ANAESTHETIC MANAGEMENT OF TRACHEAL SURGERY USING
THE NEODYMIUM-YTTRIUM-ALUMINIUM-GARNET LASER

G. VOURC'H, M. L. TANNIERES, L. TOTY AND C. PERSONNE

SUMMARY
A new technique for the management of tracheal or bronchial lesions (tumours or stenosis) using the NdYAG laser and bronchoscopy, was used in 55 patients without complications. The anaesthetic problems are discussed. In some circumstances the procedure may be performed using sedation and topical anaesthesia. In most, general anaesthesia was used, controlled ventilation being achieved through the bronchoscope using a modification of the Sander's injector with a mixture of 50% nitrogen and oxygen to avoid the risk of fire.

Microlaryngeal surgery using a carbon dioxide laser is now a well established procedure. The anaesthetic problems involved have been described by various authors (Strong and Jako, 1972; Birch, 1973; Andrews and Moss, 1974; Konchigeri and Shaker, 1974; Snow et al., 1974; Strong, 1975; Shaker et al., 1976; Strong et al., 1976; Vourc'h, Tannieres and Freche, 1979). The advantages of the laser are the absence of bleeding and oedema, and rapid healing. One of the risks is the ignition of unprotected rubber or plastic tubes, and of anaesthetic gases, as a result of the intense heat generated by the laser beam (Snow et al., 1976; Vourc'h and Tannieres, 1979).

The introduction of the carbon dioxide laser technique to the trachea and bronchial tree creates new problems since the beam travels, like light, in a straight line and cannot therefore reach lesions situated deep within the air passages. Only one report (Laforest, Berger and Vaughan, 1976) has been published describing relief of tracheal obstruction using the carbon dioxide laser. However, the neodymium–yttrium–aluminium–garnet laser (NdYAG) overcomes this difficulty since the beam is carried through a flexible fibre and can be aimed in any direction under bronchoscopic control.

This report describes the apparatus used, the anaesthetic technique adapted for this new device, and our preliminary clinical results in 55 patients.

APPARATUS
The principle of the NdYAG laser has been described by Snow (1977). The apparatus used in this study (Compagnie Industrielle des Lasers (CILAS), Route de Nozat, 91460 Marcoussis, France) provides an output of up to 90 W in the infra-red wave length (\( \lambda = 1.06 \) \( \mu \)). A combined pilot beam (helium and neon) produces a bright red spot which can be aimed towards the lesion. The two beams are conveyed through the same flexible fibre, of 1 mm diameter. The core is made of silica enclosed in a silicone sheath. A coaxial Teflon tube (1.8 mm external diameter) allows the injection of compressed air (3 litre min\(^{-1}\)) to cool the tip of the laser fibre, prevent condensation on the endoscope and to disperse fumes.

Since the laser beam has a 10° divergence, the diameter of the site of impact varies with the distance between the tip of the fibre and the target. In practice that distance is maintained between 5 and 10 mm.

The laser fibre is inserted through the biopsy channel of a standard rigid bronchoscope or may be used with a T3 Olympus flexible bronchoscope fitted with a 2.7 channel. In either case, the laser fibre can be bent in any direction and aimed towards the lesion. The power, time and distance from the lesion can be adjusted according to the needs of the patient.

Coagulation: 30 W for 0.7–1 s over a surface of about 3 mm, at a distance of 10 mm. Excision: 40–70 W for 0.3 s in bursts of one every 2 s, at a distance of about 5 mm.

Each burst triggers an auditory signal and a counter records the number of bursts.

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switch controls first the jet of compressed air and then the laser itself. Since the laser beam can induce severe burns, particularly to the eyes (Leibowitz and Peacock, 1969), special goggles (provided by CILAS) must be worn for protection by the attending personnel. They provide a reduction of \(10^6\) at a wavelength of 1.06 \(\mu\)m.

The energy delivered by the NdYAG laser is absorbed better by tissue containing melanin or haemoglobin. It may, therefore, be necessary to apply a dye such as methylene blue to a white surface before using the laser.

