Laser Bronchoscopy—Current Status

A Mohan*, R Guleria**, C Mohan***, R Sharma+

Abstract

The majority of patients with lung cancer have advanced disease with severe endobronchial symptoms such as cough, dyspnea, and hemoptysis for which palliation is required. Laser resection of endobronchial lesions located in the trachea, mainstem or proximal lower lobe bronchi provides significant and rapid improvement in the patient’s symptoms. Neodymium:yttrium-aluminium-garnet (Nd:YAG) laser is gaining popularity due to efficient photocoagulation, good penetration and excellent hemostasis. Complications are rare and can be minimized by following standardized techniques and safety guidelines. Laser resection is equally effective with the rigid and flexible bronchoscope. The future may see combinations of laser with other palliative modalities to improve the chances of a symptom-free life for lung cancer patients.

INTRODUCTION

The majority of patients with lung cancer have advanced disease, and less than 15-20% are surgical candidates at the time of diagnosis.1-2 Most of these patients are incapacitated by severe endobronchial symptoms such as cough, dyspnea, and hemoptysis. Although inoperable and faced with a poor outcome, they require palliation to relieve their symptoms and improve their quality of life. One method for the treatment of centrally situated lesions is the use of endobronchial laser that has gained popularity over the last 15 years due to good results obtained from large trials.3,4 Neodymium: yttrium-aluminium-garnet (Nd: YAG) laser is currently the most popular among the various lasers available. Though laser gives best results in lesions of short length located in the trachea, mainstem or proximal lower lobe bronchi which are easily accessible to the rigid bronchoscope,4 the use of flexible bronchoscope has expanded the reach to more distal lesions. Laser resection provides significant and rapid improvement in the patient’s symptoms, and is at least equally effective, if not more, as other palliative methods like cryotherapy, photodynamic therapy and stent placement. Hence Nd-YAG laser bronchoscopic therapy is a valuable tool for the interventional bronchoscopist in the management of advanced lung cancer.3 This review is intended to keep the primary physician up to date with the broad principles of the use of laser therapy, including historical and technical aspects, in the palliative management of chest diseases, primarily lung cancer.

HISTORICAL BACKGROUND

The use of laser in bronchoscopy started almost three decades ago when Strong and Jako6 in 1972 used CO2 laser to treat various laryngeal disorders. The positive results encouraged them to expand its use for lesions below the vocal cords. They accomplished this by using an adapter to attach the CO2 laser to a rigid bronchoscope and thereby performed the first ever laser bronchoscopy. By the next year, their data of 70 laser procedures on 15 patients was published.7 This case series formed the solid base on which further technological advances in the field of laser therapy were made.

LaForet and colleagues8 were the first to use laser to resect an intraluminal endobronchial tumor. Though the initial results were good, it was soon discovered that CO2 had many shortcomings, such as a long wavelength of 10,600 nm requiring a complicated rigid delivery system, shallow depth of penetration and hence suboptimal hemostasis.9 Subsequently many different compounds were tried, such as Nd: YAG, potassium titanyl phosphate (KTP), Xenon-chloride and Argon (Table 1); soon it became clear that the Nd: YAG compound was far superior to the others, owing mainly to its short wavelength of 1064 nm, efficient photocoagulation due to good absorption by pigmented tissues, greater depth of penetration, excellent hemostasis4,10 and the capability of being used through a flexible bronchoscope in addition to the rigid instrument. These attributes gave enough confidence to bronchoscopists for using Nd: YAG not only in obstructing malignant lesions, but also for benign tumors, tracheal stenosis and even for removal of granulation tissue. Large case studies by Toty et al11 and Dumon et al12 demonstrated good results with minimal complications and further cemented the role of Nd: YAG laser in interventional bronchoscopy.

