Laser Excision of Laryngeal Cancers

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Conservation laryngeal surgery refers to:
- Any procedure that maintains physiologic speech and swallow function without the need for a permanent tracheostoma.

Goal in conservation laryngeal surgery
- Preserve maximum laryngeal function without compromising the cure rate.
- Complete removal of all malignant disease which should be achieved while preserving the 4 basic functions of the larynx:
  - deglutition,
  - respiration,
  - phonation, and
  - airway protection.
Background

- Transoral laser microsurgery maintains all options for further treatment.
- During the approach it can be converted to external approach at any time.
- Postoperatively laser surgery can be reapplied.
Background

- **Lymphatic drainage of the larynx I**
  - Sparse anteriorly and at the level of the glottis.
  - Richer in the supraglottic and subglottic regions, as well as the posterior 1/2 of the larynx.

- **Three fibroelastic membranes serve as the major barriers to the spread of cancer from (and to) the glottic region**
  - the conus elasticus inferiorly,
  - the quadrangular membrane laterally, and the thyrohyoid membrane superiorly.
  - *Broyles’ Tendon* is the insertion of the vocalis tendon into the thyroid cartilage in the area of the anterior commissure.
Anatomy: Laryngeal Cartilage

Epiglottis
Hyoepliglottic ligament
Hyoid bone
Thyrohyoid membrane
Thyroid cartilage lamina
Oblique line
Laryngeal prominence
Corniculate cartilage
Arytenoid cartilage
Muscular process
Vocal process
Vocal ligament
Thyroepiglottic ligament
Cricothyroid ligament
Cricoid cartilage
Cricothyroid joint
Trachea

Right lateral view
Medial view, median (sagittal) section
Anatomy: Laryngeal Muscles
Pathophysiology of Laryngeal Cancer

- Limitation of true vocal cord mobility correlates with a worsening prognosis,
- Early glottic cancer infrequently metastasizes, and when it does, it is almost always to the ipsilateral neck.
- Lesions limited to the true vocal cords (e.g., T1 and T2) demonstrate a 5% incidence of cervical metastasis
- This figure jumps to 30-40% for T3 lesions.
Pathophysiology of Laryngeal Cancer

- Supraglottic squamous cell carcinoma is a different disease process from its glottic counterpart.
- Supraglottic carcinoma exhibits a much higher incidence of occult nodal metastasis and frank nodal metastasis at presentation.
- 19% of survivors will develop a second respiratory tract primary within 5 years.
# Staging - Primary Tumor (T)

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TX</td>
<td>Minimum requirements to assess primary tumor cannot be met</td>
</tr>
<tr>
<td>T0</td>
<td>No evidence of primary tumor</td>
</tr>
<tr>
<td>Tis</td>
<td>Carcinoma in situ</td>
</tr>
</tbody>
</table>
# Staging - Supraglottis

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Tumor limited to one subsite of supraglottis with normal vocal cord mobility</td>
</tr>
<tr>
<td>T2</td>
<td>Tumor involves mucosa of more than one adjacent subsite of supraglottis or glottis, or region outside the supraglottis (e.g. mucosa of base of the tongue, vallecula, medial wall of piriform sinus) without fixation</td>
</tr>
<tr>
<td>T3</td>
<td>Tumor limited to larynx with vocal cord fixation and or invades any of the following: postcricoid area, preepiglottic tissue, paraglottic space, and/or minor thyroid cartilage erosion (e.g. inner cortex)</td>
</tr>
<tr>
<td>T4a</td>
<td>Tumor invades through the thyroid cartilage and/or invades tissue beyond the larynx (e.g. trachea, soft tissues of neck including deep extrinsic muscles of the tongue, strap muscles, thyroid, or esophagus)</td>
</tr>
<tr>
<td>T4b</td>
<td>Tumor invades prevertebral space, encases carotid artery, or invades mediastinal structures</td>
</tr>
</tbody>
</table>
## Staging - Glottis