**METHODS**

In the presence of heat, nitrous oxide and oxygen support and invigorate combustion. Thus ventilation should be with air or with a 50% mixture of oxygen in nitrogen, which has been found to be safe.

The problems of achieving both ventilation and anaesthesia for endoscopic bronchial surgery with the laser are not easy to overcome and we describe and discuss our method under various headings.

**Patients**

All had lesions within the bronchial tree: tumours, benign or malignant (papillomas, granulomas, carcinoids, cancers), or scar tissue following prolonged intubation or tracheotomy. Some patients had a degree of respiratory obstruction or of respiratory insufficiency and could not tolerate further respiratory depression. Most had inflammation of the mucosa and topical analgesia is ineffective. Although the procedure is painless, it was essential to avoid coughing or restlessness to ensure accurate aim of the beam.

**Anaesthesia**

Premedication always included atropine or hyoscine and sedation was used if appropriate to the patient’s condition. Anaesthesia was conducted as follows.

Co-operative patients with normal respiratory function. The procedure could have been performed using topical analgesia and sedation such as neuroleptanalgesia, using dehydrobenzperidol (or a sedative drug such as diazepam) and pheno- peridine or fentanyl. Any residual respiratory depression caused by the analgesic was antagonized with naloxone.

Patients requiring general anaesthesia. Various examples had to be considered:

In adults, if a fibrescope was available, the procedure could be carried out using a large cuffed endotracheal tube, following the standard techniques described by Tahir (1972) and MacNaughton (1975). In Tahir’s method, the fibrescope is inserted through a rubber diaphragm within the endotracheal tube and ventilation of the lungs is achieved either manually or mechanically, using enriched air and halothane. If MacNaughton’s technique is adopted, ventilation is with enriched air only.

In other cases (in children or when a rigid bronchoscope was used) lung inflation using the Sander’s injector was found satisfactory but the apparatus had to be modified. The standard injector fitted at the proximal (machine) end of the bronchoscope was found to be unsatisfactory because the bulk of the eyepiece and the leaks through the side vents of the bronchoscope resulted in inadequate ventilation. This was particularly so when the lesion was just below the cords or when the bronchoscope was introduced through a tracheostomy. A 16-gauge brass tube was therefore welded to the inside of the bronchoscope, opening at the tip. This was found to be entirely satisfactory in all patients. Since air or enriched air was used for ventilation, unconsciousness was achieved during prolonged procedures by an i.v. infusion of short-acting agents such as Althesin, methohexitone or propanidid.

In practice, the following technique was used. An i.v. infusion was established. A dose of thiopentone sufficient to obtund the eyelash reflex was administered, followed by suxamethonium. The lungs were ventilated with oxygen and the bronchoscope inserted. Ventilation was then performed by manual control of the injector and muscle relaxation was achieved using a suxamethonium infusion. When the procedure was completed and the bronchoscope removed the lungs were ventilated using a mask or through the tracheostomy until recovery was complete.

The jet of compressed air occasionally sprayed blood down into the bronchial tree and it obscured the view through the bronchoscope. It was then necessary to stop ventilation for a few seconds to provide the operator with a clear field of vision and apply suction.
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CLINICAL RESULTS
During a 10-month period, 55 patients were treated without accident or complication (table I). This corresponds to 110 operations since most patients required treatment on more than one occasion. Twenty-three patients were treated at a single session, the others between two and five. It is too early to draw conclusions from such a small series but the technique is promising.

<table>
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Tracheal or bronchial carcinoma (28 patients)
Two groups of patients have been treated.

Tracheal carcinomas recently detected, in acute respiratory distress (12 patients). In nine, one single session achieved immediate relief. In three, the resection was more difficult because of bleeding. In the most advanced tumours, tracheal intubation for 24 h to 3 days allowed time for radiotherapy. These 12 cases were technically successful.

Recurrent carcinoma already treated medically or surgically. Seven followed surgical procedures (five pneumonectomy, two bilobectomy, and resection–anastomosis). The growth was situated either on the suture line or on the lowest tracheal rings and was obstructing either the trachea itself or the main bronchus. All patients had received radiotherapy before or after surgery and were unsuitable for any other therapy. Clearly the use of the laser was purely palliative and might be repeatable.

