The focused beam of the CO₂ laser functions as a haemostatic scalpel. With a high degree of accuracy, the surgeon can deliver, through the hollow tube of an operating laryngoscope, an intensely hot beam of invisible non-ionising electromagnetic radiation (beyond the infra-red end of the spectrum), absorbed by the water in soft tissue, able to cause thermal injury. With binocular microsurgical control, incisions can be made and tumour can be differentiated from normal tissue, allowing tumours to be excised, whether benign or malignant.

With the combination of local anaesthesia (using topical cocaine) and direct laryngoscopy (autoscopy), Kirstein pioneered office endoscopic laryngeal surgery in the late 19th century.2,3 Over the next decade Chevalier Jackson enhanced the techniques and moved them into the operating theatre.4 Techniques were refined and enhanced, aided by developments in general anaesthesia, the surgical microscope, suspension laryngoscopy, Hopkins rod imaging and endoscopic equipment. Jako’s coupling of the CO₂ laser to the surgical microscope in the 1970s5 led to Strong and Vaughan’s use of this equipment for early laryngeal cancers.6,7,8

Steiner was an ardent proponent of trans-oral endoscopic laser surgery for small, moderate-sized and even large laryngeal cancers (and has enhanced his technique for non-laryngeal head and neck cancers).9

Over the past decade, more centres around the world have been performing endoscopic laser resections of upper airway carcinomas and publishing their results. However, randomised control trials are rare and comparisons between retrospective studies are difficult to assess. A recent meta-analysis, comparing radiotherapy, open laryngeal surgery and endoscopic laryngeal surgery, concluded that “there is no good evidence available from randomised controlled trials to guide treatment choice for patients with early stage glottic cancer”.10

### Principles of technique

Using modified microlaryngeal endoscopes and surgical instruments, a CO₂ laser beam can be used to endoscopically excise a tumour, with clear margins, which can be verified histologically. Larger tumours can be managed by initially cutting through the tumour, to create several smaller but manageable specimens. “Tumour extension is clearly distinguishable under the microscope, and the lesion can be resected until healthy tissue is found and an appropriate safety margin can be maintained”.11 Although high surgical magnification does not approach the accuracy of histopathological magnification, and hence accuracy, surgical accuracy can be increased by noting the different degree of carbonisation of tumour or normal tissues, as they are cut with a laser. Intra-operative frozen section analysis is often employed to confirm clear margins.11 Since the specimen is removed in pieces, the handling of the pathology specimens and the interpretation of the pathology report is different than in a standard open radical excision.

### Advantages

Many tumours can be excised endoscopically, without skin flap elevation, dissection and preserving functionally-important structures (such as cartilage, bone, muscle and nerves), and avoiding subsequent skin graft or flap reconstruction, which in and of itself, interferes with functional results (speech and swallowing). Hence, tube feeding and tracheotomy are less often required and patient morbidity is reduced. Because wounds are not repaired or covered with a flap, a positive margin can be excised reasonably soon. Finding that margin early on, endoscopically, is more accurate; the microscope allows the surgeon more accuracy in removing the tumour and a smaller margin of normal tissue. The CO₂ laser is haemostatic, so there is less blood loss. The deep margins of the tumour can be better assessed, as it has a different reaction when lasered across, compared to lasering of normal tissue. The tumour excision can be tailored to the actual tumour.
size and shape, preserving as much normal tissue and functional tissue. Should excision not be adequate, reexision (usually by the same endoscopic laser approach) can usually easily be performed (depending on access).

Should it be needed, radical open surgery and/or radiotherapy can still be performed, without the laser treatment having interfered with the likelihood ofsuccess, nor of morbidity. With tiny glottic cancers, Strong et al found that 20% of cases have no tumour in the specimen after biopsy for squamous cell carcinoma (SCC) (definitive radiotherapy was not necessary). Laser excisions, although tedious and time-consuming, take less time than do open radical excisions and are far more expeditious than a course of radical radiotherapy, saving costs.