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>T1</strong></td>
<td>Tumor limited to the vocal cord (s) (may involve anterior or posterior commissure) with normal mobility</td>
</tr>
<tr>
<td><strong>T1a</strong></td>
<td>Tumor limited to one vocal cord</td>
</tr>
<tr>
<td><strong>T1b</strong></td>
<td>Tumor involves both vocal cords</td>
</tr>
<tr>
<td><strong>T2</strong></td>
<td>Tumor extends to supraglottis and/or subglottis, and/or with impaired vocal cord mobility</td>
</tr>
<tr>
<td><strong>T3</strong></td>
<td>Tumor limited to the larynx with vocal cord fixation and/or invades paraglottic space, and/or minor thyroid cartilage erosion (e.g. inner cortex)</td>
</tr>
<tr>
<td><strong>T4a</strong></td>
<td>Tumor invades through the thyroid cartilage, and/or invades tissues beyond the larynx (e.g. trachea, soft tissues of the neck including deep extrinsic muscles of the tongue, strap muscles, thyroid, or esophagus)</td>
</tr>
<tr>
<td><strong>T4b</strong></td>
<td>Tumor invades prevertebral space, encases carotid artery, or invades mediastinal structures</td>
</tr>
</tbody>
</table>
## Staging - Nodes

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N0</td>
<td>No cervical lymph nodes positive</td>
</tr>
<tr>
<td>N1</td>
<td>Single ipsilateral lymph node ≤ 3cm</td>
</tr>
<tr>
<td>N2a</td>
<td>Single ipsilateral node &gt; 3cm and ≤6cm</td>
</tr>
<tr>
<td>N2b</td>
<td>Multiple ipsilateral lymph nodes, each ≤ 6cm</td>
</tr>
<tr>
<td>N2c</td>
<td>Bilateral or contralateral lymph nodes, each ≤6cm</td>
</tr>
<tr>
<td>N3</td>
<td>Single or multiple lymph nodes &gt; 6cm</td>
</tr>
</tbody>
</table>
### Staging - Metastasis

<table>
<thead>
<tr>
<th>M0</th>
<th>No distant metastases</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>Distant metastases present</td>
</tr>
</tbody>
</table>
Evaluating for conservation surgery

Principles

- Must be able to confidently predict the extent of tumor
- Cricoarytenoid unit, and not the true vocal cord (TVC), is the basic functional unit of the larynx that makes conservation laryngeal surgery possible.
- Resection of normal tissue in organ preservation surgery is necessary to achieve consistent functional outcomes.
- It is impossible to know the extent of submucosal tumor involvement preoperatively.
Workup

- Preoperatively, all patients should undergo:
  - a thorough head and neck physical examination, including mirror exam or flexible laryngoscopy and videostroboscopy.

- It is vitally important to assess for the presence or absence of a mucosal wave:
  - Implies the absence or presence of involvement of the vocalis muscle.
Workup

Videostroboscopy

- **Advantages**: allows apparent “slow motion” assessment of mucosal vibratory dynamics, video documentation
- **Disadvantages**: time consuming, expensive
Laser—basics

- **Light Amplification by Stimulated Emission of Radiation**
- **Coherent**
  - photons in phase temporally/spatially
- **Collimated**
  - tight beam, parallel paths
- **Monochromatic**
  - one wavelength
Lasers

- All laser devices have an optical resonating chamber (cavity) with two mirrors.
- The space between these mirrors is filled with an active medium, such as Ar, Nd:YAG, or CO2.
- An external energy source (e.g., an electric current) excites the active medium within the optical cavity.
Lasers

- Spontaneous emission is taking place in all directions.
- Light (photons) emitted in the direction of the long axis of the laser is retained within the optical cavity by multiple reflections off of the precisely aligned mirrors.
- One mirror is completely reflective, and the other is partially transmissive.
- Stimulated emission occurs when a photon interacts with an excited atom in the optical cavity.
- This yields pairs of identical photons that are of equal wavelength, frequency, and energy and are in phase with each other.
- This process occurs at an increasing rate with each passage of the photons through the active medium.
Background

