OBJECTIVES

1. To provide a clinically relevant review of laser physics.
2. To introduce the two main lasers used in Laryngology.
3. To review settings and appropriate laser use.
4. To discuss their application to laryngeal pathology with special attention to dysplastic and early malignant laryngeal disease.

DISCLOSURES

1. Although I picture commercially available equipment, I have no financial interests in any of the companies.
2. These are powerful instruments with tremendous clinical potential, but can cause great harm to all involved.
3. I do provide my personal application of these devices, which may differ from your attending physicians.

BOARD RELEVANCE

Regarding lasers:
• Much of the facts regarding lasers are clinically relevant and are tested.

Regarding early glottic cancer:
• Early glottic cancer tends to have a low in-service and written board yield.
• More likely to have questions on path and laser specifics than early glottic cancer management.
• HIGH oral board and EVEN higher life yield.

Good references
• http://www.entdev.uct.ac.za/guides/open-access-atlas-of-otolaryngology-head-neck-operative-surgery
• Chapters 60 and 108 in Cummings.

LASER HISTORY IN ORL

Otologists were among the first to describe utilization of lasers in animal models.
• Stahle and Hogberg were among the first to investigate the potential use of lasers in Otologic surgery. Used a ruby laser to carry out inner ear surgery in pigeons.
• J. Sateloff used the neodymium glass laser to vaporize isolated isolated human footplates.

Microscopic anatomy and laser technology almost developed in tandem.
• Kleinsasser introduced microlaryngoscopy in the early 1960’s.
• Jako in the US is heralded as among the first to describe the potential of lasers.
LASER HISTORY IN LARYNGOLOGY

• In the early 1970s: CO2 laser is introduced to the world of surgery.
• Endoscopic use to treat laryngeal papillomatosis and larynx cancer.
• “Laser Surgery of the Vocal Cords: An Experimental Study With Carbon Dioxide Lasers on Dogs” (Laryngoscope, 1972;82:2204-2216).

–LASER– ANATOMY

Pumping mechanism – Energy source

Partial Reflector

Total Reflector

Laser Medium

Output Beam

–LASER–* LET THERE BE LIGHT

• Well what makes this light special
• As you know visible light is just a part of a larger electromagnetic spectrum.
• Some of the lasers that we utilize clinically do not fall within the visible spectrum.
• Using visible light as an example, what makes laser light different than the light we see emanating from our light bulbs?
• The main properties are: collimation, coherence, and monochromaticity.
• From the lower diagram you can appreciate that the laser light is parallel (collimated), of a single wavelength (monochromatic), and in the same phase with a constant phase difference and periodicity spatial and temporally coherent.
Clinically and commercially lasers have effects based on their local tissue or material interactions.

1. Reflection - Happens constantly within the laser and can happen with tissues as well, but more likely equipment. (No energy loss or tissue effects)

2. Absorption - Which is the intended outcome and deposition of the energy at the tissue. (Energy loss)

3. Scatter - Which is incomplete deposition of the energy and represented in diffuse reflection and diffuse transmission in this image. (Energy Loss and deposition in tissue) Non-specific lasers like Nd:Yag have deeper optical depths due to less absorption.

4. Transmission - (No energy loss or tissue effects)

What happens at the tissue level is dependent on several factors, but among the most relevant to the laser itself is the wavelength.

- Most tissues are optically opaque media, therefore scattering has to be taken into account. Scatter occurs at interfaces such as cell membranes, cell nuclei, etc.
- Absorption by tissue is frequently by chromophores such as melanin, hemoglobin, water.

\[ \text{Energy} = \text{Joules (J)} \]
\[ \text{Power} = \frac{\text{Energy}}{\text{time}} \rightarrow \text{Watts (W)} = \frac{\text{Joules (J)}}{\text{second (s)}} \]

\[ \text{Irradiance or Power Density} = \frac{\text{Power}}{\text{Area (Spot size)}} \rightarrow \text{Watts/cm}^2 \]

\[ \text{Fluence} = \frac{\text{Energy}}{\text{Area}} \rightarrow \text{Joules/cm}^2 \]

- Absorption reduces scattering and reduces the spread of thermal energy.
- Capitalizing on absorption reduces scatter and reduces the spread of thermal energy.

