TRANSORAL LASER MICROSURGERY (TLM) OF CANCERS & OTHER PATHOLOGY OF THE UPPER AERODIGESTIVE TRACT

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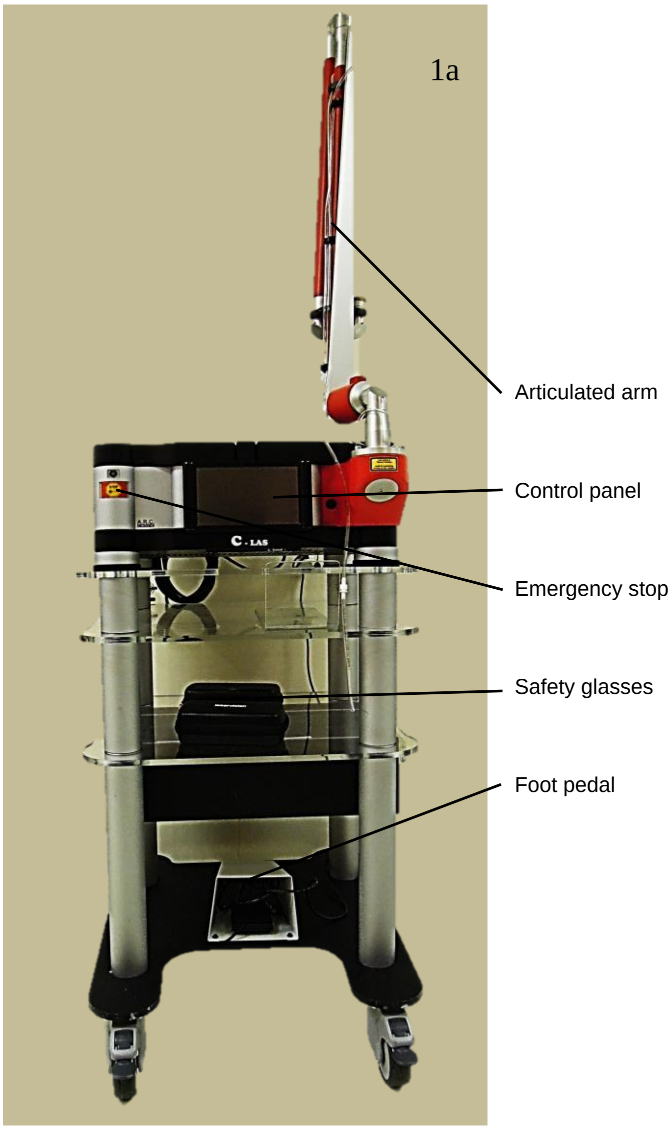
CO_2 laser is used to resect or vaporise benign and malignant lesions of the upper aerodigestive tract. This chapter focuses on transoral CO_2 laser technique using a micromanipulator attached to an operating microscope. The advantages of using CO_2 laser with an operating microscope are microsurgical precision, excellent intraoperative detail, and a dry surgical field; the functional outcomes in terms of swallowing and speech exceed that of traditional external surgical approaches.

Surgeons must familiarise themselves with the laser machine, its settings and delivery systems, and its tissue effects prior to attempting to use it clinically.

CO_2 laser machine *(Figure 1)*

Surgical lasers convert radiation energy into heat at the point of contact of the focused radiation with the tissue. The laser beam is generated in a gas-containing *discharge tube*. The light beam is collimated (coherent), is of a single wavelength (monochromatic), and can be reflected and hence manipulated by mirrors, and focused by passing it through lenses. Because CO_2 laser falls outside the visible light spectrum and is therefore invisible, the laser machine generates a red diode laser *aiming beam* that is focused at the same working distance as the microscope to indicate to the surgeon where the beam is directed. The laser beam is directed along a spring-loaded *articulated arm* which connects to a *beam applicator*. The articulated arm has mirrors at each articulation; therefore, one has to handle the articulated arm with great care so as not to disturb the alignment of the mirrors. The laser is fired when the *foot pedal* is depressed.



Figures 1a, b: CO_2 laser: Wet drapes protect the patient

Beam applicators

The laser beam exits the end of the articulated arm and is delivered to the tissue via a handpiece, laser bronchoscope or a micromanipulator attached to an operating microscope *(Figures 2, 3, 4)*.

Handpiece (Figure 2): This is generally used for excising or vaporising skin lesions or lesions in the oral cavity and oropharynx. Suction tubing is attached to a suction port located on the side of the instrument to extract smoke and laser plume. The tip extension maintains the correct distance from the tissue to keep the laser beam correctly focused.

Figure 2: Laser handpiece

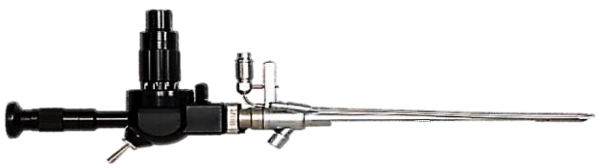


Figure 3: Laser bronchoscope

Figure 4: Micromanipulator attached to operating microscope

Micromanipulator (Figures 4, 5): The micromanipulator has a mirror located in the view path of the surgeon. The surgeon directs the laser beam precisely onto the desired tissue target. The coarse and fine focus settings are used to focus or defocus the laser beam and to set the spot size.

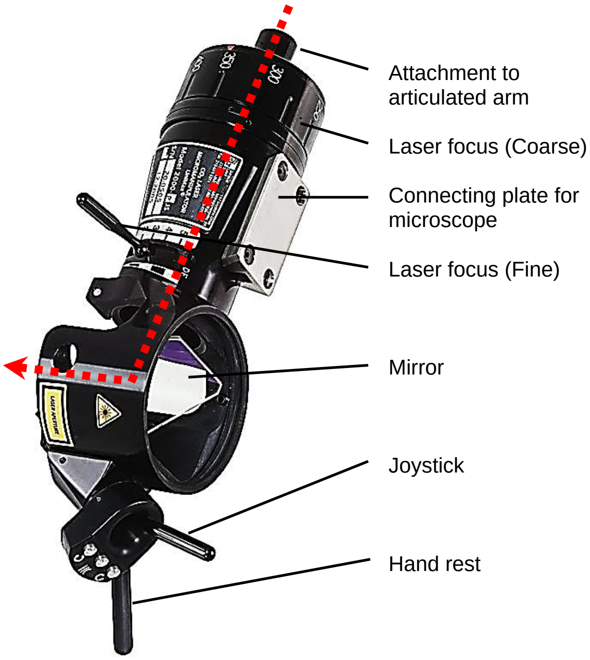


Figure 5: Micromanipulator that attaches to operating microscope (Path of laser beam indicated by red broken line)

CO_2 laser settings

Laser settings are selected according to the type of tissue to be lasered (cartilage / muscle / mucosa), the desired depth of the laser cut, the need for haemostasis, and the need to avoid excessive heating of tissue. The surgeon can optimise the benefits of CO_2 laser by adjusting:

- Laser Power Density (PD)
  - Watts
  - Laser spot size at its optimal focal distance
- Total duty cycle

Figure 6 illustrates a typical control panel of a laser machine. Settings available to the surgeon (left-to-right) include continuous *vs.* pulsed beam, lengths of pulses (milliseconds), time intervals between pulses, brightness of the aiming beam; power

(Watts); and “Laser standby” or “Laser ready” settings. Spot size is set with the focus setting of the micromanipulator.

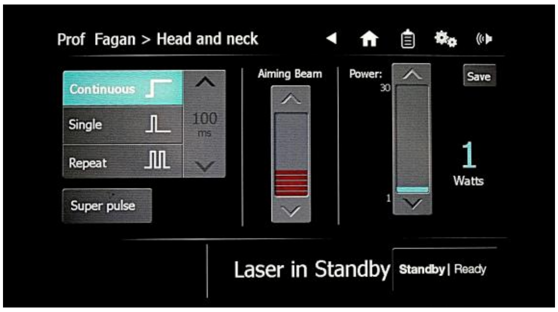


Figure 6: Example of laser control panel

Laser Power Density (PD)

Laser Power Density (PD) is a key surgical parameter. It is affected by the distance from the tissue, the diameter of the beam (laser spot size), and the number of Watts (Joules/sec); all these parameters can be controlled by the surgeon.

Key formulae to remember are:

- *Power Density (PD) = Watts (W)/cm^2*
- *Watts (W) = Joules/sec*

By controlling PD, the surgeon can maximise the benefits of CO_2 laser surgery *(Table 1)*.

Power density	Effect on tissues
0-500	Heating
500-1500	Contracture, denaturing
1500-5000	Ablation, partial vaporisation
5000-20000	Incision, complete vaporisation
20000-100000	Rapid deep incision

Table 1: Relationship between PD and tissue effects [1]

To achieve complete vaporisation, the surgeon should aim for 4500 PD at the tissue interface. *Table 2* illustrates how critical the number of Watts and laser spot size are to PD.

	Spot size			
	0.2mm	0,4mm	0.8mm	1,4mm
5 watts	16000	4000	1000	300
10 watts	32000	8000	2000	600
15 watts	48000	12000	3000	900
20 watts	64000	16000	4000	1200

Table 2: PD according to spot size and watts [1]

Power (Watts)

This is selected by the surgeon every time the laser machine is used and can be preprogrammed for different types of surgery. A laser machine with power settings of up to 40W is recommended for head and neck surgery.

Laser spot size

The smaller the spot size, the less the range of depth of focus at which the laser cuts effectively and the more accurately the laser must be focussed. Spot sizes of 0.5-0.8mm provide a comfortable compromise between depth of focus and cutting ability.

To coagulate bleeding vessels, PD must be adjusted to a level at which tissue is no longer vaporised, but is only heated and blood vessels are coagulated *(Table 1)*; *Tables 2* illustrates how increasing spot size by defocusing the laser beam reduces the PD.

Total duty cycle

The ***total duty cycle*** is the total time that laser energy interacts with target tissues.

This can be regulated in several ways *(Figure 6)*:

- *Continuous wave (CW):* Continuous emittance of laser energy while the foot pedal is depressed
- *Pulsed settings:* Energy emitted as discrete pulses; the lengths, frequencies and time intervals between pulses can be selected by the surgeon

- *Single pulse:* Single energy burst emitted every time the foot pedal is depressed
- *Repeat pulse:* Repeated energy bursts emitted while the foot pedal is depressed
- *Super pulse (SP):* Several thousand energy bursts of very high peak power laser pulses emitted per second while the foot pedal is depressed. The peak power of the bursts may be a few hundred watts, but the wattage shown on the laser machine reflects the average power transferred over time. The bursts are spaced far enough apart for efficient tissue cooling to occur between pulses; this reduces thermal damage to surrounding tissue and minimises charring. *For more coagulation, switch from SP to CW.*

Laser/tissue interaction

CO_2 laser is absorbed almost completely by intracellular water and causes vaporisation of water and cells. Because 99% of heat that is generated is lost in the vapour that is released, peripheral tissue injury and necrosis are limited to <0.01mm; this allows one to preserve laryngeal function, to limit postoperative swelling and pain, and for pathologists to be able to interpret resected tissues for margins.

Safety & Laser fires *(Table 3)*

Laser fire is a very rare but potentially fatal complication of transoral laser microsurgery. Special care must be taken to avoid this catastrophe *(Table 3)*. CO_2 laser is invisible, reflects off smooth surfaces, can cause photothermal injury to patients and staff; and can cause fires by igniting flammable materials such as drapes, plastics, oxygen, and flammable cleaning solutions. Fire may also occur if the beam ignites the endotracheal tube (only if FiO_2 too high), or when "flaming" occurs when lasering carbonised tissue as when cutting through cartilage at high watts.