- Maiman built the first laser in 1960.
- With synthetic ruby crystals, this laser produced electromagnetic radiation at a wavelength of 0.69 µm in the visible range of the spectrum.
- Although the laser energy produced by Maiman's ruby laser lasted less than 1 ms, it paved the way for explosive development and widespread application of this technology.
Two important advances allowed the laser to be useful in otolaryngology:

1. 1965, the carbon dioxide (CO2) laser was developed
2. 1968, Polanyi developed the articulated arm to deliver the infrared radiation from the CO2 laser to remote targets.

Simpson and Polanyi described the series of experiments and new instrumentation that made this work possible.

The advantages they noted were precise control, minimal bleeding, and the absence of post-operative edema.

Steiner further developed the technique of TLM with a study in Gottenberg, Germany.
Laser--basics

Light can be:

- Reflected (bounces off)
- Scattered (random dispersal)
- Transmitted (passes through unchanged)
- Refracted (change in direction)
- Absorbed (maximal clinical benefit)
Reflection
Scattering
Transmission
Absorption
Laser injury

- The wound created by the carbon dioxide laser, showing the representative zones of injury.
Laser – emission modes

- Continuous
  - Uninterrupted beam
  - Relatively constant power
- Pulsed/Superpulsed (microsec)
  - Higher energy/shorter duration pulses
- Q-switched (nanosec)
  - Extremely high energy/short pulse duration
Lasers

- With most surgical lasers, the physician can control three variables:
  - (1) power (measured in watts);
  - (2) spot size (measured in millimeters); and
  - (3) exposure time (measured in seconds).
Power

- Power is the least useful variable
  - May be kept constant with widely varying effects, depending on the
    - spot size and
    - duration of exposure

- Irradiance
  - more useful measure of the intensity of the beam at the focal spot
    - it considers the surface area of the focal spot.
Spot Size

- Power and spot size are considered together, and a combination is selected to produce the appropriate irradiance.
Exposure Time

The surgeon can vary the amount of energy delivered to the target tissue by varying the exposure time.

- Fluence refers to the amount of time (measured in seconds) that a laser beam irradiates a unit area of tissue at a constant irradiance.
Laser – tissue interaction

- Each tissue differs in absorption characteristics and relaxation time (time necessary to release 50% of energy)

- Penetration is influenced by target chromophore (more absorption = less penetration)
Laser spectrum

![Image of laser spectrum with various wavelengths and absorption bands](image-url)

- Alexandrite 0.755μm
- Ruby 0.694μm
- FLPD 0.585μm
- KTP 0.532μm
- Excimer 0.194μm
- Nd:YAG 1.064μm
- Nd:YAG 1.32μm
- Er:YAG 2.94μm
- CO2 10.6μm

Relative Absorption

- melanin
- hemoglobin
- water
- scatter

Wavelength (microns)

U.V.  I.R.
## Laser spectrum

<table>
<thead>
<tr>
<th>Laser</th>
<th>Wavelength (nm)</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Er:YAG</td>
<td>294</td>
<td>Skin resurfacing</td>
</tr>
<tr>
<td>Argon</td>
<td>488/514</td>
<td>Vascular lesions</td>
</tr>
<tr>
<td>KTP:YAG</td>
<td>532</td>
<td>Vascular lesions</td>
</tr>
<tr>
<td>Copper vapor</td>
<td>578</td>
<td>Vascular lesions</td>
</tr>
<tr>
<td>FLPPD</td>
<td>585</td>
<td>Vascular lesions</td>
</tr>
<tr>
<td>Long pulse</td>
<td>595-600</td>
<td>Leg veins</td>
</tr>
<tr>
<td>Ruby, Q-switched</td>
<td>694</td>
<td>Tattoo removal</td>
</tr>
<tr>
<td>Long pulse</td>
<td>694</td>
<td>Hair removal</td>
</tr>
<tr>
<td>Q-switched Alexandrite</td>
<td>755</td>
<td>Tattoo removal</td>
</tr>
<tr>
<td>Nd:YAG</td>
<td>1064</td>
<td>Deep vascular</td>
</tr>
<tr>
<td>Q-switched YAG</td>
<td>1064</td>
<td>Tattoo removal</td>
</tr>
<tr>
<td>CO2</td>
<td>10600</td>
<td>Cut/coag/resurf</td>
</tr>
</tbody>
</table>
CO2 Laser