Six other lesions were not operable and had been irradiated. The laser was the only means of providing temporary relief as the trachea or main bronchus had been invaded.

In two patients, oesophageal carcinoma had invaded the pars membrana of the trachea and in one patient a thyroid tumour had invaded and obstructed the trachea. Treatment with the laser, followed by radiotherapy, afforded relief lasting 7 months.

Benign tumours (four patients)
These are very rare.
An amyloid tumour, 8 mm diameter, involved the middle part of the trachea obstructing a third of the lumen. It was resected in one session. Diathermy might have achieved the same result, but the laser treatment was completely successful. A papilloma of the main bronchus, situated on the pars membrana was destroyed following five bursts with 70 W.
A laryngo–tracheal papilloma had developed for 10 years. The patient underwent tracheotomy and was completely relieved; the tracheostomy was then closed. A papilloma of the left main bronchus in a respiratory cripple who was unfit for major surgery was treated.

Moderately malignant tumours (four patients)
A carcinoid tumour of the left lower lobe bronchus required three treatment sessions for resection although bronchoscopy had shown the pedicle to be thin. It is still too early to tell whether the resection was complete.

Another carcinoid tumour of the apical segment of the right lower lobe bronchus was obstructing the main bronchus, moving up and down on its stalk. It was resected in one session, another session being required to treat the pedicle. This was the only therapy feasible for this patient who had very severe respiratory disease (FEV$_1$ = 840 ml).

The third carcinoid tumour was in a 72-yr-old patient and again the laser offered the only possible treatment. It was a recurrent growth. The patient had been submitted to a carinal resection (Barclay’s procedure) 13 years previously. The new carina was invaded by a tumour obstructing the whole lumen of the left main bronchus, while the right was partially occluded. The left main bronchus was nearly completely cleared of tumour in three sessions.

The fourth patient had a widespread recurrent cylindroma as a sequel to left pneumonectomy
performed 12 years before, followed by radiotherapy. A year previously an oesophagocoloplasty had been performed to treat oesophageal stenosis caused by recurrence of the cylindroma and by radiotherapy. Two-thirds of the right main bronchus was obstructed. Otherwise the patient's condition was good. Following two laser sessions the right main bronchus was cleared, but recurrence is obviously likely.

**Iatrogenic tracheal stenosis following either tracheotomy or intubation (15 patients)**

These vary considerably in their site, from the subglottic region to the lower third of the trachea; the speed of their development, from a few weeks to some years; their length—simple diaphragm or a long cylinder, and their severity. They often affect young otherwise healthy patients.

It is obvious that the laser beam cannot attack more than the fibrous tissue implanted on the tracheal wall. Seen through the bronchoscope, the impression is of a funnel-like lesion arising from an endotracheal stenosis. The main part of the stenosis is always a result of collapse of the tracheal wall itself. In some cases it may stem from the destruction of the cartilage rings.

Our preliminary trials with the laser have fully endorsed these findings. Any tracheal stenosis was primarily because of collapse of the tracheal wall and the fibrous tissue growing into the lumen merely increased the restriction of the hour-glass-like collapse of the cartilage framework.

It was interesting to note that in nearly all examples of narrow stenosis (less than 5 mm), the laser produced a 70-100% increase in the lumen size, which afforded immediate relief to patients in respiratory distress. This did not achieve radical cure, however, because the obstruction of the tracheal wall persisted. A subsequent resection-anastomosis had to be performed, but in excellent respiratory conditions and not as an emergency procedure.

In eight patients, laser therapy was preparatory to a resection-anastomosis. However, in seven cases of obstruction because of a diaphragm it has apparently achieved radical cure, thus avoiding a surgical procedure; three of these patients could not have tolerated major surgery.

**Granulomas (four patients)**

Laser therapy is the ideal technique for the cure of granulomas developing on a tracheal or bronchial suture or following prolonged tracheal intubation in intensive care units. They must not be neglected since they may lead to a fibrous stenosis.