Safety precautions (Surgical)
• Place laser warning signs outside the operating room • Cover windows and securely close doors while the laser is "on" or in "standby" mode • Personnel and patients must use eye protection specific for CO_2 laser; it should also be available at entrances to the room; standard prescription eyeglasses are sufficient for CO_2 laser; side-guards are recommended • Tape the patient's eyes shut and apply moist pads • Do not use alcohol or flammable cleaning prep solutions or in the operating room • Use flame retardant materials and drapes • Keep an open container filled with water or saline immediately available to douse a laser fire • Placed moistened swabs/sponges adjacent to the path of the laser beam to protect surrounding tissues and structures • Minimize the possibility of a "blow-torch effect" by carefully protecting endotracheal tubes with wet cloth or neuro patties • The locking key to laser machine should be accessible only to people trained in the use of laser; it should not be stored in or on the laser machine, but kept in secure location; some lasers have electronic keypads • Keep the laser turned off or in "standby" mode unless in use • Instruments should have brushed, beaded or sand-blasted surfaces to prevent reflection of the laser beam • The surgeon should give the anaesthetist prior warning to reduce the FiO2 before the laser is activated
Safety precautions (Anaesthetic)
• "Nonflammable" endotracheal tubes may be used (all tubes are flammable) • Fill the cuff of the endotracheal tube with saline coloured with methylene blue (Senior author (WS) prefers air, not saline) • Maintain inspired oxygen (FiO_2) as low as clinically feasible (<30%$Fi0_2$) • Wait a few minutes for the oxygen concentration in the airways to drop before approving activation of the laser • Avoid nitrous oxide if possible
Laser airway fire
• Turn off laser at emergency switch • Turn off all anaesthetic gases • Remove swabs and flammable materials from the airway • Immediately remove the endotracheal tube if intubated • Pour saline down the airway
Fire extinguished
• Re-establish ventilation • Use air/oxygen at lowest FiO_2 that maintains oxygenation • Avoid 100% O_2 if possible • Examine endotracheal tube to see if fragments left in airway • Consider bronchoscopy

Table 3: Laser safety precautions and management of laser fires

Because CO_2 laser is absorbed and "neutralised" by water, wet swabs and patties are used and the cuff of the endotracheal tube may be filled with saline. To reduce the risk of airway fire, it is critical that the anaesthetist keeps the FiO_2 at a minimum (+/- 30%) to avoid a blow-torch effect if the oxygen in the airways is ignited. It is advisable that an open bowl of water/ saline be kept at hand to douse a laser fire.

Anaesthesia for CO_2 laser surgery

The principal anaesthetic challenges are to use endotracheal tubes that permit the surgeon to work in the confined space of the larynx and pharynx, and to eliminate the risk of laser fire *(Table 3)*.

Gases: Avoid nitrous oxide if possible and maintain inspired oxygen FiO_2 as low as is clinically feasible; this requires continuous monitoring of the patient's oxygenation by pulse oximetry. The surgeon must notify the anaesthetist before activating the laser and give the anaesthetist enough time to reduce the delivered oxygen concentration to a minimum, to stop using nitrous oxide, and then to wait a few minutes for the oxygen concentration in the airways to drop to a safe concentration.

Airway: The airway may be maintained in several ways:

- Endotracheal intubation (nasal or oral)
- Intermittent jet ventilation; lasering is done during apnoeic intervals
- Intermittent extubation with lasering done during apnoeic intervals (2nd author's preference over jet ventilation)
- Open airway
  - Spontaneous breathing of anaesthetic gases administered through the suction port of the laryngoscope
  - Intravenous anaesthesia
- Tracheostomy (rarely)

It is important that the surgeon discusses with the anaesthetist the optimal method of maintaining an airway for a specific patient *e.g.* nasotracheal intubation may be best for base of tongue cancer but is problematic for an endolaryngeal tumour as it fixes the position of the endotracheal tube.

Endotracheal tubes: All tubes are flammable; no tube is therefore "safe". The problem is not the type of tube but perforating the tube when the O_2 concentration in the tube is too high. The authors use regular PVC tubes but take special care to protect them with a strip of wet cloth cut from *e.g.* surgical drapes *(Figure 7)*, or with neuro patties.

Figure 7: Tube protected by strip of wet cloth

The drawbacks of "laser tubes" are that they have thicker walls and are expensive. PVC tubes with 5mm inner diameter are more flexible, less expensive and pose no increased risk for fire if the FiO_2 is < 30%. The cuff of the tube may be filled with saline tinted with methylene blue to act as a marker for cuff puncture, and to flood the airway with saline to prevent a fire when the cuff is punctured by the laser. The 2nd author (W.S.) however prefers to fill the cuff with air because it is easier to rapidly extubate a patient in case of emergency, and to avoid fluid running into the bronchi when a fluid-filled cuff is perforated.

Surgical Instrumentation

To prevent reflection of the laser beam, instruments with beaded or mat surfaces are used *(Figure 8)*. An integrated suction channel to remove smoke is essential. Adequate tumour exposure is critical for TLM; ***It is therefore crucial that a variety of laryngoscopes and pharyngoscopes is available*** *(Figure 8).*

Figure 8: Laryngopharyngoscope (a), oropharyngoscope (b), laryngoscopes (c, d), light carrier (e), laryngoscope holder (f), graspers (g), insulated suckers (h), microforceps (i), coagulation forceps (j), diathermy lead (k), and ligaclip applicators to left and right (l) (Karl Storz)

- ***Distending laryngopharyngoscope:*** To access lesions in the hypopharynx and supraglottic larynx *(Figures 8a, 9)*
- ***Distending oropharyngoscope****:* To access lesions in the tongue base, vallecula and lingual epiglottis; note the side-flaps that keep the endotracheal tube and soft tissues out of the surgical field *(Figures 8b, 10)*

Figure 9: Distending laryngopharyngoscope

Figure 10: Distending oropharyngoscope

- ***Large laryngoscope:*** To access endolaryngeal, upper tracheal and hypopharyngeal lesions *(Figures 8c, 11)*
- ***Small laryngoscope:*** Laryngoscope is smaller and longer; used for difficult exposures such as anterior commissure, subglottis and upper trachea *(Figures 8d, 11)*
- ***Light carrier*** *(Figure 8e)*
- ***Laryngoscope holder:*** *(Figure 8f)*
- ***Grasping forceps:*** Different sizes *(Figure 8g)*

Figure 11: Larger & small laryngoscopes

- ***Suction tubes:*** insulated for monopolar diathermy *(Figure 8h)*
- ***Microforceps*** (for small vocal fold lesions): *(Figure 8i)*
- ***Coagulation forceps*** *(Figure 8j)*
- ***Diathermy cable:*** *(Figure 8k)*
- ***Liga clip applicators (left & right):*** *(Figure 8l)*
- ***Weerda diverticuloscope:*** For Zenker's diverticulum and for carcinoma of the hypopharynx extending to the upper oesophagus *(Figure 12)*

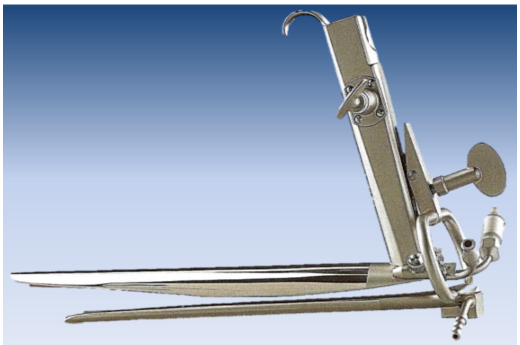


Figure 12: Weerda diverticuloscope

- ***Adjustable supporting plate for laryngoscope holder:*** This avoids placing pressure on the patient's chest; the support can be moved away from the midline to angulate the laryngoscope if necessary *(Figure 13)*

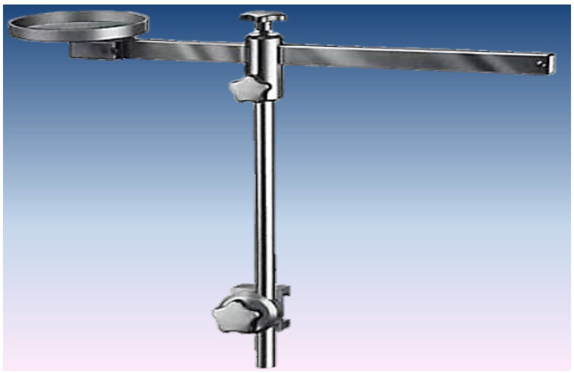


Figure 13: Adjustable supporting plate for laryngoscope holder

Operating room setup *(Figure 14)*

Figure 14: Typical operating room setup

A typical setup has the ***anaesthetic machine placed at the patient's feet***; this requires extensions for anaesthetic tubing and intravenous lines. A camera is attached to the microscope so that the assistant and nurses can follow the procedure on a monitor. ***Two suction systems*** are required, one attached to the laryngoscope to extract smoke from the surgical field and the other attached to the hand-held suction tube. ***Monopolar diathermy*** should be available for laser procedures other than mid-cord T_1 glottic carcinomas.

Preparation of operative site

- Wound scrubs and paints should be aqueous or non-flammable
- Ensure that surgical prep solution does not puddle on or around the patient
- Use draping and gown material that is flame retardant or non-flammable, or wet it with water
- Surround the scope with moistened towels, sponges or cotton to reduce the possibility of fire or burns to the patient's face

Surgical exposure

Surgical exposure is a critical element of TLM. It may sometimes prove impossible to proceed with TLM due to inadequate access

- Place patient in supine position with neck extended
- Check that the head is resting on the bed and not suspended in mid-air
- Check for loose or crowned teeth
- Insert a gum guard
- Do panendoscopy to exclude synchronous malignancies
- Insert laryngoscope / laryngopharyngoscope / oropharyngoscope and expose the tumour
- Several different scopes may have to be used to best visualise the tumour during the course of an operation
- Suspend scope with the laryngoscope holder
- It may be necessary for the assistant to press on the larynx, or to place tapes attached to the theatre table across the neck to displace the larynx posteriorly
- Rarely an external approach is required for access. This may be achieved by passing the laryngoscope through a suprahyoid approach into the vallecula *(Figure 15);* or by doing a partial laryngofissure, cutting only through the upper half of the thyroid cartilage so as not to disrupt the anterior commissure *(Figure 16)*

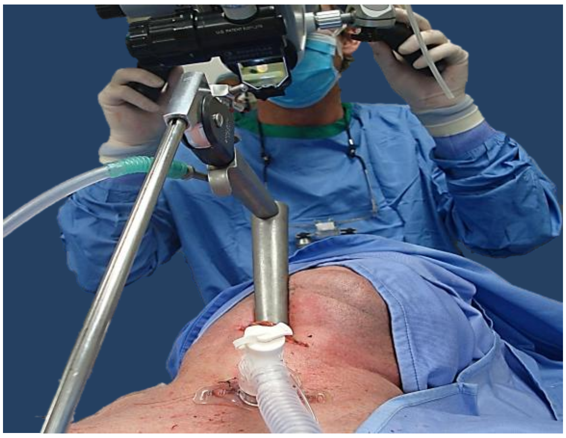


Figure 15: Suprahyoid approach to the vallecula

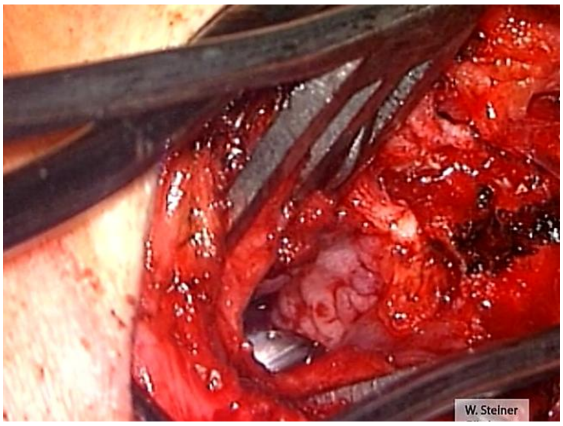


Figure 16: View of glottic cancer via a partial laryngofissure

Principles of CO_2 laser surgery

CO_2 laser may be used to incise, excise or vaporise (ablate) tissue. Novices should start by operating on simpler cases *e.g.* smaller tumours of the aryepiglottic fold, supraglottis, or medial wall of piriform fossa. Important principles of CO_2 laser surgery include:

1. ***Correct laser settings:*** Selecting spot size, focus, power, and superpulse/ pulsed/continuous mode, are important in order to achieve the desired effects, and may have to be altered during the course of an operation for different tissues, or

to achieve coagulation, cutting or vaporisation effects *etc*

2. ***Tension:*** Constant traction must be applied to the tissue to expose the dissection plane, maintain good exposure and facilitate dissection
3. ***Hand speed:*** The surgeon should maintain a relatively slow, smooth hand speed
4. ***Haemostasis:***
   - Laser does not cut through blood; so keep the field dry with suction / suction cautery / coagulation forceps / liga clips
   - Use Liga clips, not suction diathermy, for large vessels to avoid postoperative bleeding
5. ***Charring:*** Charring is reduced by generating less heat by using the superpulse setting. Wipe carbon off the surgical field with a wet cotton ball to maximise the vaporisation effect on target tissue
6. ***Minimise peripheral tissue injury:*** (Super)pulse as opposed to CW setting avoids excessive heating of tissue
7. ***Avoid desiccation of tissues:*** Use normal saline or water to wet tissues to be lasered as CO_2 laser interaction is improved if tissue is well hydrated
8. ***Test the alignment of the aiming beam with that of the laser beam:*** This is important, especially when using CO_2 laser in otology where the margin for error is much more critical; direct the laser at a wet, wooden tongue depressor to check the alignment
9. ***Past-pointing:*** Avoid the possibility of past-pointing of the laser beam as this may burn tissue or cause laser fires. Be aware of reflection of the laser beam off instruments and scopes, and ensure that the backstop *e.g.* neuro patty is correctly positioned to protect the endotracheal tube
10. ***Resecting structures for improved access:*** Resecting suprahyoid epiglottis improves access to the pre-epiglottic space and to tumours on the laryngeal surface of the epiglottis. Although resecting the false vocal cord improves access to the laryngeal ventricle both for resection and follow-up, the benefit of improved access must be weighed against possible functional deficits as the preserved false vocal cord can be used to produce a good voice after glottectomy. A small laryngoscope introduced from laterally will in most cases adequately expose the ventricle; only with tumours spreading up to cartilage (T3) may it be necessary to sacrifice the false vocal cord for access.
11. ***Debulking:*** This is a key TLM technique and allows the surgeon to create space within which to move tissues around and to apply traction to tissue, or to resect a bulky tumour through an endoscope *(Figure 17)*. The debulked tissue is discarded, and only the deeper tissues along the tumour margins are sent for histology to determine the adequacy of the resection

Figure 17: Example of tumour that must be debulked before oncologic resection can commence

12. ***Hydrodissection:*** Water can be used as a barrier to penetration of the laser beam. Dissecting in the plane of Reinke's space or around nerves and vessels can be facilitated by infiltrating saline solution into Reinke's space or into tissue planes around nerves and vessels. Haemostasis can be promoted by injectting a solution containing epinephrine

13. ***Interface between tumour and normal tissue*** *(Figure 18)****:*** The surgeon distinguishes tumour from normal tissue when transecting tumour by checking the pliability of the tissues (tumour is rigid), and by the colours of the tissues (tumour chars and is brown / black when transected with laser)

Figure 18: Note clear demarcation between dark brown transected tumour and pale-coloured normal tissue of paraglottic space

14. ***Bread slicing:*** *(Figure 19)* In order to ensure an adequate oncological deep margin, but to minimise impairment of voice quality by not resecting too much tissue, the surgeon needs to precisely determine the tumour depth and to resect along the deep aspect of the tumour under high magnification. This is achieved by serially sectioning (bread slicing) the tumour. This is applicable to all tumours other than ***very superficial*** (T_{is} or T_1) tumours which are simply peeled off the vocal ligament staying in Reinke's space
15. ***Orientating specimens:*** Take special care not to lose the orientation of specimens when removing them from the patient. Specimens are pinned to small cut-outs of cork floor tiles that are placed in formaldehyde so that the pathologist can orientate the specimen *(Figure 20).*

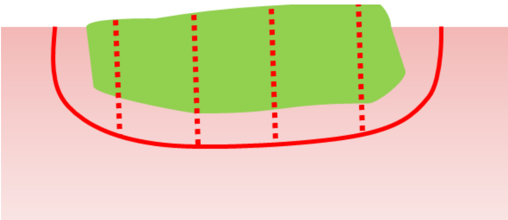


Figure 19: Bread slicing the tumour to evaluate tumour depth and guide depth of resection

Figure 20: Specimens are pinned to cut-outs of cork floor tiles so that pathologist can orientate the specimen

16. ***Tumour topography:*** Include a detailed drawing on the pathology form and in the patient's notes of the precise location of all the resected specimens

What is an adequate resection margin?

This is a controversial topic, and one that may cause surgeons a great deal of anxiety as to whether the patient should be returned to the operating room for an additional resection, whether simply to advise close surveillance, or whether to recommend adjuvant irradiation. Factors that play a role in reaching such a decision include tumour location, size, function (voice and swallowing), patient fitness, extent of the initial resection *e.g.* onto cartilage or carotid, not knowing precisely where a positive or close margin is located, and the reliability of regular follow-up. Frozen section may be useful with larger resections *e.g.* base of tongue and hypopharynx; pathologists are reticent to do frozen sections on small resections *e.g.* T_1 glottic cancers, as it makes it difficult to comment definitively on adequacy of margins. The surgeon's impression of the adequacy of a resection as seen through the microscope is also important; he/she may elect to adopt a watchful waiting approach even when tumour is reported to be "present at the margin", with the knowledge that cells are denatured and killed adjacent to the incision during laser excision; such a watchful waiting approach applies especially to small mid-vocal fold carcinomas that can be carefully monitored and reoperated on timeously without adversely affecting prognosis.

Glottic Carcinoma

The challenge for the laser surgeon is to strike the correct compromise between an oncologically adequate resection and preservation of voice quality. The new laser surgeon should initially select smaller tumours and progress to larger tumours only once he/she has gained a good understanding of the endoscopic "inside-out" surgical anatomy of the larynx and has become proficient with laser surgery technique. We do not advise voice rest after surgery except for superficial defects of the membranous cord.

Classification of laser cordectomy

The *European Laryngological Society* proposed a useful classification of endoscopic cordectomy in 2000 [2], updated in 2022 *(Table 3, Figure 21).*

Cordectomy	Type	Resected tissue
Subepithelial	I	Epithelium
Subligamental	II	Epithelium, Reinke's space, vocal ligament
Transmuscular	III	Through vocalis muscle
Complete	IV	
Extended	Va	Contralateral vocal fold, anterior commissure
	Vb	Arytenoid
	Vc	Ventricular folds
	Vd	Subglottis

Table 3: European Laryngological Society classification of endoscopic cordectomy (2022)

I. Subepithelial
II. Subligamental
III. Transmuscular
IV. Complete
V. Extended

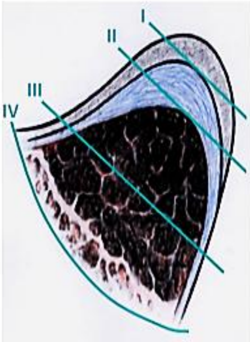


Figure 21: European Laryngological Society classification of endoscopic cordectomy (2022)

One can anticipate an excellent speaking voice following Type I or subepithelial resection of T_{1s} and T_1 cancers of the membranous vocal fold *(Figures 22, 23).*

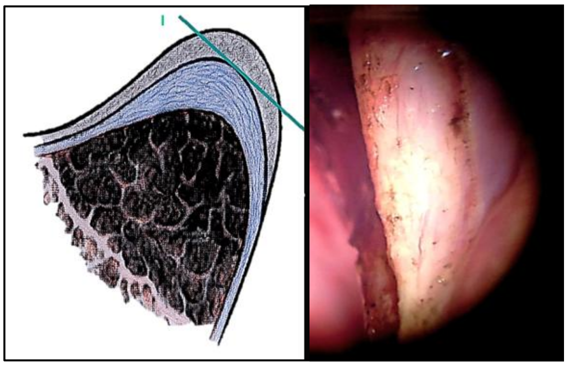


Figure 22: Type I cordectomy; note intact vocal ligament

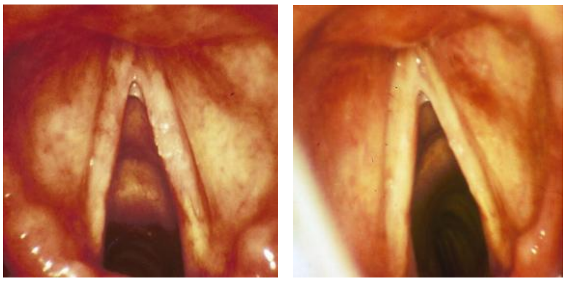


Figure 23: Type I cordectomy: Pre- and postoperatively

Figures 24 & 25 illustrate T1 glottic cancers that required Type II cordectomy and subsequent "new cord" formation due to a scar band; such patients can be expected to have a good, though not quite normal quality voice.

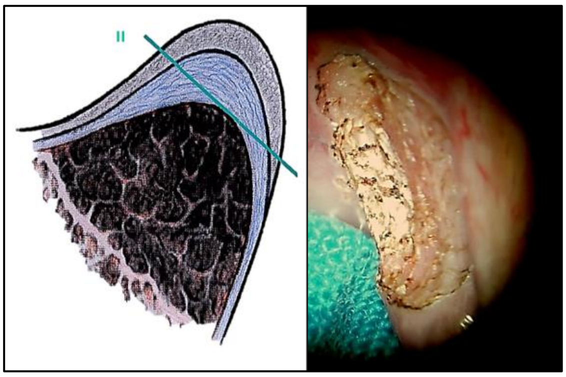


Figure 24: Type II cordectomy

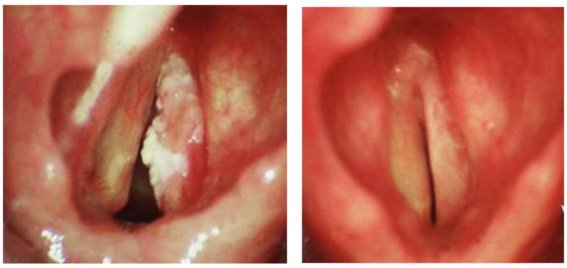


Figure 25: T1 glottic carcinoma required Type II cordectomy; final result

Figure 26 illustrates transmuscular or Type III cordectomy for T_2 glottic carcinoma. This defect is subsequently filled by a scar band leading to a very adequate speaking voice.

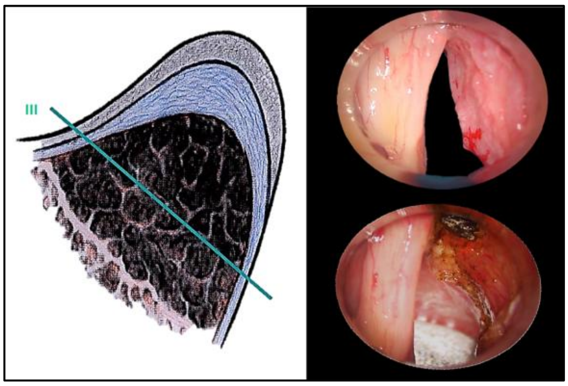


Figure 26: Type III cordectomy

With Type IV cordectomy the resection extends onto thyroid cartilage with loss of volume of the hemilarynx and less predicttable voice outcome *(Figure 27)*.

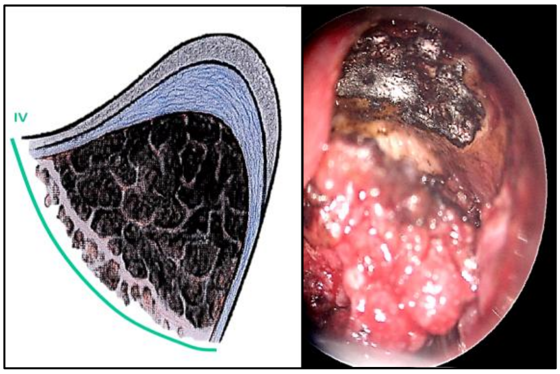


Figure 27: Type IV cordectomy

This applies to patients who undergo complete resection of the paraglottic space for T3 glottic carcinoma. Such patients may have to phonate using the false vocal cords and may produce a good voice; hence the value of preserving the false vocal cords if possible.