- Microspot CO2 Laser
  - CO2 laser energy is absorbed by water allowing Reinke’s space to act as a natural barrier to protect the vocal ligament
  - Provides excellent hemostasis
  - Thermal trauma can be detrimental

- Retrospective study
  - 151 patients treated from April 1982 to June 1996
  - defined when laser resection of early-stage glottic carcinoma is indicated and
  - compared the results obtained by laser surgery with other therapeutic options.

- Glottic tumors treated with
  - type III, type IV, and type Va cordectomies according to the classification of endoscopic cordectomies proposed by the European Laryngological Society in 2000.
Table 1. Endoscopic Cordectomy: Classification by European Laryngological Society.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
<th>Type IV</th>
<th>Type V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subepithelial cordectomy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subligamental cordectomy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transmuscular cordectomy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total or complete Cordectomy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extended cordectomy encompassing the contralateral vocal fold</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extended cordectomy encompassing arytenoid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extended cordectomy encompassing the ventricular fold</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extended cordectomy encompassing the supraglottis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Table 2. Indication by Stage for Laser Resection**

<table>
<thead>
<tr>
<th>T Stage</th>
<th>Type of Excision</th>
<th>Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1a</td>
<td>Type I</td>
<td>Depending on the extent of the involved area and the results of preoperative investigation (e.g., videostroboscopy)</td>
</tr>
<tr>
<td>T1a</td>
<td>Type II</td>
<td>Small superficial tumor involving the middle third of true vocal fold (≥ 0.5–0.7 mm)</td>
</tr>
<tr>
<td>T1a</td>
<td>Type III</td>
<td>Tumor size &gt; 0.7 mm and/or deep infiltrative pattern and/or extent to the anterior commissure</td>
</tr>
<tr>
<td>T1b</td>
<td>Type Ia</td>
<td>Involvement of the anterior commissure or horseshoe lesions</td>
</tr>
<tr>
<td></td>
<td>Bilateral condeexcision</td>
<td>Multifocal cancer</td>
</tr>
</tbody>
</table>
Cordectomies performed using a CO2 laser mounted on a Zeiss surgical microscope.

Performed under general anesthesia.

En-bloc excised tissue was completely detached. The specimen was whole-mounted on a slide and oriented to mark the anterior and the medial margins.

An accompanying legend was drawn adjacent to the lesion.

If the histologic examination revealed a positive margin, on frozen sections, the resection was extended until healthy margins were obtained.
They recommended that

- the transmuscular cordectomy (type III) is indicated in cases of small superficial tumors of the mobile vocal fold (T1a);
- the total cordectomy (type IV) is indicated in cases of T1a cancer with extension to the anterior commissure, and/or when the tumor involves the vocal fold in an infiltrative pattern and/or when the tumor size is more than 0.7 mm;
- the extended cordectomy encompassing the contralateral vocal fold (type Va) is indicated in cases of T1b cancer involving the anterior commissure or in horseshoe lesions.
They found that all patients with carcinoma in situ Tis are free of disease with local control rate at 3 years of 100%; 2 died of other causes without evidence of local recurrence with an overall survival rate at 3 years of 83.2%.