**TABLE 3.5** Summary of laser types

<table>
<thead>
<tr>
<th>Laser type</th>
<th>Band</th>
<th>Genus</th>
<th>Mode of generation</th>
<th>Chromophore</th>
<th>Delivery system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argon</td>
<td>488n</td>
<td>RGU</td>
<td>Visible light</td>
<td>Melanin</td>
<td>Fiber optic</td>
</tr>
<tr>
<td>KTP</td>
<td>532n</td>
<td>RGU</td>
<td>Visible light</td>
<td>Hemoglobin</td>
<td>Fiber optic</td>
</tr>
<tr>
<td>Nd:Yag</td>
<td>1064</td>
<td>RGU</td>
<td>Continuous</td>
<td>Melanin</td>
<td>Fiber optic</td>
</tr>
</tbody>
</table>

**-LASER-** VARIABLES

Energy = Joules (J)

Power = Energy/time → Watts (W) = Joules (J) / second (s)

Spot size : Fiber size → Determined by focal length (f) → distance from surface

Irradiance or Power Density = Power/Area (Spot size) → W/cm²

Fluence = Energy/Area → J/cm²
KTP LASER

On the KTP laser which is a fiber based laser and classified as a photoangiolytic laser

• Power is adjusted as Wattage and Irradiance will be determined by the Wattage and the Fiber size
• Area is based on the size of your fiber
• Time is in the mode settings, most frequently used as pulsed. A pulse Width is the duration of the pulse and a pulse rate is the frequency.
• Typical settings for pulsed cases will be 26-30 Watts, 15-20 ms pulse widths, and 2-3 pulses/sec.

WHY PULSE?

1. Avoid resident iatrogenic damage.
2. Reduce energy dispersion by molecular relaxation.
3. Capitalize on the heat sink effect.

CO2 LASER

• The CO2 laser is a continuous wattage laser that can be set to a pulse mode as well as “Scanning” modes.
• Power is similar set by the surgeon as Wattage, but tissue interaction again is dependent on the Irradiance (Power/area).
• A continuous small spot sized focused laser will have a tremendous power density (Irradiance) and will have considerable vaporization.
• On scanning modes with super pulse you adjust the spot size/shape and the pulse rate dim off.
• While scanning, the laser is “painted” or “printed” in many energy bursts of high wattage that average the wattage set over time.
• Bursts allow tissue cooling and relaxation to reduce thermal damage.
• Typical settings will be around 3 Watts continuous, sometimes less for fine cutting some times more for thicker/denser tissue.
• 5-10 Watts on scan/SP.


1. Chapter 60. Cummings
Laser tissue interactions depend on the wavelength of the laser light, the power and duration of a single pulse, the repetition rate, and the spot diameter. These are all laser settings.

In this graph is the laser tissue interaction depicted as power density of the laser vs the exposure time of the laser. With lower energy deposition and increased duration there is not any photothermal effects but rather photodynamic effects, which produce reactive oxygen species. Coagulation is frequently

For a thermal effect to occur the light energy must be converted to heat. This is also dependent on wavelength and exposure time. With longer exposure times heat builds and produces coagulation zones beyond the penetration depth of the wavelength. Thermal effects may spread beyond the optical penetration depth. The active depth takes this into the account.

This is very dependent by the tissue properties such as heat conduction, capacity, and blood flow. There is the optical penetration depth.

Similarly to time your distance and more so focal length at that distance will effect the efficacy of your laser. As can be seen here an unfocused laser (not 1:1) results in lower power density. A focused laser and again spot size all controlled for the same power can dramatically increase the amount of energy deposited. Spoken in another way lower power and a defocused laser or large area is more likely to coagulate than vaporize as seen in this second graph.

The obvious:
- Fiber based
- Visible spectrum with doubled frequency and halved wavelength of Nd-YAG

Advantages:
- Awake laryngeal procedures
- Contact/Noncontact
- Less bleeding

Disadvantages/Considerations:
- Less precise beam of light
- Higher depth of penetration
- Bulky disease
- Cannot work with bleeding.

KTP LASER

For degrees of freedom of difficult angles a hand piece is beneficial. This could be performed with a laryngeal CO2 hand piece (wave guide as well), but I prefer KTP from experience with it.

CO2 laser is great as well, but for anterior disease, the vectors can become quite difficult.

RRP
TLM FOR SUPRAGLOTTIC MASSES

- This is an older patient who presented with voice change and was noted to have supraglottic cysts.
- Excision certainly can be done with a line-of-site free beam.
- But for tactile feedback and vectors, a fiber-based approach is superior in my opinion.

AWAKE LASER TREATMENT

\[ \text{AWAKE LASER TREATMENT} \]

The Obvious:
- Far infrared needs aiming beam (HeNe)
- Articulated Arm and/or hand piece (wave guide)

Advantages:
- Line of site (free beam)
- Tight quarters
- 3 Instruments
- Highly efficient + high absorption (versatile)

Disadvantages/Considerations:
- Non-specific chromophore
- Superficial absorption
- Access/Degrees of freedom
- Sessile disease
- Less bleeding

CO2 LASER

AIRWAY STENOSIS

No question, the free beam in small laryngoscopes makes laser excision of stenosis with some hemostasis beneficial.