Superficial lesions of membranous cord

The objective is to do a Type 1 resection, and to restore a normal speaking voice. Resection margins of <1mm are acceptable, as with close follow-up, recurrences can be resected without affecting oncologic outcome. Set the laser at its smallest spot size, low power (1.5-3W) and CW superpulse mode; this allows a very precise dissection with minimum lateral thermal injury to the tissues. Surgery is done under high magnification. The initial incision is made only through epithelium *(Figure 28)*.

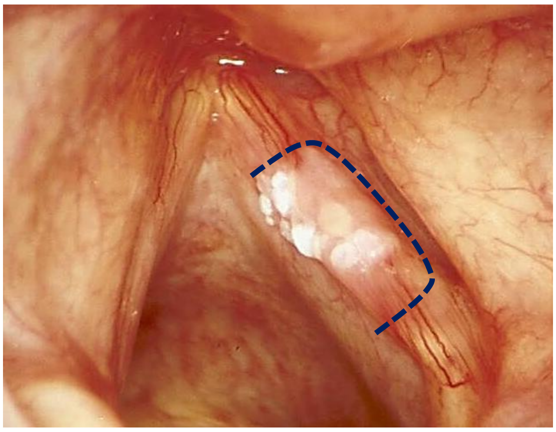


Figure 28: Initial incision for Type 1 cordectomy

The cut edge of the epithelium is picked up with microforceps and the tumour is dissected off the vocal ligament, taking care to remove and pin the tumour to the cork without losing spatial orientation *(Figure 20)*.

Deeper lesions of membranous cord

With deeper tumours requiring Types II-IV resections the objective is to do an adequate resection (>1mm margin), and to maintain an adequate speaking voice *(Figure 29)*.

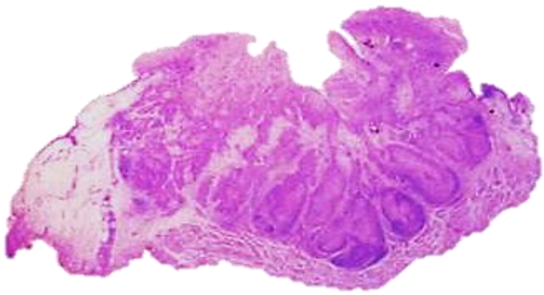


Figure 29: Example of margins required

Set the laser at its smallest spot size, power of 3-5 W and superpulse mode; this allows a very precise dissection with minor lateral thermal injury. Surgery is done under high magnification. It is ***imperative to bread-slice the tumour*** in order to determine the depth of the tumour and the deep resection plane, and to remove it in sections *(Figures 18, 19, 30, 31)*.

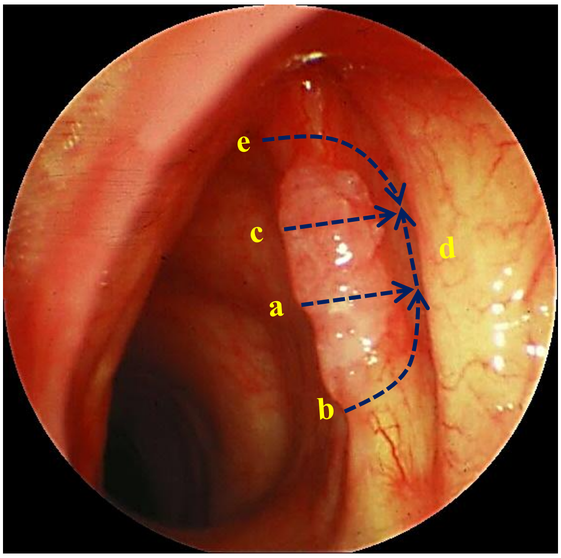


Figure 30: Example of sequence of incisions for a partial cordectomy

It is generally easiest to 1st remove the posterior segment, especially if access to the anterior commissure if poor *(Figure 32)*.

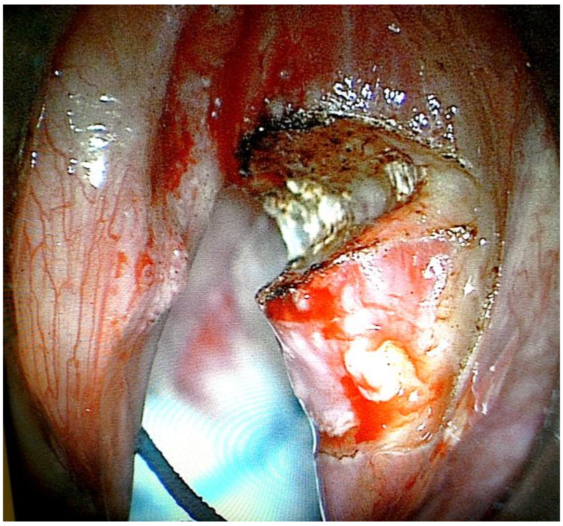


Figure 31: Tumour has been transected to determine depth of invasion

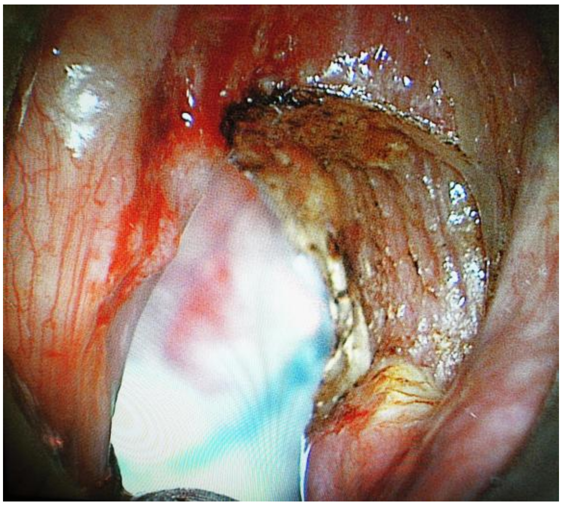


Figure 32: Type 3 resection of posterior half of tumour

Bleeding may be encountered especially when dissecting adjacent to, or below, the anterior commissure and lateral to the vocal process of the arytenoid. Small vessels may be coagulated by defocusing the laser beam. More brisk bleeding is controlled using monopolar or bipolar coagulation forceps. Avoid using suction diathermy on the vocal fold. Take care to remove and pin the tumour segments to the cork without losing spatial orientation, and to make a detailed drawing of the orientation of the segments in the patient records and on the pathology request form. It is also useful to paint the basal area (deep margin) blue, and to ask the pathologist to determine whether the painted area is free of tumour.

Anterior commissure

The authors do not consider anterior commissure cancer to be a contraindication to laser resection. However, some surgeons consider involvement of the anterior commissure to be a contraindication for laser resection and advocate vertical, supracricoid or even total laryngectomy.

The following needs to be considered when managing cancers of the anterior commissure with laser resection:

- *Proximity to thyroid cartilage:* This makes it difficult to obtain wide margins and raises the possibility of cartilage invasion *(Figure 33)*. The authors do not routinely obtain imaging but follow the tumour during the resection and may resect cartilage with CO_2 laser if necessary. Once the vocal ligaments have been severed from the cartilage with the laser, the surgeon can strip the tissues in a plane deep to perichondrium up to the inferior margin of the cartilage, and then defocuses the laser and "sterilises" the cartilage of any residual cancer cells *(Figure 34)*.

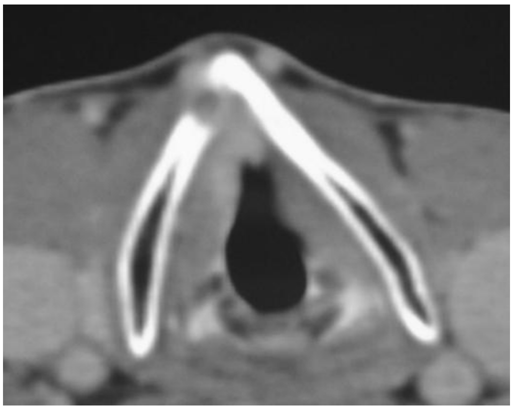


Figure 33: Extension through thyroid cartilage

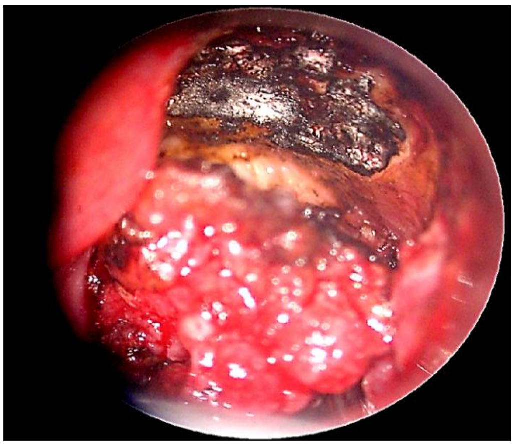


Figure 34: Tissues stripped in subperichondrial plane and cartilage "sterilised" of cancer cells

- *Subglottic tumour extension below thyroid cartilage and through cricothyroid membrane (Figures 35, 36):*

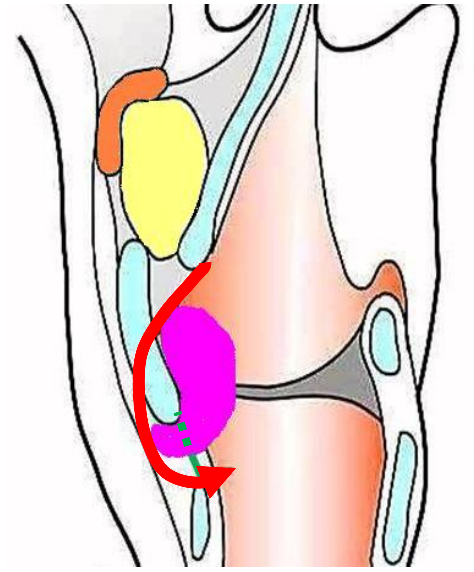


Figure 35: Subglottic extension through cricothyroid membrane; endoscopic resection (red line)

The surgeon follows the tumour endoscopically. Thyroid cartilage may have to be resected with laser to improve exposure and for resection of extra-laryngeal tumour; resection may extend to just deep to the skin of the neck if needed *(Figure 36)*

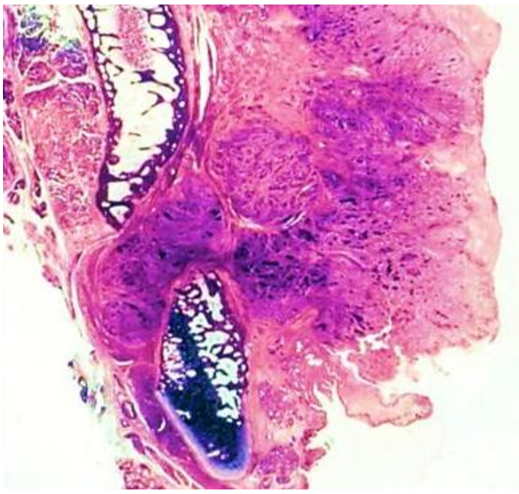


Figure 36: Tumour escaping between thyroid and cricoid cartilages

Webbing of anterior commissure causing poor voice (Figure 37): Webbing occurs when the anterior ends of both vocal cords are denuded or resected *(Figure 38)*. This can be avoided by doing a two-stage resection, initially resecting only up to the midline, and completing the resection of the 2nd vocal cord tumour about a month later *(Figure 39)*.

It may be difficult to correct a web. Simply dividing the web with laser invariably leads to a new web. An option is to apply Mitomycin C after excising the scar tissue with laser, or to divide the web with laser and to place a silastic keel for 3 weeks to allow the cut edges to epithelialize [3] *(Figures 40, 41, 42)*. The keel is fixed into position with sutures that are passed through needles passed from externally above and below the anterior commissure [3].

