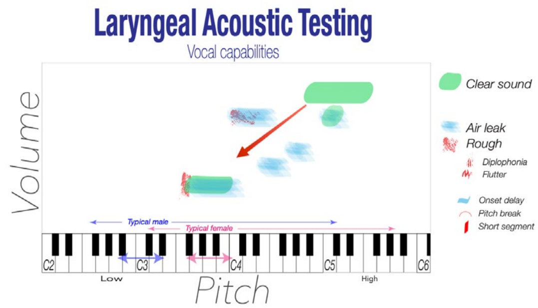
Hearing & Seeing: Vocal polyp, stroboscopy: mid range, closing phase photographed to reveal the large air leak which generates a very husky voice. The surgeon sees the polyp, the laryngologist sees the air leak.

Seeing is only one portion of the laryngeal exam. A good history is also essential. The ability to hear a voice disorder though greatly enhances the listener's acumen for searching, visualizing and identifying a voice disorder.

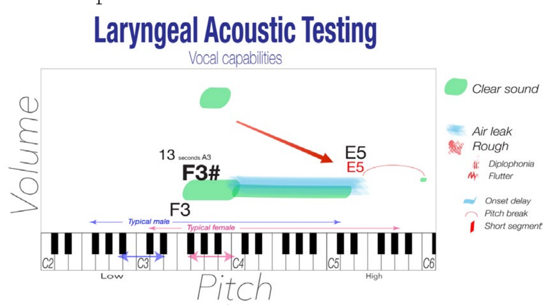
I encourage you to explore Vocal Capabilities assessment as a central part of your exam once you have the appropriate equipment.

In fact, both vocal capabilities assessment and high-definition endoscopy are self-teaching, in that when a new vocal impairment pattern is heard, the examiner who views the vocal cords endoscopically using the same vocal maneuvers that elicit an impaired voice on vocal capabilities testing, will often discover the reason for the vibratory impairment, even if it is new to the examiner.

The examiner who records audio of vocal capabilities pattern matching will also have feedback to discover and learn when the phonatory system is altered during surgery on the vocal cords or in the vicinity of the motor nerve supply of the larynx, whether intentionally or unintentionally.



Vocal capabilities of lateral cricoarytenoid muscle paresis



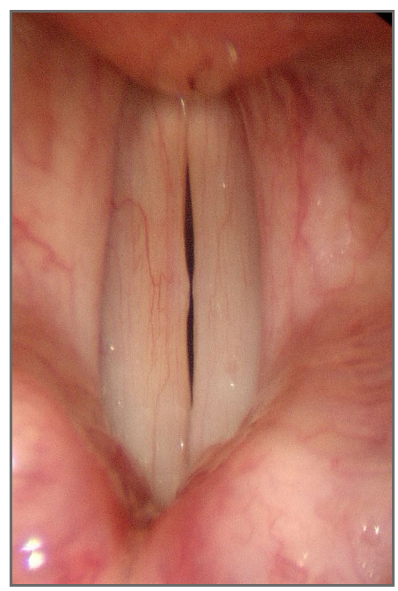
Vocal capabilities of vocal margin swelling.

Overview of vocal capabilities

Vocal impairments can be described in terms of roughness and breathiness, the "R" and "B" of the GRBAS system. Roughness is typically diplophonia, although other quantities of multiple simultaneous pitches can be produced, all creating the perceived quality of roughness. Breathiness is unwanted air leak or air escape between vocal cords that do not completely approximate or are stiff. We can be more precise than simple grading of the amount of roughness and breathiness. A more accurate descriptive method is noting the onset of roughness and/or breathiness as present at high pitch, low pitch or at both. We can be even more precise and note the specific pitch at which diplophonia begins to be produced or breathiness become significantly noticeable, and then whether or not this condition is present from this onset pitch upward or this onset pitch downward. The most accurate record is to have dated audio and video recordings maintained for future review or comparison.

Utilizing the following parameters for vocal capabilities pattern matching; comfortable speaking pitch, maximum phonation time at comfortable speaking pitch, vocal range (lowest pitch, highest pitch), loudness capability, vegetative sound capability and vocal swelling test we can then define or describe the vocal signature of each patient with a complaint of hoarseness. This vocal signature orients the examiner to the where (vocal cord margins), when (pitch and volume) and what to observe for (gap or diplophonia) during recording of laryngoscopy and stroboscopy.

If each physician were to record the vocal capabilities of every patient before and after interventions to the vocal cords, and before and after interventions in the region of the recurrent laryngeal nerve, we would learn more about vocal injuries. We would more precisely learn when we are successful in altering the voice, since harmonic sound production is a successful outcome, not vocal cord appearance. Vocal capabilities pattern matching essentially tests the status of the laryngeal muscles, the status of the closure of the margins of the vocal cords, the flexibility of the vocal cord mucosa, as well as the status of the symmetry of the vocal cords.



Hearing & Seeing: Very small bilateral vocal swellings on stroboscopy at phonatory onset at a very high pitch.