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Table 1: Commonly used medical lasers

<table>
<thead>
<tr>
<th>Laser</th>
<th>Wavelength (nm)</th>
<th>Characteristics</th>
<th>Advantages/Disadvantages</th>
</tr>
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<tbody>
<tr>
<td>Nd: YAG</td>
<td>1064</td>
<td>Invisible, absorption proportional to tissue pigmentation</td>
<td>Deep tissue penetration with excellent hemostasis, can be used with flexible scope</td>
</tr>
<tr>
<td>KTP</td>
<td>532</td>
<td>Green light; low absorption in water</td>
<td>Delivery via flexible scope possible; more precise cutting than Nd: YAG; useful in endoscopic sinus surgery</td>
</tr>
<tr>
<td>CO₂</td>
<td>10600</td>
<td>Invisible; complicated delivery system required; poor haemostatic effect</td>
<td>Precise cutting but more bleeding; only possible via rigid scope</td>
</tr>
<tr>
<td>Argon</td>
<td>488-514</td>
<td>Blue-green; good affinity for hemoglobin</td>
<td>Useful for small cutaneous and retinal vessel coagulation; needs contact with tissue for resection</td>
</tr>
<tr>
<td>Xenon-chloride</td>
<td>400</td>
<td>Precise cutting without much scatter</td>
<td>Delivery via flexible scope possible; useful in corneal surgery, angioplasty</td>
</tr>
</tbody>
</table>

Table 2: Choice of lesions amenable to laser therapy

<table>
<thead>
<tr>
<th></th>
<th>Favourable lesions</th>
<th>Unfavorable lesions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confined to trachea and main bronchi</td>
<td>Upper lobe and distal lesions</td>
<td></td>
</tr>
<tr>
<td>Short length, polyoidal</td>
<td>Long tapering obstruction</td>
<td></td>
</tr>
<tr>
<td>Distal lumen visible and functioning lung distal to obstruction</td>
<td>Total obstruction with chronic distal collapse</td>
<td></td>
</tr>
<tr>
<td>Large endobronchial component</td>
<td>Extrinsic compression or extensive submucosal disease</td>
<td></td>
</tr>
</tbody>
</table>

**LASER PHYSICS**

Laser is an acronym for Light Amplification by Stimulated Emission of Radiation. In simpler language, lasers are devices that produce light that gets transformed into heat upon interacting with living tissue. Three properties differentiate laser light from naturally occurring light:

1) **Monochromaticity**: the laser light contains only one color or a narrow band of wavelengths, unlike natural light that is a blend of various wavelengths.

2) **Spatial coherence**: laser light hardly diverges and maintains its intensity as it travels forward.

3) **Temporal coherence**: The packets of energy travel in uniform time with equal alignment.

The effect of laser on the tissue depends on several factors, such as the power settings and wavelength employed, distance of the laser tip from the target, duration of impact and certain physical characteristics of the tissue, mainly its color, surface, and water content. The term power density (in watts per square centimeter) is used to describe the amount of energy delivered to the tissue, and it determines whether the laser will simply cut, photocoagulate or vapourize. Hence the desired effect on the tissue can be achieved by either changing the power settings or by simply changing the distance of the laser tip from the target. The Nd: YAG laser can penetrate upto 5-10 mm from the focal point and coagulate blood vessels upto 5 mm in diameter, making it an ideal choice for large vascular tumours. However, laser energy has a tendency to scatter and damage the adjoining tissues. Reducing the duration of impact and giving short energy bursts of 0.5 second each instead of a continous beam can minimize this complication.

**INDICATIONS**

It is now clear that relief of central airway obstruction by intraluminal growths, either malignant or benign, constitute the primary indication for this procedure. These comprise more than two-third of the patients in most published series. Squamous cell and adenocarcinomas are the most common, followed by bronchial adenoma and carcinoids (where laser may even be curative). Patients who are not surgical candidates or those who refuse surgery may also be offered laser therapy. The common metastatic lesions involving the airway, such as the thyroid, colon, kidney, esophagus and melanoma may also be subjected to this form of treatment. Other benign lesions like lipomas, papillomas, hamartomas, granulation tissue and endobronchial amyloidosis are also amenable to laser.