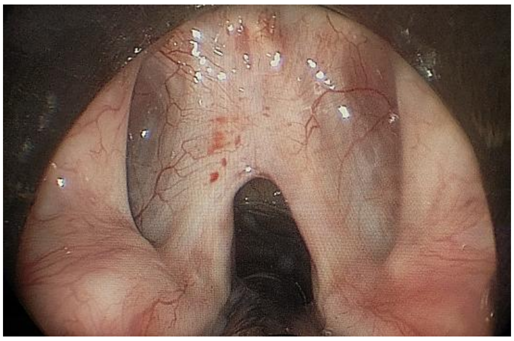


Figure 37: Webbing of commissure

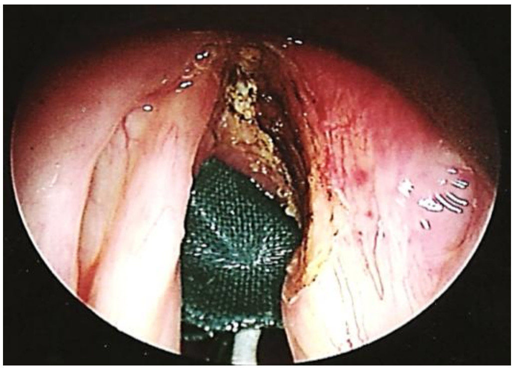


Figure 38: Denuding both vocal cords makes webbing likely

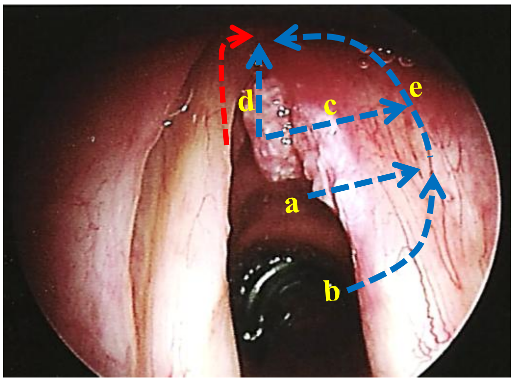
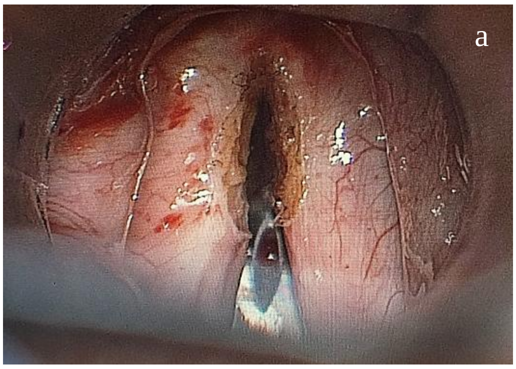
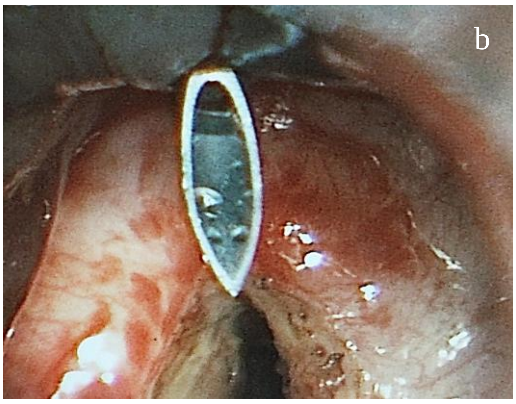


Figure 39: Typical sequence of initial (blue) resection and delayed 2nd stage (red) resection of anterior commissure tumour to avoid webbing

Keels can be cheaply made in the operating room either by folding cellotape back onto itself over a nylon suture *(Figure 40)*, or by weaving a suture through the edge of a silastic sheet *(Figure 41)*.





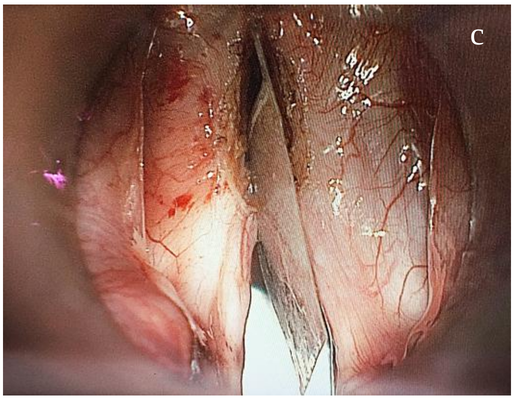


Figure 40: Web has been divided and needle passed through thyroid cartilage below anterior commissure (a); Second needle above commissure (b); Keel made from cellotape folded onto itself over a suture, tied into place (c)

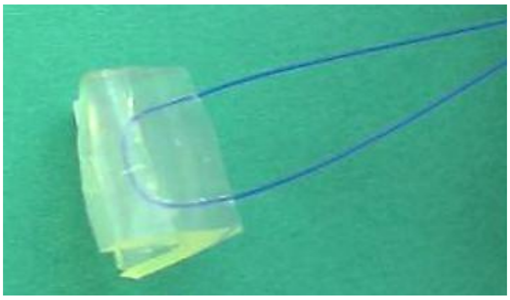


Figure 41a: Simple keel made by weaving a "double-armed" (needle attached to each end) 4/0 nylon/ prolene suture through a thin silastic sheet

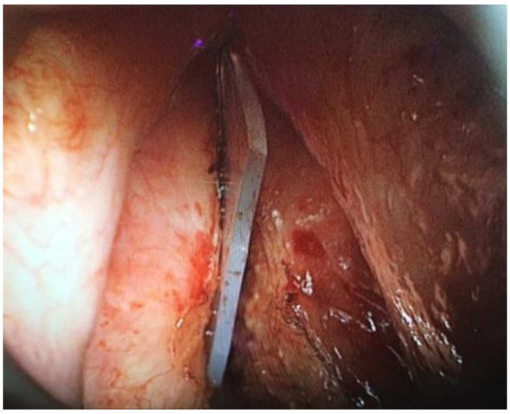


Figure 41b: Silastic keel held in place by passing the two needles through the cricothyroid membrane (below) and the thyroid cartilage (above)

Figure 42: Sutures tied over a silastic sheet to fix the keel in position

An alternative which has been successful in the 1st author's hands is to divide the anterior commissure and to temporarily lateralise the vocal cord(s). Two injection needles are passed from the outside of the neck through thyroid cartilage above and below the vocal cord. A suture is fed in and out of the larynx through the needles, and the cord is lateralised by tying the sutures together outside the neck for 3 weeks *(Figure 43, 44)*.

Figure 43: Suture passed around vocal cord to lateralise the cord

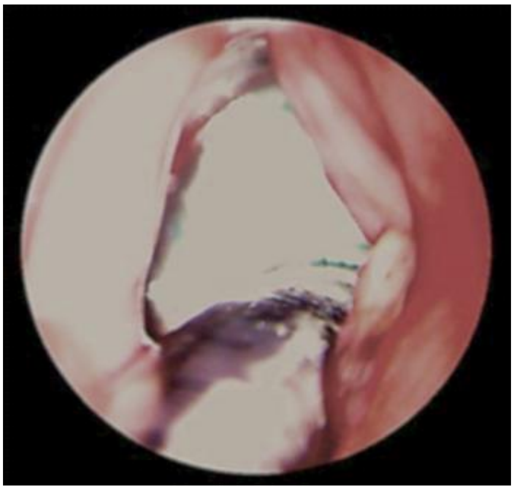


Figure 44: Lateralised vocal cord

Supraglottic carcinoma

Supraglottic carcinoma is resected using a distending laryngopharyngoscope *(Figure 9)*, graspers, and Liga clip applicators to clip the superior laryngeal vessels that traverse the pharyngoepiglottic folds. Because the vocal cords are not being operated on, the surgeon sets the laser at a higher power (>5W), slightly larger spot size, and on superpulse mode to both cut and coagulate. Surgery is done under high magnification, maintaining >5mm from the edge of the tumour. Provided a neck dissection is not done simultaneously, antibiotics are not generally required.

Cancer of suprahyoid epiglottis

The suprahyoid epiglottis can be resected with only transient and relatively minor difficulty with swallowing (aspiration) that settles once postoperative pain resolves.

Cancer of infrahyoid epiglottis and false vocal cords

Postoperative aspiration is minor when compared to open supraglottic laryngectomy; the nasogastric tube is usually removed within a few days. The resection is adapted to the tumour and may *e.g.* involve only removing one half of the epiglottis

- Insert a distending laryngopharyngoscope with the anterior blade in the vallecula, and open it widely
- Determine the extent of the tumour and plan the resection
- Remove the suprahyoid epiglottis for exposure and to remove the suprahyoid component of the tumour
  - Make a curved incision in the vallecula *(Figures 45, 46)*
  - Bisect the suprahyoid epiglottis in a sagittal plane, cutting through tumour if need be (require higher power setting to cut through epiglottis *(Figure 45)*
  - Cut transversely across the epiglottis at the level of the hyoid *(Figure 46)*
  - Remove the left and/or right segments of the suprahyoid epiglottis

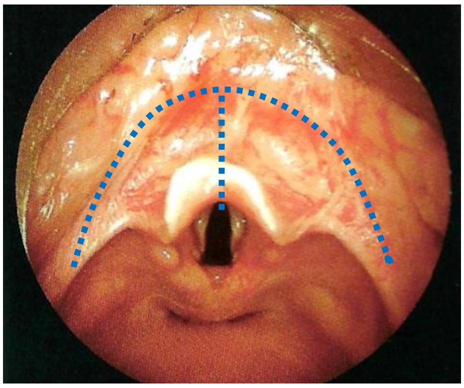


Figure 45: Initial incision in the vallecula and though the epiglottis

- Readjust the position of the distending laryngopharyngoscope to improve access to the infrahyoid component of the tumour
- Incise the pharyngoepiglottic folds, taking care to identify the branches of the superior laryngeal vessels. Although small vessels can be coagulated with the angled grasping coagulation forceps, resist the temptation to coagulate the superior laryngeal artery with electrocautery; rather apply 2 Liga clips to the artery before dividing it with laser
- Preepiglottic dissection *(Figure 46)*
  - Cut transversely into the avascular pre-epiglottic fat, preserving a layer of fat on the anterior aspect of the specimen as a resection margin
  - Palpate with the sucker to determine the position of the hyoid bone and the superior edge of the thyroid cartilage
  - Cut down onto and expose the thyroid cartilage

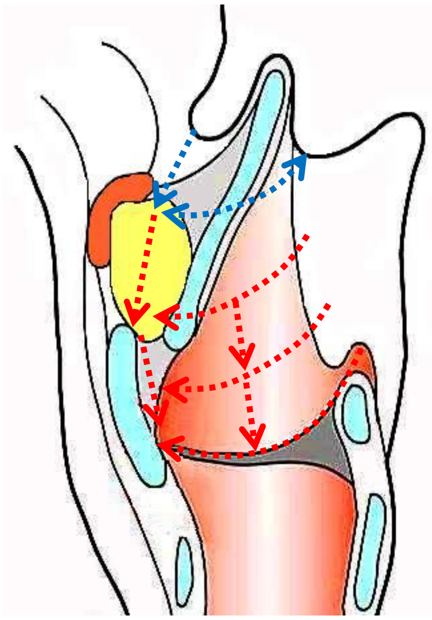


Figure 46: Suprahyoid (blue) and infrahyoid (red) incisions for laser supraglottic laryngectomy; pre-epiglottic fat (yellow)

- Bisect the infrahyoid epiglottis in a sagittal plane, cutting through tumour if need be (require higher power setting to cut through epiglottis)
- Follow the tumour *e.g.* through the thyrohyoid membrane; thyroid cartilage may also be resected
- Remove tumour in as many segments as is required, taking care to maintain their orientation for the pathologist
- Frozen section may be used to direct the extent of the resection

- Secure haemostasis with monopolar suction cautery or coagulation forceps, preferably bipolar

Figures 47a-d & *48a-c* illustrate supraglottic cancers, their excision and recovery.

