# General anaesthesia for Nd:YAG laser resection of obstructing endobronchial tumours using the rigid bronchoscope

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*Provision of general anaesthesia for patients undergoing Nd:YAG laser resection of obstructing endobronchial tumours using the rigid bronchoscope presents unique problems for the anaesthesiologist. We studied 15 patients who underwent 20 of these procedures under general anaesthesia. Patients were anaesthetized and ventilated with either potent inhalation agents via the side arm of the ventilating bronchoscope (Group I: N = 8), or with intravenous agents and the Sanders jet injector attached to the rigid bronchoscope (Group II: N = 12). Patients were paralyzed and ventilation was controlled. The inspired gas mixture was nitrogen and oxygen, and the $FIO_2$ was decreased to 0.3–0.4 during periods of resection. Group I patients had significantly higher peak $pCO_2$'s than Group II (8.3 kPa (62 mmHg) vs. 5.6 kPa (44 mmHg); lowest recorded $pO_2$'s were comparable and similar to pre-induction values. Both groups exhibited wide blood pressure fluctuations. Heart rates remained within 15 per cent of pre-induction levels. There were no intraoperative deaths, and no airway fires, massive haemorrhages or pneumothoraces. We conclude that these procedures can be undertaken with the use of general anaesthesia and the rigid bronchoscope, but that patients may encounter potentially serious respiratory or haemodynamic instability during the procedure.*

**Key words**

EQUIPMENT: laser, laser: Nd:YAG; SURGERY: bronchoscopy, bronchoscopy: rigid; VENTILATION: Venturi; MEASUREMENT TECHNIQUES: oximetry.

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Neodymium-yttrium-aluminium garnet (Nd:YAG) lasers have recently been used for the resection of obstructing tracheal and endobronchial lesions.[1-4] These lasers may be introduced through a fibreoptic instrument, and have favourable characteristics for use in the tracheo-bronchial tree. General anaesthetic techniques for these laser resections must address the problems anticipated in patients with significant large airway obstruction combined with the technical requirements of laser surgery. In this paper, we report our experience with the provision of general anaesthesia for Nd:YAG laser excision of obstructing endobronchial tumours via the rigid bronchoscope.

## Methods

Over a ten-month period, we performed 20 laser excisions of endobronchial tumours on 15 patients, using general anaesthesia. Procedures were undertaken according to a protocol approved by our Institutional Review Committee. All patients had dyspnoea at rest. Within 24 hours prior to the induction of anaesthesia, each patient underwent fibreoptic bronchoscopy under topical anaesthesia for evaluation and partial laser resection or coagulation of their lesion.[4] Patients selected for laser resection through the rigid bronchoscope had large obstructing tracheal or bronchial tumours. Extensive debulking of these tumours using fibreoptic bronchoscopy and topical anaesthesia alone is tedious, time consuming, and tolerated poorly by some patients. The use of the rigid bronchoscope enabled the operators to coagulate the bases of these tumours with the laser, and then remove large bulk pieces of tumour with biopsy forceps placed through the rigid bronchoscope. The use of general anaesthesia insured airway control and increased patient comfort during these extensive procedures.

*Equipment*

All procedures were performed using the MediLas 2 Nd:YAG laser (Angewandte Technologie, Federal Republic of Germany). The laser light guide was inserted through the working channel of a 6.0 mm fibreoptic bronchoscope (Olympus ITR, Olympus Corporation, Tokyo) or through a specially incorporated flexible deflector built into the 8.5 mm ventilating bronchoscope (Storz Instrument Company, St. Louis, Mo.). The fibreoptic bronchoscope was introduced through the ventilating bronchoscope, which was modified for both side-arm and Sanders jet ventilation.

An air-oxygen blender (Bennett Corporation, Los Angeles, Ca.) with both high (50 PSI) and low pressure outlets was arranged so that the low pressure air-oxygen flow from the blender was diverted through mounted vapourizers and through a standard circle system. An oxygen analyzer (Instrumentation Laboratory, Andover, MA) was placed proximally on this line. The high pressure outlet was connected directly to the Sanders injector attached to the rigid bronchoscope. A single dial on the blender controlled the oxygen concentration of both the high and low pressure gas lines.