When an individual is a difficult exposure, traditional approaches with sickle knife and rigid dilation may prove difficult.

AIRWAY STENOSIS/PGS

A free beam laser provides the surgeon to have 3 hands.

With manipulation of the surgical field to the laser, one can accomplish this task.

This is a posterior advancement flap for PGS as described by Ed Damrose.

TLM?

No question the CO2 laser with super pulse ability can result in a great oncologic outcome with less collateral damage.
TLM?

You must be versatile as under certain circumstances with difficult exposure. The vectors for the CO2 laser will be limited for the anastomosis. You certainly could use a YAG handpiece. In this circumstance I used a KTP laser.

AIRWAY FIRE

- A laser tube fire is caused by combustion of laser gases inside the tube, which acts like a flamethrower.
- The endotracheal tube does not burn on the outside; a fire occurs when the laser beam pierces the tube wall and ignites the inside of the tube.
- Noncombustible or fire-resistant materials (metal spiral tube or compressed foam made resistant by moisture).
- Reducing oxygen concentration alone is not an effective safety measure, once an ignition occurs a fire happens at room air all the time.
- Immediate stop and shut off laser → extubate → extinguish → secure airway → assess.

TENETS OF TLM

"Ultra-radical treatment of the primary is not justifiable in a disease for which the main causes of death are advanced neck recurrences, distant metastases, second primaries, and serious general diseases. Aggressive combined therapy (chemotherapy, radiotherapy, and radical surgery) have not improved the poor prognosis. Again, if local control can be obtained with conservation laser surgery, the argument in favor of radical ablation clearly declines."

LARYNGEAL ANATOMY

ANATOMIC QUIZ

Are the supraglottis and glottis embryologically separate entities?

- Yes

Branchial Arch Derivatives?

- 3rd - 6th

Name the Laryngeal Cartilages?

- 9. Three single: Epiglottis, Thyroid, Cricoid + 3 paired: Arytenoid, Corniculate, Cuneiform

Blood supply

- Superior and inferior thyroid arteries

What are the anatomic barriers to malignant invasion

- Conus elasticus, submucosal fibrous membrane, submucosal fibrous membrane, submucosal fibrous membrane

What are anatomic paths of spread

- Broyle’s ligament*, paraglottic space, pre-epiglottic space

Conus Elasticus

Submucosal fibrous membrane radiating from anterior commissure to the superior border of the cricoid cartilage and vocal process of the arytenoid cartilage. The free superior margin of the conus elasticus thins to form the vocal ligaments. Acts in supporting the vocal fold during phonation and is a barrier to carcinoma spread.

Quadrangular Membrane

Connective tissue running in the ventricular folds. Attached anteriorly to the lateral border of the thyroepiglottic ligament passing through the ventricular and aryepiglottic folds to continue to the perichondrium of the arytenoid cartilages. Barrier against inflammation and carcinoma spread.

Paraglottic space

Potential space of loose connective and adipose tissue. Bound laterally by the thyrohyoid membrane, posteriorly by the hypopharyngeal mucosa, medially by the thyroepiglottic ligament, AE muscle, TA muscle and conus elasticus, and the cricothyroid muscle inferiorty. It is a potential space for spread of carcinoma.

Pre-epiglottic space

Potential space of loose connective and adipose tissue. Bound laterally by the thyrohyoid membrane, posteriorly by hypopharyngeal mucosa, and Thyroid cartilage anteriorly, and by the Thyrohyoid ligament and epiglottic cartilage posteriorly. It too is a route of spread for carcinoma.
TUMORS ARE LAZY

WHERE DOES IT BEGIN?
Associated factors:
- Smoke exposure (carcinogens)
- HPV
- Environmental exposures (drugs/chemicals)
- Reflux?
- Idiopathic/Genetic?