Figure 47a: (L) supragottic cancer

Figure 47b: Resecting the 1st segment; note endotracheal tube has been displaced anteriorly to improve visibility for the posterior resection

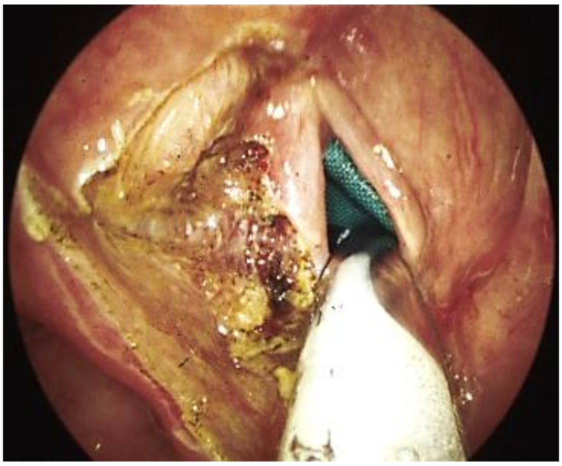


Figure 47c: Completed resection

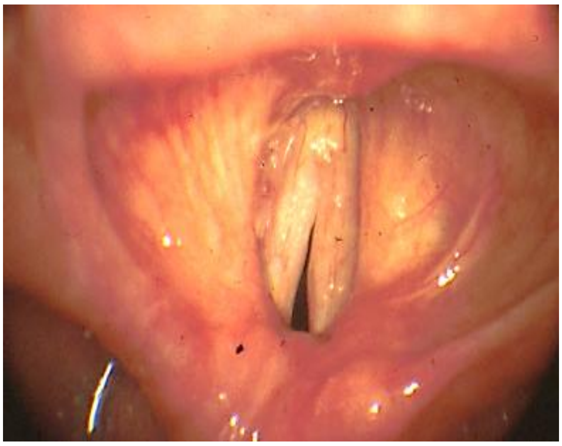


Figure 47d: Following healing

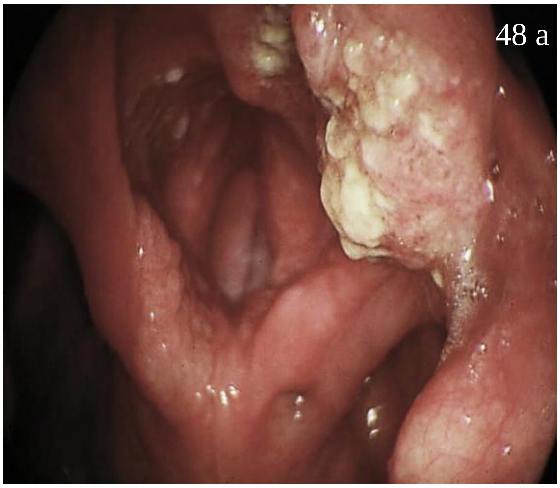


Figure 48a: Supraglottic cancer extending onto right aryepiglottic and pharyngoepiglottic folds

Figure 48b: Completed resection

Figure 48c: Following healing

Hypopharyngeal carcinoma

Cancers of the piriform fossa may extend medially into paraglottic space, cricoid and cricoarytenoid joint; anteriorly into pre-epiglottic space; and laterally to invade thyroid cartilage, and behind thyroid lamina, to the soft tissues of the neck and the carotid sheath *(Figure 47).*

At diagnostic endoscopy assess

- Depth and mobility of tumour
  - Tumours clearly limited to mucosa are easily resected
  - Deeply invasive tumours of the lateral wall need additional CT +/ MRI imaging as deeply invasive tumours infiltrating soft tissue around the carotid artery are not amenable to laser excision
- Whether lateral wall tumour extends behind thyroid lamina *(Figures 49, 50)*
  - Proximity of carotid sheath
  - ***Need to delay neck dissections by 2 weeks to avoid thru'-and-thru' fistula into the neck***
- The distal extent of tumour as one should attempt to avoid a circumferential resection at the narrow cricopharyngeus region as this may cause a stricture

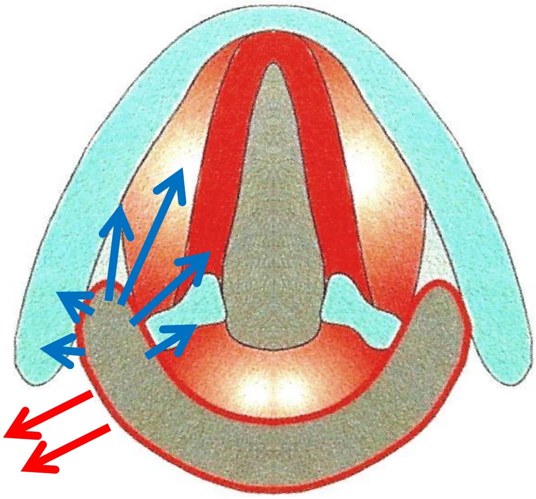


Figure 49: Extension of piriform fossa cancer: red arrows indicate higher risk resection due to proximity to carotid

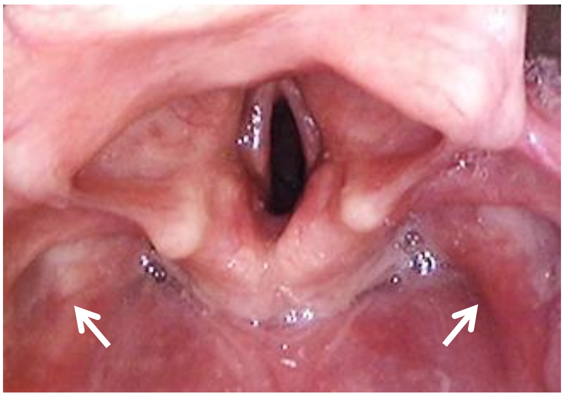
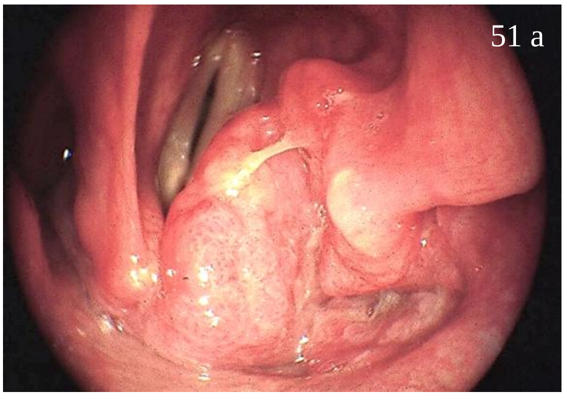


Figure 50: Posterior edges of thyroid laminae

Resection technique

Surgery is done under high magnification through laryngoscopes and a distending laryngopharyngoscope *(Figure 9)* using graspers, and Liga clip applicators to clip the superior laryngeal vessels that traverse the pharyngoepiglottic folds. Maintain a distance of 5-10mm from the mucosal edge of the tumour. Because the vocal folds are not being operated on, the surgeon sets the laser at a higher power (>5W), slightly larger spot size, and on CW mode to both cut and coagulate tissue. Reduce the power when dissecting posterior to the thyroid lamina in the region of the carotid sheath. Both authors have on occasion exposed the carotid artery during resection of hypopharyngeal cancers without any adverse effects; the vessel was either left uncovered or sealed with fibrin tissue glue. The tumour is excised in segments, taking care to orientate the specimens relevant for histology of the deep margins for the pathologist. With major resections insert a nasogastric feeding tube under direct vision to avoid the tube transgressing the tumour bed and entering the soft tissues of the neck or arrange for a PEG. Provided a neck dissection is not done simultaneously, antibiotics are not required.

Figures 51&52 show examples of piriform fossa and postcricoid cancers both before resection and after healing has occurred.



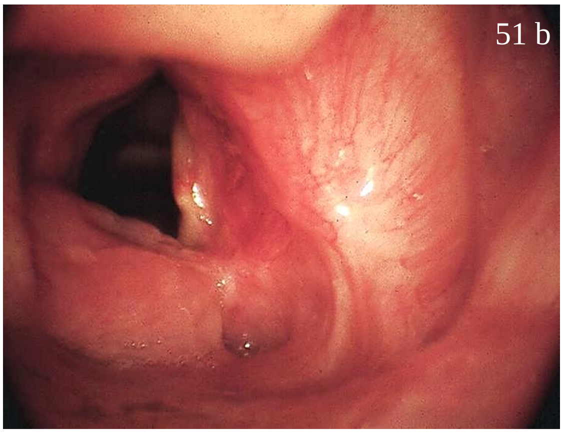


Figure 51: Postcricoid cancer with extension to piriform fossa (a) and following resection and healing (b)

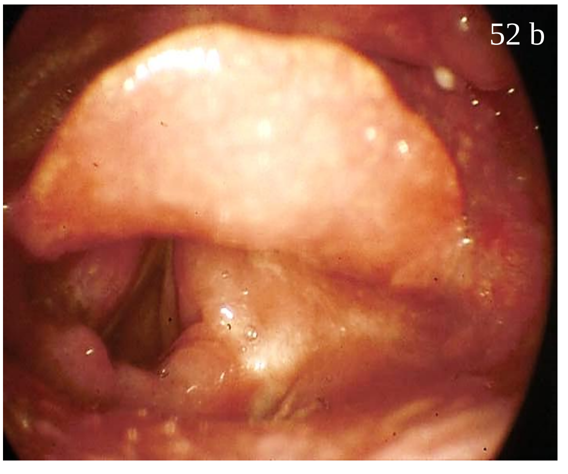
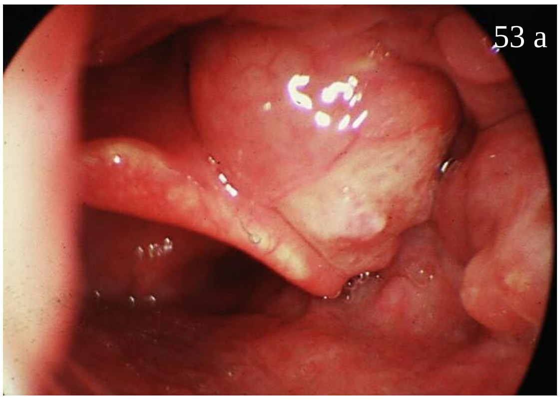


Figure 52: Piriform fossa cancer with extension to postcricoid area before resection (a) and following healing (b)

Base of tongue (BOT) *(Figures 53, 54)*

Functional outcomes are superior to external surgical resections. Depending on anatomical factors, accessing BOT tumours for laser excision may be very easy or impossible (other than in the hands of the expert using small scopes.



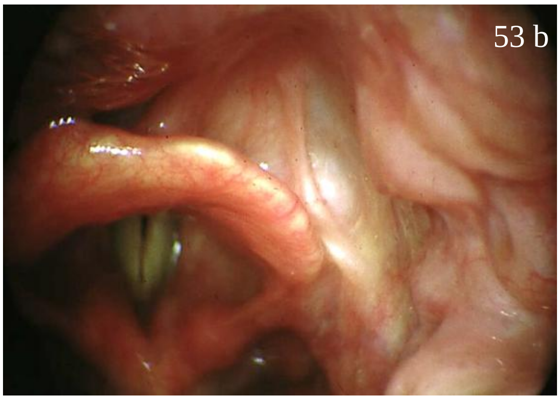


Figure 53: Cancer of BOT (a) and following resection and healing (b)

Key issues relating to BOT cancer resection:

- Obtain a CT, or preferably an MRI scan, both in axial and sagittal planes to assess
    - Tumour depth
    - Anterior deep extension of tumour
    - Involvement of pre-epiglottic fat
- Insert a nasotracheal tube to improve access and protect it with a wet cloth or a neuro patty
- Apply anterior traction to the tongue with a suture passed through the tongue

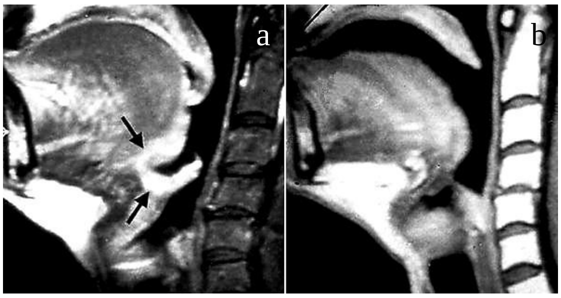


Figure 54: Preoperative (a) and postoperative scan showing absent epiglottis and reduced volume of BOT (b)