Another common indication for laser usage is in the treatment of tracheal and bronchial stenosis which may occur as a result of endotracheal intubation or tracheostomy or as a consequence of systemic disorders such as sarcoidosis, tuberculosis and Wegener’s granulomatosis. The laser is applied prior to mechanical dilatation using a rigid bronchoscope or balloon; however, distortion of the airway and scarring are frequent complications. Lasers are also used to cut metallic stents and foreign bodies prior to their removal and to close small proximal bronchopleural fistulae occurring after lung resection. Several patients with post obstructive pneumonia have had their source of obstruction removed by laser. The best results are seen in growths obstructing the larger airways, namely the trachea, mainstem bronchi and bronchus intermedius. The more distally we attempt to treat, less rewarding the result. Table 2 lists the favorable and unfavorable lesions for laser treatment.

**CONTRAINDICATIONS**

Contraindications are divided into those concerning the anatomical location of the obstruction and those related to the patients’ clinical condition. The main anatomic contraindications are: extrinsic lesions without endobronchial growth and lesions bordering or infiltrating adjoining vascular structures (e.g. pulmonary artery), esophagus or the mediastinum. Clinically, patients suitable for surgical resection,
those with unfavorable short-term prognosis, coagulation disorders, or total obstruction since 4-6 weeks or more are definite exclusion criteria for laser.

**Equipment**

Traditionally, the rigid bronchoscope has found greater favour compared to the flexible one for laser treatment and many large studies have reported good results using the rigid scope.\(^{10,30}\) This is probably due to the fact that the optical telescopes with the rigid bronchoscope offer better visualization than in the flexible instrument. Suctioning is also better through the rigid bronchoscope and bleeding can be better controlled. Furthermore, the chances of an airway fire, a dreaded complication of this procedure, are negligible using rigid bronchoscopes. In recent times, rigid bronchoscopes with special channels have been designed\(^{31,32}\) which allow suctioning while keeping the laser fiber in situ, something that is not yet possible in the flexible bronchoscope. All these advantages help to shorten the treatment time at each session. However, the main disadvantage of the rigid bronchoscope is the lack of training and experience with most pulmonologists and the fact that it can reach lesions upto the mainstem bronchi only.

In contrast, the flexible bronchoscope is well handled by most pulmonologists and has been used by many groups for laser therapy with reasonable success.\(^{33,34}\) It allows access to distally placed lesions, which a rigid scope cannot reach. There does not appear to be any significant difference in the survival rate or complication rate between procedures performed by the rigid or fiber optic instrument.\(^{35}\)

**Laser Bronchoscopy Procedure**

**Anesthesia**

The type of anesthesia used depends on whether a rigid, flexible or combined bronchoscopic delivery is planned. Combustible gases, such as halothane should be strictly avoided. Intravenous propofol supplemented with midazolam and fentanyl is a popular regimen.\(^{10}\) The inspired oxygen concentration (FiO\(_2\)) should be kept below 40%. Continuous monitoring of oxygen saturation by pulse oximetry is essential and should be maintained above 90%. Since Nd: YAG tends to be absorbed by pigmented lesions, the use of pigmented endotracheal tubes should also be avoided.\(^{36}\)

**Technique**

This procedure requires a combined team effort of the bronchoscopist, anesthetist, laser operator and the nurses. Nd: YAG laser bronchoscopy using a fiber optic bronchoscope can be performed on awake, spontaneously breathing patients. The instrument is passed transnasally or transorally and then the laser fiber is guided through it till the target lesion. Keeping the tip of the laser fiber at least 1 cm away from the tip of the bronchoscope\(^{36}\) and 4 to 10 mm from the lesion to be treated, the laser is fired in pulses of 0.5 to 1 second at energy settings between 20 and 40 watts. Initially, lower power settings are kept to photocoagulate the lesion and subsequent vaporization is done by gradually increasing the amount of energy delivered. The beveled end of the rigid bronchoscope can sometimes be used to shear off a portion of protruding tissue. The bronchoscopist should be able to vaporize a small lesion completely or cause sufficient sloughing off the tissue to be easily coughed out or removed using a biopsy forceps.