Of the 117 patients with stage T1a cancer:
- 110 are free of disease at 3 years with local control rate of 94%;
- 4 patients died of other causes without evidence of local recurrence with an overall survival rate of 96.5%.

Of the 22 patients with stage T1b cancer:
- 20 are free of disease at 3 years with a local control rate of 91%;
- 1 patient died of other causes without evidence of local recurrence with an overall survival rate at 3 years of 95.4%.

They concluded that endoscopic laser surgery is an efficacious and cost-effective treatment for early stage glottic cancer.
Retrospective study of 160 patients treated from 1988 to 1996
determine if laser endoscopic microsurgery is a reliable and appropriate approach in the treatment of laryngeal cancers.

Glottic tumors were treated with either type I, type II, or type III cordectomy

For supraglottic cancers, excision limited to
  a part of the vestibule,
  a trans-preepiglottic resection, or
  a radical supraglottic resection
Moreau: Laryngoscope, Volume 110(6). June 2000.1000-1006 (B)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Tumors (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tis</td>
<td>26</td>
</tr>
<tr>
<td>T1a</td>
<td>62</td>
</tr>
<tr>
<td>T1b</td>
<td>24</td>
</tr>
<tr>
<td>T2a</td>
<td>4</td>
</tr>
<tr>
<td>T2b</td>
<td>7</td>
</tr>
<tr>
<td>T3</td>
<td>1</td>
</tr>
</tbody>
</table>

TABLE I. Classification of N0 Glottic Tumors (N = 124).
TABLE II.
Classification of Supraglottic Tumors (N = 19).

<table>
<thead>
<tr>
<th>Tumor Stage</th>
<th>N0</th>
<th>N1</th>
<th>N2b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tis</td>
<td>1</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>T1</td>
<td>4</td>
<td>—</td>
<td>1</td>
</tr>
<tr>
<td>T2</td>
<td>8</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>T3</td>
<td>4</td>
<td>1</td>
<td>—</td>
</tr>
</tbody>
</table>
A type I cordectomy, which passes through Reinke’s space, is used for carcinoma in situ (Fig. 1A).

If the lesion is bilateral, a one-sided type I cordectomy is carried out up to the midline at the anterior commissure, at the first operation.

This is completed on the other side 2 months later, with removal of the anterior portion of the previous resection. The two excisions thus overlap slightly at the anterior commissure (Fig. 1B).
Depending on the thickness of the resected glottic musculature, the type II cordectomy is subdivided into three subgroups, types IIa, IIb, and IIc (Fig. 1C).

When the tumor does not involve the inferior part of the cord, an inferior muscular band can be preserved over the whole length (Fig. 1D).

It is mandatory to use palpation to assess the mobility of the tumor at the anterior commissure with respect to the thyroid cartilage (Fig. 1E).
The trans-preepiglottic vestibulectomy for tumors of the laryngeal surface of the epiglottis with no radiological involvement of the preepiglottic space (Fig. 2B).

Radical vestibulectomies if this space was partially occupied with tumor (Fig. 2C).

Limited supraglottic involvement, resection limited to the involved zone (Fig. 2A).
A neck dissection is carried out for supraglottic tumors, except for microinvasive infrahyoid cancers (with <2 mm of infiltration).
- A bilateral dissection is carried out for midline tumors.
  - 5/19 patients with supraglottic tumors had bilateral neck dissections,
  - 9 had unilateral dissections, and
  - 5 were not dissected

Postoperative radiotherapy was carried out in nine patients.
- Two had glottic tumors
- One patient had a subglottic tumor
  - involvement of the inferior edge of the resection.
- Six patients had supraglottic tumors,
  - with histologically demonstrated nodal involvement in five and
  - a multifocal tumor in the sixth.
Survival at 5 years
- 97% for the 98 infiltrative glottic tumors
- 100% for the 18 infiltrative supraglottic and 27 in situ carcinomas.

No local recurrences were noted, in either group
- One patient died of his cancer, with lung metastases after neck recurrence.