- Use a distending oropharyngoscope *(Figures 10a, b)* +/ large laryngoscope +/ tonsil gag for access
- With long procedures, relieve pressure of the scope from time-to-time to restore blood circulation to the tongue
- Do not sacrifice both lingual arteries as the tongue may infarct
- Do not sacrifice both hypoglossal nerves as the patient will then be an oral cripple (dysphagia and dysarthria)
- Resect the tumour in multiple segments
- Frozen section is used to guide the surgery as margins may not be as clearly visible as with laryngeal cancer
- Orientate the resected segments accurately for the pathologist to comment on margins
- No flaps are required, as the defect heals spontaneously
- Tracheostomy is generally not required
- With big resections that include resecting the epiglottis, a nasogastric tube is inserted for feeding
- When expecting persistent deglutition problems *e.g.* with extended resections for large tumours requiring adjuvant radiotherapy, a PEG should be considered early

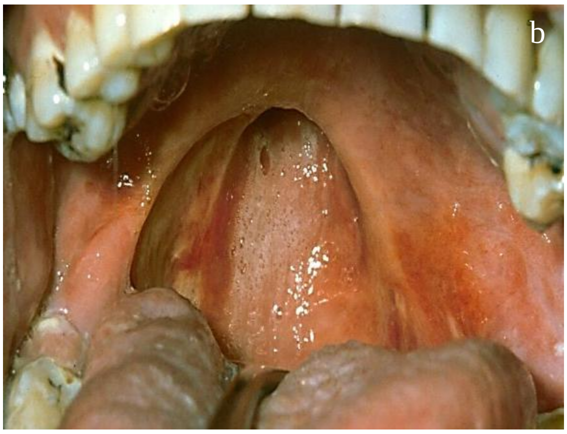
Oral cavity and oropharynx

Oral and oropharyngeal lesions may be excised with CO_2 laser using the microscope. Lesions should always be ***excised*** for histological evaluation and not vaporised. *Figures 55a & b* illustrate the excellent functional outcome after leaving a tumour bed to heal following laser excision.

Figures 55a, b: Cancer tongue before (a) and after resection and healing (b)

Figures 56a & b illustrate resection of cancer of the soft palate.

Figure 56a: Cancer of soft palate, tonsils and posterior pharyngeal wall before resection



Figures 56 b: Cancer of soft palate, tonsils and posterior pharyngeal wall after resection and healing

CO_2 laser for benign disease

Laryngocoeles and saccular cysts

Internal laryngocoeles and saccular cysts do very well with wide marsupialisation with CO_2 laser and removing the contents of the cyst with a sucker *(Figures 57, 58).*

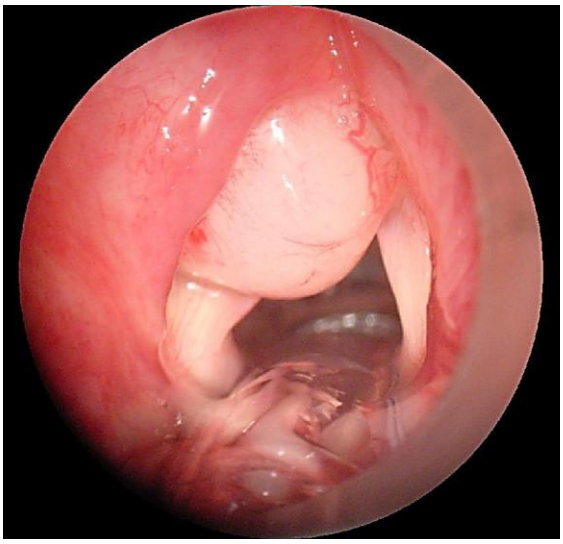


Figure 57: Saccular cyst suited to CO_2 laser marsupialisation

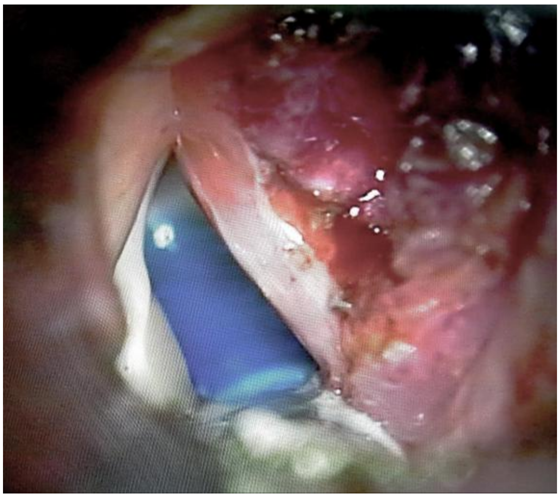


Figure 58: Inside surface of large internal laryngopyocoele following marsupialisation with laser

Viral papillomatosis *(Figure 59)*

The objectives of surgery for viral papillomatosis are not to eradicate all virally infected tissue, but to maintain airway and voice. The most popular techniques are CO_2 laser and microdebriders. Ablation of papillomata is done with CO_2 laser on a low power setting and by slightly defocusing the beam to create a larger spot size. Surgery should be conservative to preserve voice.

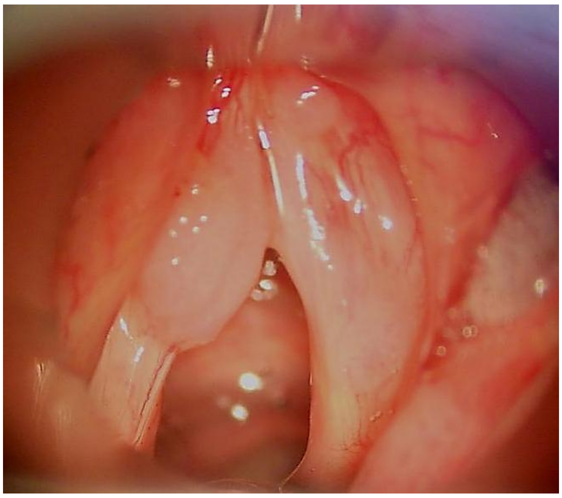


Figure 59: Viral papillomata

Papillomata at the anterior commissure present a challenge in terms of avoiding webbing and a poor voice. One may elect to stage the treatment at the anterior commissure by ablating only one side at a time to avoid webbing. Tracheal papillomata can be ablated using the microscope by advancing a smaller and longer laryngoscope between the vocal cords; or by using a laser bronchoscope *(Figure 3)*.

Intubation granuloma

Intubation granulomas originate on the traumatised vocal process of the arytenoid *(Figure 60)*.

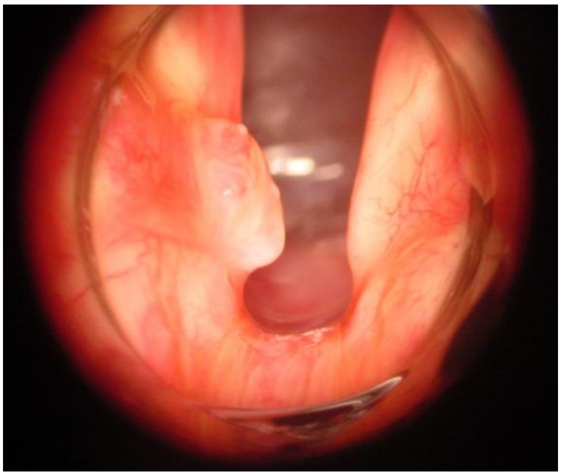


Figure 60: Intubation granuloma

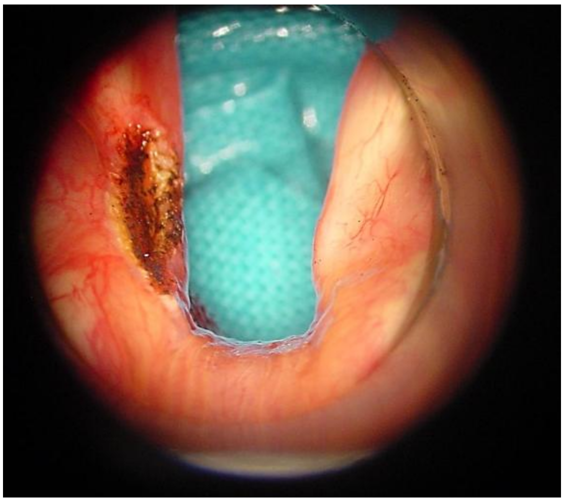


Figure 61: Excised granuloma

Only if they do not resorb after a few months and remain symptomatic are they removed, taking care not to expose the cartilage to reduce the likelihood of recurrence *(Figure 61)*.

Paralysed vocal cords

With surgery done to relieve airway obstruction due to bilateral vocal fold paralysis, the patient must be forewarned about the trade-off of airway *vs.* voice quality, and that a 2nd operation may be required should the airway still not be adequate. While some surgeons prefer initially to do unilateral posterior cordectomy, the 2nd author routinely does bilateral posterior cordectomy as in his experience this yields a good outcome both in terms of airway and voice.

The surgery is done around a small (5mm) endotracheal tube with the laryngoscope placed behind the tube to expose the posterior larynx. CO_2 laser is used to excise only the vocal process of the arytenoid (posterior 1/3 of vocal fold) and a variable amount of tissue lateral to the vocal process *(Figure 62)*. It is important that the anterior 2/3 (vibrating part) of the vocal fold be presserved to optimise voice quality.

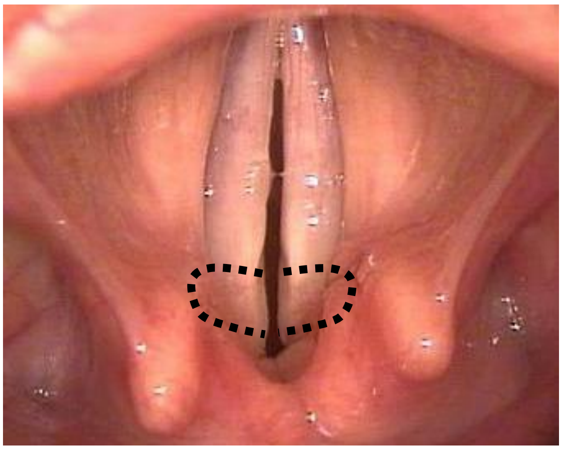


Figure 62: Bilateral posterior cordectomy

The final result is only apparent months after the surgery once fibrosis and healing have matured. The voice quality is usually very adequate as there is improved airflow through the larynx due to the larger airway, and because surgery is limited to the posterior glottis *(Figure 63)*.

Figure 63: Result of unilateral posterior cordectomy

Subglottic and tracheal stenosis

CO_2 laser is best suited to thin webs. The surgery is done by passing the smaller, longer laryngoscope past the vocal folds. Anaesthesia is done with an open airway, either having the patient breathing spontaneously with intravenous anaesthesia, or with intermittent jet ventilation; the 2nd author prefers using intermittent extubation with the surgery done during apnoeic intervals. The stricture is incised in a radial fashion, preserving mucosal bridges between the cuts *(Figures 64)*.

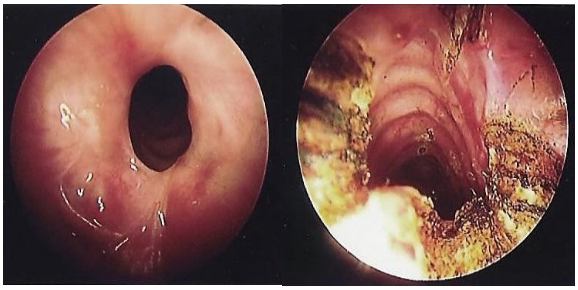


Figure 64: Tracheal stenosis; preserved mucosal bridges

Pharyngeal pouch (Zenker's diverticulum)

Endoscopic diverticulotomy involves dividing the "party wall" between the oesophagus and the diverticulum, as well as the cricopharyngeus muscle which is located within the superior part of the "party wall" *(Figure 65)*. It may be performed with a stapler *(Figure 66)* or with CO_2 laser. The 2nd author (W.S) has preferred CO_2 laser endoscopic diverticulotomy for the past 30 years. Both techniques have proven to be effective and safe.