Bronchoscopy should be repeated 2-4 days later to assess the results of treatment. These sessions should be repeated every 2-4 days till maximum benefit is achieved. A complete response is defined as complete clearing of the tumor whereas a partial response is a reduction in tumor size or improvement in the smallest tracheobronchial diameter.\(^{37}\) Symptomatic improvement of the patient’s symptoms, improvement in pulmonary functions, resolution of atelectasis on chest radiograph and improved performance status as noted by dyspnea indices, are other parameters to gauge the success of this procedure.

**Complications**

Although laser bronchoscopy is not a procedure totally free of complications, it has an impressive safety record in most of the trials conducted till date, specially considering that majority of the patients had advanced illness with significant central airway obstruction. These procedures are usually well tolerated in experienced hands as is evident from several large series conducted over the last two decades\(^{12,16,19,30}\) where the complication rates ranged from 2.3% to 6.5%. The commonly encountered complications are listed below:

1) **Hemorrhage** is one of the most frequently reported complications.\(^{36,38}\) Usually it is mild persistent ooze from the tumor bed; however, certain tumors such as carcinoid, melanoma and renal cell carcinoma are more vascular and may bleed profusely. Massive hemorrhage greater than 250 ml is reported in 1% to 10% of cases.\(^{39}\) Management includes continuous suctioning, lavage with saline and epinephrine and photocoagulation of the surrounding tissue. If bleeding persists, selective embolization of the bleeding area can be considered. Although most hemorrhages subside with the above measures, accidental laser perforation of the major vessels like the pulmonary artery is uniformly fatal.\(^{40}\)

2) **Airway fire** is probably the most dreaded complication of laser therapy.\(^{41}\) This usually occurs when flammable material such as endotracheal tubes, flexible bronchoscope sheaths, suction catheters and laser fibers get ignited. So far, rigid bronchoscopes have never caused an endobronchial fire. This complication can be avoided by keeping the laser tip clean to minimize chances of self-ignition, removing all flammable objects from the laser path, avoiding combustible inhaled anesthetics, keeping the FiO\(_2\) below 50% and delivering laser pulses of 40W or less. In the event of a fire, the bronchoscope and all instruments should be immediately removed and the fire extinguished. The airway should then be reinspected and all debris removed; steroids, antibiotics...
and bronchodilators should routinely be administered. Scarring and stenosis are common long-term sequelae of endobronchial fires.32

3) **Airway perforation** is another rare, but dangerous complication. Perforation may occur either by a misdirected laser beam or due to mechanical rupture by a rigid bronchoscope. The posterior membranous portion of the trachea is particularly susceptible to rupture. The most important preventive strategy against perforation is to use minimum energy setting for short durations. The general recommendation is to fire 45 W energy for 0.5 seconds each.27,43 Furthermore, the energy should be directed parallel to the bronchial wall instead of an angle.

4) **Pneumothorax** may occasionally occur, either as a result of laser perforating the bronchial wall or due to a ruptured bleb in a hyperinflated lung.27

5) **Hypoxemia** is not an unexpected complication considering that all patients have a compromised airway. Irrespective of whether hypoxia occurs perioperatively or postoperatively, it needs to be corrected immediately because it can lead to life-threatening events like myocardial infarction and shock. Hypoxia may also be the result of bronchospasm or laryngospasm, and these should be treated before proceeding with the laser procedure. Maintaining a good pulmonary toilet and clear airways is the most important precaution against hypoxia.27

6) **Cardiac events**, like arrhythmias, hypotension and myocardial infarction, which were common in the past, are rarely seen now with better monitoring of cardiac rhythm and oxygen saturation.