Disadvantages and risk

Exposure of the tumour can be compromised by anatomical variations (eg. trismus, stiff neck, prominent teeth and full tongue) or by the size, localisation or extent of the tumour. The anterior commissure is a well-known site of difficult exposure, as is the subglottis, deep tongue base and para-oesophageal space.

The experience of the surgeon is important, as either incomplete excision can occur, or an increased risk of complications. Special surgical and anaesthetic precautions must be taken to prevent laser fire of the endotracheal tube, a very dangerous but rare occurrence.

Intra-operative bleeding can hamper the performance of the operation, more from obscuring the surgeon’s view then from dangerous blood loss. Secondary haemorrhage, particularly on the first night after surgery, or delayed 10-14 days, can be dangerous because of aspiration or exsanguination. The general anaesthetic required to control haemorrhage occurring above the laryngeal inlet is dangerous.

Other complications include post-operative airway obstruction, aspiration, hoarseness, dysphagia, infection and surgical emphysema. Delayed web formation may result from radiotherapy and may be a clear margin around a cancer. However, vocal deterioration may result from radiotherapy and be significant if loss of vocal cord bulk results from tumour necrosis or if fibrosis develops.

Adjuvant treatment

When indicated, neck dissection is performed about a week after the trans-oral laser excision of the primary tumour. All of the various types and indications for lymphadenectomy exist. Depending on the author, postoperative radiotherapy is sometimes used. Steiner and Ambrosch use post-operative radiotherapy or chemoradiotherapy to the primary site if the tumour cannot be removed completely despite further endoscopic attempts, and the only alternative would be a radical operation (eg. laryngo-pharyngectomy or glossectomy). Adjuvant cervical radiotherapy is given after neck dissection for the usual indications (two or more involved nodes, extra-capsular pread, lymphovascular invasion or a large solitary node). Zeltels uses post-operative radiotherapy, almost routinely, after endoscopic laser excision of all supraglottic carcinomas. Some would argue, that since radiotherapy alone or in combination with chemotherapy, renders good results for supra-glottic carcinoma, the laser excision is nothing more than an “excisional biopsy”.

Trans-oral laser microsurgery (TOLM) in laryngeal SCC

Strong and Jako first described use of the CO₂ laser to endoscopically resect laryngeal cancers. Strong showed that in up to 20% of cases, no residual SCC remained after the initial diagnostic biopsy, often making radiotherapy unnecessary. Steiner and Ambrosch showed six local recurrences and only one laryngectomy in 159 patients followed for at least five years using TOLM techniques. Since then, TOLM has been widely adopted as an alternative to definitive radiotherapy in the treatment of early laryngeal cancer.

If local control and survival are comparable, the choice between surgery and radiotherapy for early laryngeal cancer is determined by patient preference after discussion of risks, benefits and likely functional outcomes. Steiner showed that most TOLM cases could be done as day cases with modest pain for a few days. Patients must be warned that approximately one third of patients require a second procedure often to biopsy suspicious granulation tissue. Most radiation protocols take six weeks, cause painful mucositis lasting a further two to four weeks and carry the small but real risk of causing a radiation induced tumour (estimated at 1/300).

Voice outcomes following TOLM compared with radiotherapy

One of the arguments in favour of radiotherapy for early glottic cancer is the supposed better voice outcome, as compared to that after laser resection. TOLM advocates have stated that their voice results are good, but why then would Remacle et al need to publish a paper titled Reconstruction of glottic defects after endoscopic cordectomy: voice outcome?

Cragle and Brandenburg reported that surgical treatment of early glottic cancers may produce a vocal result that is equivalent to that following irradiation. These investigators evaluated voice profiles in 11 patients treated with TOLM and 20 patients treated with irradiation. Both groups had similar voice profiles, characterised by decreased maximum phonation times and increased jitter, shimmer and signal-to-noise ratios.