CO_2 laser is particularly useful for pouches of < 4cms because the stapler does not divide the distal 1-2cms of the party wall due to its design *(Figure 65)*.

Figure 65: Party wall that contains crico-pharyngeus muscle separates oesophagus (anterior) from pouch (posterior)

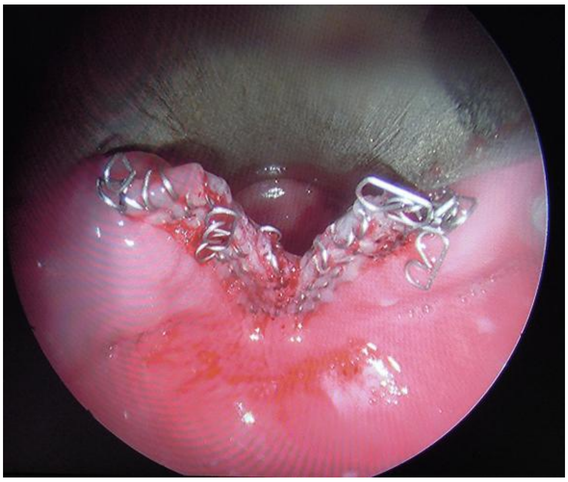


Figure 66: Diverticulotomy with stapler

Figure 67: Large and small diverticula

The operation is done with a Weerda diver-ticuloscope *(Figure 68)*.

Figure 68: Weerda diverticuloscope

It is not always possible to insert the scope due to anatomical limitations. In inexpe-rienced hands the Weerda scope is a par-ticularly dangerous instrument as it may be difficult to insert and may penetrate the posterior pharyngeal wall or the pouch causing cervical sepsis and mediastinitis *(Figure 69)*.

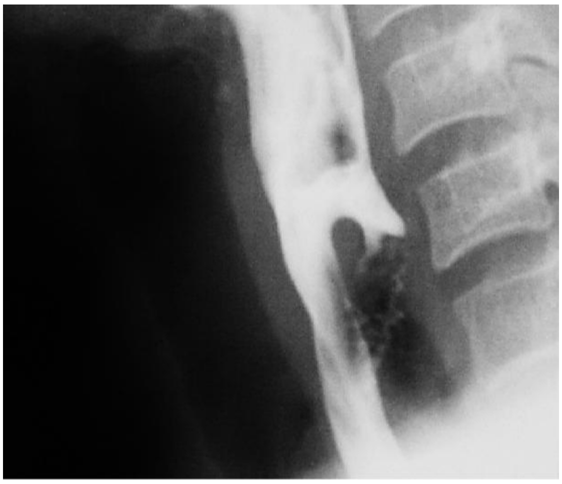


Figure 69: Perforated pouch

Surgical steps for laser diverticulotomy

- Determine the anatomy of the pouch and the location of the opening of the oesophagus with rigid oesophagoscopy
- Pass the rigid oesophagoscope down the oesophagus to dilate the proximal opening at the anterior margin of the pouch
- It may be difficult to locate or to enter the oesophagus….a useful trick is to locate the oesophageal opening by probing the lumen with a suction cannula (off suction), and railroading the oesophagoscope over the cannula
- Pass the closed end of the Weerda scope into the pouch taking care not to perforate its thin wall
- Open the blades, and retract the scope until the oesophageal opening appears anteriorly
- Pass the anterior blade of the Weerda scope into the oesophagus and keep the posterior blade in the pouch
- Distract the blades further to bring the party wall into view, and suspend the scope *(Figure 65)*
- Clear the pouch of food debris
- Insert a wet strip of cloth into the oesophagus to protect it from injury due to past pointing of the laser
- Set the laser at 5W, CW mode and small spot size
- Transect mucosa and cricopharyngeus muscle of the party wall *(Figure 70)*
- Stop the dissection 5mm from the fundus of the pouch
- Broad spectrum antibiotics are given perioperatively

Figure 70: Divided party wall

- Introduce free fluids on Day 1; progress to a soft and then solid diet over the course of a week (Some surgeons elect to insert a nasogastric feeding tube for 2 days)

Complications of laser surgery

Patients have surprisingly little pain following laser resections. They commonly mention having to clear their throats for a few weeks due to discharge from the surgical bed.

Early complications

- *Dental:* Use a gum guard to protect the teeth, and check for crowns or implants and explain the risks to the patient before surgery
- *Oropharyngeal trauma:* It is not uncommon to cause minor tears of the tonsillolingual mucosa when having difficulty with endoscopic access
- *Lingual nerve:* Prolonged upward traction on the base of the tongue can cause

transient sensory change of the oral tongue due to traction injury to the lingual nerve

- *Bleeding:* It is important to apply Liga clips, and not to cauterise, major vessels. Though infrequent, this can be a catastrophic event, especially when it originates from the lingual, superior laryngeal or carotid arteries
- *Surgical emphysema:* This occurs mainly in the setting of surgery in the subglottic region *e.g.* resection through the cricothyroid membrane and is treated conservatively; it occurs with small defects, as air is then trapped in the soft tissues. To avoid emphysema one can press on the larynx during extubation and subsequently apply a bandage around the neck
- *Airway obstruction:* This is an uncommon event; hence prophylactic tracheostomy is only rarely indicated
- *Aspiration:* This does not occur with cordectomies but may complicate supraglottic laryngectomy and BOT resections. It is rarely a persistent problem and occurs less frequently than with open resections. Initial management may include good pain control, thickened foods (rather than liquids); and temporary nasogastric tube or PEG feeding
- *Laser burns:* This occurs when the tissues *e.g.* facial skin, are not properly protected with wet drapes
- *Airway fire:* This is an extremely rare event and is entirely preventable

Late complications

- *Granuloma (Figure 71):* This occurs especially where cartilage has been exposed *e.g.* at the anterior commissure and the vocal process of the arytenoid. It generally resolves with time, but may require biopsy if it cannot be distinguished from tumour recurrence
- *Chondronecrosis:* This rarely occurs when cartilage has been exposed or excised, especially after salvage surgery in a post chemoradiation setting. The patient is treated with antibiotics and microlaryngoscopy to remove mucus and sequestra, and by sterilizing the remaining cartilage with the laser to improve healing and to exclude residual tumour *(Figure 72)*

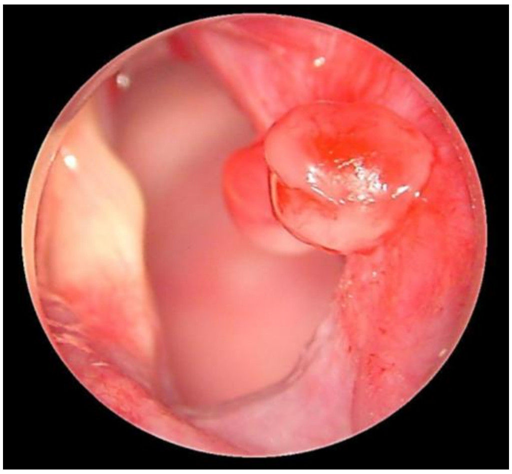
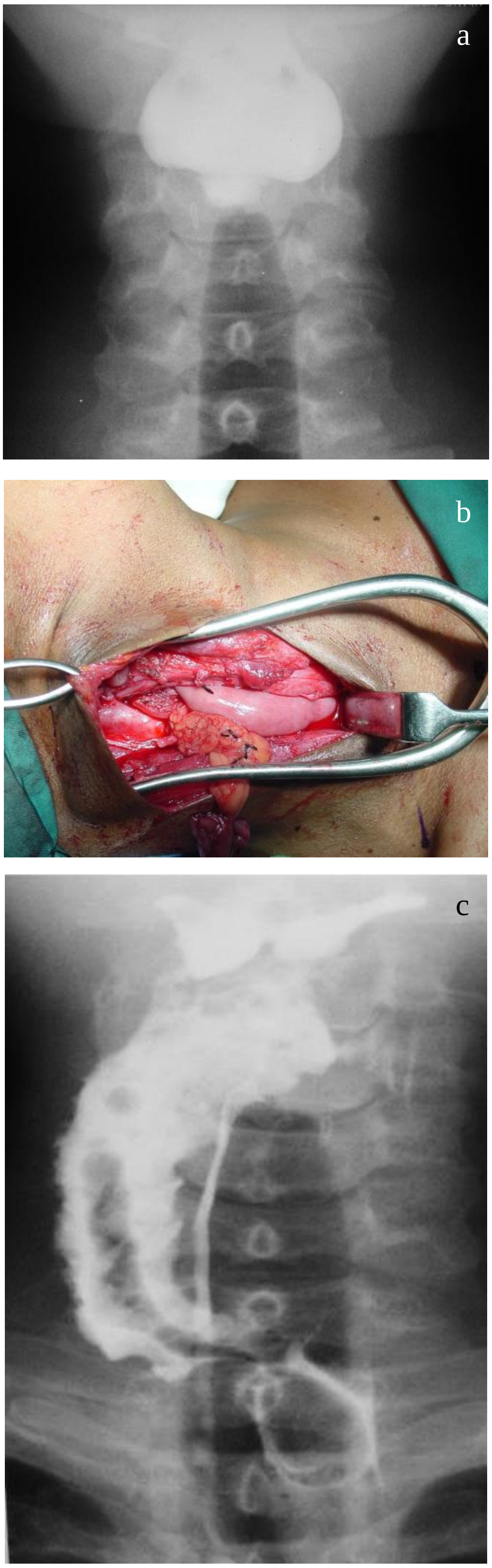


Figure 71: Granuloma on arytenoid

Figure 72: Chondronecrotic sequestra

- *Stricture:* This occurs very rarely with tumour surgery. *Figures 73a-c* illustrate a patient who developed a complete stricture in the region of the cricopharyngeus following circumferential excision of a tumour of the hypopharynx; the stricture was bypassed with a jejunal free flap



Figures 73a-c: Stricture of hypopharynx (a); inset of jejunal free flap (b); and postoperative result (c)

Suggested Reading

- Endoscopic Laser Surgery of the Upper Aerodigestive Tract: With Special Emphasis on Cancer Surgery. W Steiner, P Ambrosch (2000) ISBN-10: 08657-7996, ISBN-13: 978-0865779969
- Transoral Laser Microsurgery for Cancer of the Upper Aerodigestive Tract (incl. DVD): Steiner W. 2013 (Distributed at no charge by *Karl Storz, Tuttlingen*)
- American Society for Laser Medicine and Surgery http://www.aslms.org/public/standardpsgs.shtml
- Apfelbaum JL *et al*. Practice advisory for the prevention and management of operating room fires: an updated report by the American Society of Anesthesiologists Task Force on Operating Room Fires. *Anesthesiology*. 2013 Feb;118(2):271-90

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1. Peter H. Eeg. CO_2 Lasers: The Four Keys to Success. *Veterinary Practice News Posted: May 23, 2011* http://www.veterinarypracticenews.com/vet-dept/small-animal-dept/c02-lasers-the-four-keys-to-success.aspx
2. Remacle M et al. Endoscopic cordectomy. A proposal for a classification by the Working Committee, European Laryngological Society. *Eur Arch Otorhinolaryngol*. 2000;257(4):227-31
3. European Laryngological Society Classification for Endoscopic Cordectomy (2024) https://www.otoscape.com/eponyms/els-classification-of-endoscopic-cordectomy.html

Relevant chapters in *Open Access Atlas*

- Surgery for pharyngeal pouch / Zenker's diverticulum:

- https://vula.uct.ac.za/access/content/group/ba5fb1bd-be95-48e5-81be-586fbaeba29d/Surgery%20for%20pharyngeal%20pouch%20_Zenker_s%20diverticulum_.pdf
- Cricopharyngeal myotomy surgical technique: https://vula.uct.ac.za/access/content/group/ba5fb1bd-be95-48e5-81be-586fbaeba29d/Cricopharyngeal%20myotomy%20surgical%20technique.pdf
- Surgery for laryngocoeles (laryngoceles): https://vula.uct.ac.za/access/content/group/ba5fb1bd-be95-48e5-81be-586fbaeba29d/Surgery%20for%20Laryngocoeles%20_Laryngoceles_.pdf

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