DNA Damage
- Positive gene regulation in dysplasia
  - IGF-1, EPDR1, MMP-2, S100A4 (Dailey, et al)

Cells in the basement membrane become atypical and undergo altered growth patterns

THE CONCEPT OF PREMALIGNANCY OF THE VOCAL FOLDS
- It started in the 20th century
- Mass production of cigarettes
- Chevalier Jackson - 1922 Congress of American Laryngology Association "Laryngeal Cancer: Is it preceded by a recognizable precancerous condition?"
- James Ewing, pathologist, acknowledged the existence of a precancerous condition
- Lore - 1934: "Decortication of the vocal cords" Laryngoscope

HIGH GRADE DYSPLASIA = CARCINOMA IN SITU

Tumor Angiogenesis
1966: Jako and Kleinsasser
1971: Folkman

WHO Classification Scheme
ANGIOGENESIS

HALOGEN AND NARROW BAND IMAGING

PRESENTING SYMPTOMS

Hoarseness
Vocal Fatigue
Torsion Muscle Dysphonia
Keratosis and/or erythroplakia of the glottic surface
Slaughter, et al.: “Field Cancerization”

DYSPLASIA

WILL IT BECOME CANCER?

LEUKOPLAKIA CAN BE CANCER

Presence of Atypia
+ 7 series meta-analysis: 16.3% with atypia, 3% without atypia developed invasive carcinoma.
+ Other studies showed 23% incidence of malignant degeneration in dysplastic lesions.

Hojjat, et al.: 40% of malignant degeneration in moderate atypia; 4% for mild atypia.
Iseemberg et al. Reviewed 2186 reported biopsies for leukoplakia. No dysplasia (53.9%), mild to moderate dysplasia (34.3%), and severe dysplasia or CIS (12.2%). After 3 years 3.7% of patients with no dysplasia, 10.1% with mild to moderate dysplasia, and 18.1% with severe dysplasia or CIS developed invasive SCC.

MALIGNANT DEGENERATION
### ANATOMIC Staging Laryngeal Cancer

<table>
<thead>
<tr>
<th>Stage</th>
<th>T</th>
<th>N</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>T0</td>
<td>N0</td>
<td>M0</td>
</tr>
<tr>
<td>1</td>
<td>T1</td>
<td>N0</td>
<td>M0</td>
</tr>
<tr>
<td>2</td>
<td>T2</td>
<td>N0</td>
<td>M0</td>
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<tr>
<td>3</td>
<td>T3</td>
<td>N0</td>
<td>M0</td>
</tr>
<tr>
<td></td>
<td>N1</td>
<td></td>
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<tr>
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<td>N2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### MANAGEMENT STRATEGIES DYSPLASTIC DISEASE

1. **Targeted biopsies and follow-up (CA-)**
   - Targeted biopsies are questionable because they only show a part of the lesion.

2. **Targeted biopsies and radiation or surgery (CA +)**
   - Radiation for premalignant disease is an excess and can induce malignant degeneration.

3. **Targeted biopsies and laser therapy (atypia)**

### N(odal) Staging Laryngeal Cancer - CLINICAL

<table>
<thead>
<tr>
<th>Clinical Node</th>
<th>Tumor's Clinical Node</th>
<th>Nodal's Clinical Node</th>
</tr>
</thead>
<tbody>
<tr>
<td>T0</td>
<td>Primary tumor cannot be assessed</td>
<td>Regional nodes cannot be assessed</td>
</tr>
<tr>
<td>T1</td>
<td>Cancer in neck</td>
<td>No regional lymph node metastasis</td>
</tr>
<tr>
<td>T2</td>
<td>Tumor extends to supraclavicular fossa</td>
<td>Metastasis in a single regional lymph node or a single regional lymph node plus one or more satellite nodal groups of any size</td>
</tr>
<tr>
<td>T3</td>
<td>Tumor extends beyond the neck to prevertebral fascia or beyond</td>
<td>Metastasis in a single regional lymph node plus the primary tumor plus one or more satellite nodal groups of any size</td>
</tr>
<tr>
<td>T4</td>
<td>Tumor extends to other regions or distant metastasis</td>
<td>Metastasis in any region or clinically overt EMN</td>
</tr>
</tbody>
</table>

### N(odal) Staging Laryngeal Cancer - Pathological

<table>
<thead>
<tr>
<th>Pathological Node</th>
<th>Tumor's Pathological Node</th>
<th>Nodal's Pathological Node</th>
</tr>
</thead>
<tbody>
<tr>
<td>N0</td>
<td>Regional lymph nodes cannot be assessed</td>
<td>Regional lymph nodes cannot be assessed</td>
</tr>
<tr>
<td>N1</td>
<td>Single regional lymph node or multiple regional lymph nodes, none &lt; 6 cm in greatest dimension and ENL</td>
<td>Single regional lymph node or multiple regional lymph nodes, none &lt; 6 cm in greatest dimension and ENL</td>
</tr>
<tr>
<td>N2</td>
<td>Metastasis in a single regional lymph node, any size, or any size in greatest dimension and ENL</td>
<td>Metastasis in any regional lymph node or single regional lymph node plus one or more satellite nodal groups of any size</td>
</tr>
<tr>
<td>N3</td>
<td>Metastasis in a single regional lymph node, any size, or any size in greatest dimension and ENL</td>
<td>Metastasis in any regional lymph node or single regional lymph node plus one or more satellite nodal groups of any size</td>
</tr>
<tr>
<td>N9</td>
<td>Metastasis in any regional lymph node or single regional lymph node plus one or more satellite nodal groups of any size</td>
<td>Metastasis in any regional lymph node or single regional lymph node plus one or more satellite nodal groups of any size</td>
</tr>
</tbody>
</table>