Most investigators, however, contend that a better voice more reliably follows treatment with radiotherapy rather than TOLM. Unlike surgery, radiotherapy does not require removal of adjacent healthy tissue to provide a clear margin around a cancer. However, vocal deterioration may result from radiotherapy and may be significant if loss of vocal cord bulk results from tumour necrosis or if fibrosis develops.

One of the key papers in the question of which treatment to choose came from Ton-Van and others who evaluated 356 patients with early glottic cancer. They determined that the quality of voice after treatment with radiotherapy was “indisputably superior” to that after conservation surgery. However, these investigators pointed out that a functional larynx was preserved in 92% of patients treated surgically.
compared with 81% initially treated with radiotherapy. This reflects the use of total laryngectomy for radiation salvage. As a result of these findings, Ton-Van and others advocate the use of surgery as a primary mode of therapy in patients capable of safely undergoing an anaesthetic. Exceptions include patients who are willing to accept a greater risk of total loss of the larynx in the effort to preserve the highest quality voice.

The absolute quality of their voice may not be as important a consideration for many patients in selecting treatment as is their general ability to communicate. For these patients, speech intelligibility may be more meaningful as a criterion to assess results rather than acoustic and aerodynamic measurements. Schuller and others used interviews and questionnaires to evaluate 75 patients treated with TOLM for early laryngeal cancers. They found that 88% of the respondents were content with the postoperative voice.29

Laryngeal preservation following TOLM versus radiation treatment

One of the key differences between TOLM and radiation is the ability to repeat TOLM in the event of local failure, whereas radiation failures are most commonly treated with total laryngectomy.21 Consequently final laryngeal conservation is probably higher for T2 tumours using TOLM.22 Morris and others carried out an intensive literature review and identified an overall 8.6% failure rate at the primary site for T1 glottic cancers managed surgically, compared with a 16.7% failure rate among similarly staged cancers managed with radiotherapy.23

Patients with T2 glottic tumours may be better treated primarily with surgery because T2 glottic cancers have an even higher local recurrence rate after irradiation. Surgical salvage with less than a total laryngectomy is unlikely to be successful.24

One of the advocates for radiation, Jorgenson and others described 1005 Danish patients treated at a single referral centre between 1965 and 1998. All early glottic cancers (99%) within a catchment area of 1.33 million people received primary radiotherapy and follow-up was excellent (only three patients were lost to follow-up). Three-hundred and twelve T1 glottic cancers were treated with irradiation with a five-year local control of 88%. Including surgical salvage, five-year disease-specific survival was 99%. Two hundred and thirty-three T2 glottic cancers were treated with irradiation with a five-year local control of 67.4%. Including surgical salvage, the five-year disease-specific survival was 88.4%. These investigators identify that this high recurrence rate (one out of three) for T2 glottic cancers resulted in an overall laryngeal preservation of 80%. This is substantially lower than the 95% organ preservation reported by Chevalier's group using organ preservation surgery.24

Jorgenson observed that improved radiotherapy techniques, as well as the capacity to salvage irradiation failures with supracricoid laryngectomy, will likely decrease the ultimate need for total laryngectomy. Undoubtedly the salvage rate of TOLM for local recurrences is high.27 More recently, Steiner has shown that radiotherapy failures may also be salvaged by TOLM in many cases.28

Involvement of the anterior commissure by tumour

The anterior commissure of the larynx is a site of special concern. There is no perichondrium on the surface of the thyroid cartilage at this point to resist tumour invasion. Broyle's ligaments pass through the thyroid cartilage, providing a passage of low resistance to tumour spread. Early data of TOLM suggested anterior commissure involvement may increase local recurrence.29 As TOLM has evolved surgeons have resected more cartilage and soft tissue in the region of the anterior commissure. Consequently Steiner showed a five-year local control rate of 79% in 45 patients with anterior commissure involvement for a 93% larynx preservation rate. In the 30 cases without anterior commissure involvement, the five-year local control rate was a similar 74% and the corresponding larynx preservation rate 97%.30

Radiation oncologists have experienced similar difficulties with tumours at the anterior commissure. Maheshwar reported increased local recurrence rates (57.1%) with anterior commissure involvement compared with similar staged tumours not involving the anterior commissure (15.8%).31 They hypothesised that a lack of pre-treatment CT imaging may have under staged tumours and contributed to their poor results.