**SPECIAL PROBLEMS**

**Haemorrhage.** Bleeding occurs mainly from malignant tumours. The laser does not obviate it completely, but it is less troublesome than with diathermy or piecemeal surgical removal. It may be disturbing even though limited to a few drops, but is easily aspirated. However, the jet of air triggered by the laser, and particularly the blast of gases coming from the Sander's injector, sprays the blood down into the trachea and may obscure the view. This difficulty can be avoided by withdrawing the eyepiece slightly and looking at a distance from the target. The anaesthetist may be asked to discontinue ventilation for some seconds while the bronchoscopist is at work. All blood must be removed to avoid lung collapse.

**High sited tumours** are difficult to manage because the tip of the bronchoscope lies between the cords.

**Tumours involving a main bronchus.** Since the growth obscures the lumen and sometimes involves the carina, it is often difficult to achieve accurate aim in the right plane. One should be careful and work slowly. In one patient we managed to clear a 2-cm passage without ever seeing the bronchial wall, but ended the procedure to avoid damage to the bronchus.

The anatomical boundary to be avoided (the cartilage) is the main problem. The bronchoscopist must balance caution and daring to attack the lesion, but he must not be overenthusiastic; it is a matter of judgment and training. Some structures are more dangerous, such as the pars membrana and those in relation with large vessels (aorta, innominate artery). In our small series, we had no accidents involving either the oesophagus or a large vessel. The range of the beam is about 20 mm and only axial, but one must be careful to aim accurately.

It may be safer to avoid excessive therapy in one session and to repeat the procedure. After a time, charring prevents accurate demarcation of the tracheal wall, but the slough disappears after a few days. A control bronchoscopy and new session can then be performed safely. On many occasions we were pleasantly surprised to discover that the
The introduction of the NdYAG laser provides a new concept in the management of tracheal and bronchial lesions. It enables the surgeon to treat new tumors or stenosis sited deeply within the bronchial tree, either radically, or simply to relieve an obstruction. Some patients show signs of respiratory distress, and cannot withstand respiratory depression. The duration of the procedure is often unpredictable.

The technique described was found to be entirely satisfactory and there were no complications. It is too early yet to define the scope of this new technique, but it seems promising.

REFERENCES


CONDUITE ANESTHÉSIQUE DE LA CHIRURGIE TRACHEALE EN UTILISANT LE LASER NEODYMIUM-YTTRIUM-ALUMINIUM-GARNET

RESUME
Une technique nouvelle destinée au traitement de lésions trachéales ou bronchiques (tumeurs ou sténoses) en utilisant le laser NdYAG sous couvert de bronchoscopie a été employée sur 55 malades sans complications. Nous analysons les problèmes anesthésiques. Dans certains cas, l'opération peut se faire sous sédation et anesthésie de contact. Dans la plupart, nous avons utilisé l'anesthésie générale; la ventilation a été assurée par le bronchoscope, en utilisant une modification de l'injecteur de Sanders, avec un mélange de 50% d'azote et d'oxygène pour éviter le risque d'incendie.

ÜBER DIE BETÄUBUNG BEI TRACHELCHIRURGIE MITTELS NEODYMIUM-YTTRIUM-ALUMINIUM-GARNET-LASERS

ZUSAMMENFASSUNG

GERENCIA DE LA ANESTESIA PARA LAS OPERACIONES QUIRURGICAS TRAQUEALES USANDO EL LASER DE NEODIMIO-YTRIO-ALUMINIO-GARNET

SUMARIO
Se hizo uso de una técnica para la gerencia de lesiones traqueales o bronquiales (tumores o estenosis), usando el laser NdYAG y broncoscopia, en 55 pacientes y sin complicación alguna. Se discuten los problemas anestésicos. En algunas circonstancias el procedimiento puede llevarse a cabo usando tranquilizantes o anestesia local. En la mayoría de estos casos, se usó anestesia general, lográndose la ventilación controlada a través del broncoscopio, haciendo uso de un injector modificado de Sander con una mezcla de nitrógeno y de oxígeno al 50% con el fin de evitar el peligro de incendio.