Concluded
- series demonstrated oncologic validity of this surgical approach
Report of an international symposium of 25 years with TLM

- Noted that Steiner has promoted selective neck dissection for the treatment of N0–N2 necks since the early 1980s

The Göttingen experience

- Oncological results achieved with routine selective neck dissection are similar to those reported after (modified) radical neck dissection
Noted that the role of radiotherapy is based on intraoperative and histopathologic findings.

Referred to Göttingen concept of function preserving therapy for the advanced neck pN2/3, extracapsular spread, infiltration of lymph vessels or incomplete removal of primary tumor.
Laser Safety – Eye protection

- Patients undergoing CO2 laser surgery should have a double layer of saline-moistened eye pads placed over the eyes.

- All operating room personnel should wear protective eyeglasses with side protectors.
  - Regular eyeglasses or contact lenses protect only the areas covered by the lens, do not provide protection from possible entry of the laser beam from the side.

- Surgeon need not wear protective glasses.
  - The optics of the microscope provide the necessary protection.
Laser Safety – Eye protection

- Patient undergoing carbon dioxide laser microlaryngoscopy with jet ventilation.
  - A, Saline-moistened eye pads are secured with silk tape. The eyes are first taped closed with silk tape to prevent corneal abrasions from the eye pads.
  - B, Saline-moistened towels are placed around the patient's head to cover all skin surfaces.
Laser Safety – Eye protection
Laser Safety

**Skin Protection**

- When microlaryngeal laser surgery is being performed,
  - Beam might partially reflect off the proximal rim of the laryngoscope rather than go down it.
  - Saline-saturated surgical towels completely drape the patient's face. Only the proximal lumen of the laryngoscope is exposed.
- Teeth in the operative field also need to be protected. Saline-saturated Telfa, surgical sponges, or specially constructed metal dental impression trays can be used.
Laser Safety

- Aside from a few minor eye injuries from a laser beam exposure, most serious accidental injuries related to laser use can be traced to the ignition of surgical drapes and airway tubes.
Laser Safety

- Methylene blue-colored saline should be used to inflate the cuff.
- Saline-saturated cottonoids are then placed above the cuff in the subglottic larynx to further protect the cuff.
- If the cuff deflates cottonoids turn blue to warn the surgeon of impending danger.
- The tube should then be removed and replaced with a new one.
Complications

- One of the most devastating complications is endotracheal tube ignition and resulting injury to the laryngotracheal mucosa.
- A nonflammable, universally accepted endotracheal tube for all types of laser surgery of the upper aerodigestive tract does not exist.
- The traditional polyvinyl endotracheal tube should not be used, either wrapped or unwrapped.
  - It offers the least resistance to penetration by the laser beam and tissue destruction associated with combustion of this tube is the most severe.
- Endotracheal tubes for laser surgery that are wavelength specific are now available from several manufacturers and should be used at all times unless jet ventilation techniques are used.
Complications

- Granuloma formation at the anterior commissure was a common occurrence in the study by Moreau.
  - These granulomas tended to last for several months before spontaneous resolution.

- Other complications, which were few, included:
  - Laryngeal hemorrhage,
  - Pneumothorax,
  - Aspiration pneumonia,
  - Subcutaneous air, and p
  - Relaryngeal abscess.
  - Anterior webs can result from anterior commissure resection; these were treated with repeat endoscopic procedures.
Conclusions

- **Microendoscopic laser surgery**
  - provides an excellent alternative to radiotherapy in the treatment of early-stage glottic cancer.

- **Advantages of laser resection include**
  - minimal bleeding, precise control of resection, and the absence of postoperative edema.

- **Cure rates of patients with early-stage glottic carcinoma treated with CO2 laser are equal to those achieved with radiation therapy.**

- **Nevertheless, the role and the indications of this technique in the treatment of early-stage glottic cancer has not been defined accurately and remains controversial.**
References

References