TOLM for other head and neck cancers

Conservation surgery has long been an alternative to primary radiotherapy for early cancers of the supraglottis and oropharynx. Many argue TOLM has merely introduced another tool that removes the need for external incisions. The frame shift from traditional oncology shown by Steiner and others has been the ability to transect the tumour. The CO2 laser beam presumably seals adjacent lymphatics and does not carry tumour cells into deeper tissues. This allows piecemeal removal of large tumours via trans-oral endoscopes. The operative bed heals quickly by secondary intention restoring the indigenous surface and preserving adjacent neural coordination and sensation.

In his early results, Steiner reported 43 untreated patients with early supraglottic cancers.32 He showed a 90.5% local control and all failures were salvaged via further conservation surgery. No-one lost their larynx. The five-year Kaplan-Meier overall survival was 73%. Most (84%) required a temporary nasogastric feeding tube but few (5%) a temporary tracheostomy. One patient returned to surgery for bleeding. Steiner also reported on 56 patients with higher stage supraglottic cancer. Surgery was used in 84% for neck disease and 22 (39%) had radiotherapy after surgery. Local control was obtained initially in 80.5% and the overall five-year Kaplan-Meier survival was 50%. Three (6%) patients
developed laryngeal stenosis and two (4%) required a permanent tracheostomy. Five patients (10%) suffered significant aspiration, leading to total laryngectomy in three. Significant bleeding requiring a further anaesthetic occurred in 8%.

Steiner has also reported 48 patients treated with TOLM for base of tongue squamous cell carcinoma between 1986 and 1997. Selective neck dissection was performed in 43 patients; 23 patients underwent postoperative radiotherapy with or without simultaneous chemotherapy. The Kaplan-Meier five-year local control rate was 85%. There was no local recurrence in T1 and T2 lesions, but there was a 20% local recurrence rate in T3 and T4 tumours. Kaplan-Meier five-year recurrence-free and overall survival rates were 73% and 52% respectively. Mean performance status scale scores were 92% for normalcy of diet and 88% for intelligibility of speech.

Most impressive is Steiner’s results with hypopharyngeal primaries. These tumours commonly present in advanced stages and of 103 patients mainly with pT4N2 disease, 63 patients had pT2 cancers and 14 had pT3. Patients with simultaneous second primaries, very advanced neck disease (N3), or distant metastases (ie. not treatable for cure) were excluded. In addition to TOLM, 75% also had neck surgery and 50% had postoperative radiotherapy. Of these 103 patients, 93 were controlled locally after a 44-month mean follow-up. The five-year Kaplan-Meier survivals were 69.2% for combined stage I and II, and 52.5% for stage III and IV.

Even in the most selective patients, Steiner’s overall local control and overall survival compares favourably with published chemotherapy and radiotherapy laryngeal preservation protocols that have replaced the traditional total laryngectomy and postoperative radiotherapy for hypopharyngeal carcinomas. The primary aim of combined chemotherapy and radiotherapy is to preserve a functioning larynx and the largest such study of anterior commissure involvement on local control of early glottic carcinoma treated by laser microsurgery in 112 patients. Ann Otol Rhinol Laryngol. 1997;106:364–369.

References
4. Jackson C. Tracheo-bronchoscopy, esophagoscopy and gastroscopy. The Laryngoscope Co: St. Louis (MO); 1907.