### M(etastasis)

- **Distant metastasis (M)**
  - M0: No distant metastasis
  - M1: Distant metastasis
  - M1c: Distant metastasis, microscopically confirmed
MANAGEMENT STRATEGIES DYSPLASTIC DISEASE

4. Vocal Fold Decortication/Cordectomy
   - It puts the vocal result at risk

5. Excisional Biopsy (Microflap Resection)
   - Accurate diagnosis and cost-effective treatment
   - ELS I (subepithelial cordectomy)
   - Schweinfurth, 2001 - repeated resections

MICROFLAP RESECTION USING THE SUPERFICIAL LAMINA PROPRIA INFUSION TECHNIQUE (LPS)

- Allows repositioning of the lesion
- Outline the depth of the lesion
- Provides a "buffer" for LPS during dissection

ARTICLES

➢ 585-nm pulsed dye laser treatment of glottal dysplasia.
  Franco RA Jr, Zeitels SM, Farinelli WA, Faquin W, Anderson RR.

➢ Office-based treatment of glottal dysplasia and papillomatosis with the 585-nm pulsed dye laser and local anesthesia.
  Zeitels SM, Franco RA Jr, Dailey SH, Burns JA, Hallman ME, Anderson RR.

➢ Office-based 532-nm pulsed KTP laser treatment of glottal papillomatosis and dysplasia.
  Zeitels SM, Akel LM, Burns JA, Hallman ME, Broadhurst MS, Anderson RR.

COMPARISON OF TREATMENT MODALITIES IN EARLY GLOTTIC CANCER

Endoscopic resection vs. Radiotherapy
  - Osborn, et al. (2011): oncological results and VRQOL are similar
  - Flint (2003): contributed similar results
TREATMENT OUTCOMES

CHANGING TRENDS

American Cancer Society: Among patients with early stage larynx cancer, primary surgery increased (from 20% in 1985 to 33% in 2007), and the use of RT decreased from 64% to 52%. (AY Chen et al, 2011)

LASER

Successful Tumor Resection

Optimize Vocal Outcome

Couple with laryngoscopes that allow better exposure of the anterior commissure!

“SURGERY IS THE ART OF RECOGNITION NOT THE ACT OF DISCOVERY”

- Tumors are not en bloc resected, but debulked and divided in situ.
- Wherever the local tumor extends, the microscope and the laser try to follow.
- Complete removal always requires that the entire mucosal margin of the tumor be exposed.
- The limit becomes the exposure for each step.
- Healing by secondary intention is key.
- Second-look endoscopies become a way to revisit the primary site.
What to TLM?

Most data is in Clinically N0 Disease

There is little argument against T1a disease regarding the superiority of surgery.

- Single treatment
- Cheaper
- Preservation of Radiation therapy for second Primary

T1b and T2 disease the data is muddier.

- There is plenty to support surgery as well as radiation failure for these tumors
- Staged (multiple) surgeries to mitigate poor primary/primary healing
- Neck treatment
- If you can Exposure all of the larynx necessary, you have a very reasonable shot at a good outcome.

SURGICAL EXCISION – DO WHAT THE DISEASE MANDATES

MICROFLAP EXCISION

SO A GUY PRESENTS TO YOU WITH HOARSENESS?

TUMOR MANAGEMENT

Your margins are the most important factor with surgery. The bulk of tumor can first be removed and for outcome is of little importance.
EVALUATE THE LESION

ANTICIPATE YOUR LIMITATIONS

No where you are going to get beaten.
The anterior commissure is notoriously difficult in both surgery and radiation.

PLAN YOUR RESECTION

TREATMENT OF MARGINS

When we talk about laser resection, a more recognized concept is margin photocoagulation. A 2012 Italian study showed that surgical margin photocoagulation increases local disease control in case of superficial margin positivity. In such cases, no additional treatment (surgical revision or radiotherapy) seems to be necessary in these patients. In case of deep positive margins, surgical revision or radiotherapy should be performed.

Thanks!