Other complications reported include noncardiogenic pulmonary edema,44 focal pulmonary hyperinflation,45 airway scarring/stenosis46 and systemic or air embolism.47,48 Fortunately these are rare and can be prevented to a great extent by following the safety measures for bronchoscopic laser therapy as outlined by Dumon et al36 and Shapshay and Beamis.50 Some basic precautions are listed in Table 3. Endoscopic electrosurgery may prove to be a useful alternative to laser therapy in selected patients.51

**Table 3 : Safety precautions during laser resection:**

- Use lowest possible oxygen concentration during laser firing
- Avoid laser firing towards airway wall
- Remove all flammable material from the vicinity of the equipment
- Cover patient’s eyes with saline pads and aluminium foil
- All personnel in the room should wear goggles
- Perform frequent bronchial toilet to keep airway patent
- Avoid prolonged periods of apnea
- Use the laser sparingly; rely more on mechanical resection

**OUTCOME**

When Nd: YAG laser was first introduced, the results were so good that it was rapidly approved by the Food And Drug Administration as a therapeutic modality. Due to this reason, there are no long-term prospective studies comparing laser with other therapeutic options and all studies done so far are retrospective analyses of treated cases. Though the benefits of laser therapy are undisputed, the yardstick for gauging its efficacy differs in most case series. Since it is mainly a palliative procedure, survival time is not a suitable endpoint; instead, parameters such as relief of symptoms increase in airway caliber, quality of life assessments and freedom from the ventilator are better indicators of measuring successful laser therapy.29

Totty et al31 in a series published more than two decades ago, achieved good airway restoration in 164 patients with benign or malignant tumors, with two postoperative deaths. Shapshay et al52 performed 506 surgeries on 249 patients with central airway obstruction and reported satisfactory palliation in 85% of the subjects. Personne and co-workers50 reported the first large series in which they performed 2284 laser sessions on 1310 patients. 25% of their patients survived more than a year and more than half of all subjects had significant relief of airway obstruction, with an overall mortality of only 1.6%. Burtinel et al53 treated 116 patients of lung cancer with Nd: YAG laser, out of whom 83.4% had significant airway restoration. Tracheal lesions gave the best results followed by lesions in the mainstem bronchi. They were also successful in opening 57.7% of completely occluded airways. 60% of treated patients were alive at seven months compared to 100% mortality in a control group of 25 patients. Stanopoulos et al54 used this modality in 17 ventilated patients of lung cancer and successfully weaned off 9 patients who went on to live longer compared to the other 8 subjects who remained on ventilator. Ranser and Beamis55 performed 140 laser applications using the rigid bronchoscope on 100 patients and achieved significant symptomatic benefit in 85.7% of the cases with a complication rate of 6.5% and no mortalities. In the largest series till date, Cavaliere and colleagues reported their 13-year experience with 2008 patients having malignant airway obstruction in whom combined therapy of Nd: YAG, brachytherapy and stents were used.5 Out of 1838 patients who underwent laser resection, 93% obtained immediate symptomatic relief with an overall mortality rate of only 0.4%.

**SUMMARY**

Lung cancer remains a relentless plague for modern society. In spite of rapid medical advances, only 40% of newly detected lung cancers are potentially curable. Furthermore, recurrence rate is high after both radiation therapy55 and surgical resection56 and subsequent treatment by surgery, drugs or radiation is often limited by the poor general condition of the patient. Almost 90% of all lung cancer patients require treatment to relieve symptoms caused by the disease at some stage of their illness. In such a grim scenario, palliative relief of symptoms, especially related to endobronchial obstruction (cough, dyspnea, hemoptysis and recurrent post-obstructive pneumonia) is of paramount importance to permit a good quality of life. The neodymium: yttrium-aluminium-garnet (Nd:YAG) laser is a strong addition to the therapeutic armamentarium available to the interventional
Numerous studies have compared the efficacy of laser treatment of endobronchial lesions with other palliative modalities and found that laser bronchoscopy was superior with regards to the rapidity and degree of symptomatic relief, improvement in performance status, length of survival, quality of life and complication rate. With over twenty years of worldwide experience and numerous large case series pertaining to it, laser therapy is undoubtedly one of the safest and most effective modalities to alleviate central airway obstruction. The future may see better results by combining Nd: YAG laser with other technologies like argon plasma coagulation, cryotherapy and endobronchial electrosurgery, and may further help in making the patients' life much more comfortable.

REFERENCES