*Anaesthetic technique*

Selection of anaesthetic technique was determined by availability of equipment and personal preference of the attending anesthesiologist. Patients received either a potent inhalation agent or intravenous agents for maintenance anaesthesia, depending on whether they were ventilated using the side-arm of the bronchoscope (Group I), or the Sanders injector (Group II), respectively. All patients received anticholinergic premedication. Analgesics and sedatives were withheld until the patient's arrival in the bronchoscopy suite. Standard monitoring included five lead EKG, precordial stetheoscope, peripheral nerve stimulator, and an oscillotonometer. An indwelling arterial cannula for blood pressure monitoring and frequent sampling of arterial blood was placed prior to or shortly after induction of anaesthesia. After insertion of an intravenous catheter, the patient was given 100 per cent oxygen by mask, and general anaesthesia was induced using a combination of intravenous and inhalation agents. After satisfactory ventilation was established using a mask, a succinylcholine infusion or an intubating dose of pancuronium (0.08 $mg \cdot kg^{-1}$) was administered. The rigid bronchoscope was introduced under direct vision, and adequacy of ventilation was assessed through visual inspection of chest excursion, and auscultation. In those patients ventilated through the side-arm of the ventilating bronchoscope (Group I), ventilation was done by hand, and anaesthetic depth was controlled by varying the concentration of inspired inhalation agent in the air-oxygen mixture. In those patients ventilated using the Sanders injector (Group II), depth of anaesthesia was controlled using intermittent bolus injections or continuous infusion of thiopentone, along with intermittent bolus injections of fentanyl. If coughing was a persistant problem, intermittent bolus injections of lidocaine were given, and patients who exhibited signs of awareness in spite of the thiopentone infusion were occasionally given small doses of diazepam or

TABLE I Pre-induction comparison of sidearm (Group I) vs. Sanders (Group II) patients

| *Variable* | *Group I* | *Group II* |
|---|---|---|
| Number of procedures | 8 | 12 |
| Site of obstruction | | |
| Trachea | 4 | 6 |
| Mainstem bronchus | 4 | 6 |
| Age (years) | 70 ± 7 | 66 ± 12 |
| $pO_2$ (kPa) | 10.2 ± 3.2 | 8.8 ± 1.6* |
| (mmHg) | 76 ± 24 | 66 ± 12 |
| $pCO_2$ (kPa) | 4.7 ± 0.9 | 5.1 ± 0.8* |
| (mmHg) | 35 ± 7 | 38 ± 6 |
| Systolic blood pressure | | |
| (kPa) | 21.5 ± 4.4 | 19.0 ± 4.3 |
| (mmHg) | 161 ± 33 | 142 ± 32 |
| Heart rate (beats/minute) | 101 ± 20 | 94 ± 13 |

Mean ± S.D.
*N = 10. Two Group II patients did not have pre-induction blood gas determination.

droperidol to promote amnesia. Additional muscle relaxant was given according to train of four response and surgical requirements.

The patients were ventilated with 100 per cent oxygen through the bronchoscope until the operator indicated he would be activating the laser in the next five minutes. At this point, the oxygen concentration flowing from the blender was reduced to between 30 and 40 per cent, and remained at this level until laser resection ceased, or hypoxemia, as determined by cyanosis or arterial $pO_2$ of $< 8$ kPa (60 mmHg) occurred. Hypoxemia was treated by cessation of laser resection, repositioning of the bronchoscope, and increasing the $FiO_2$, if possible.

At the conclusion of the procedure, neuromuscular blockade was reversed, the bronchoscope removed, and patients were evaluated for respiratory adequacy and wakefulness. Patients who still exhibited marked respiratory dysfunction were intubated and mechanically ventilated. Patients who were awake at the conclusion of the procedure with satisfactory respiratory mechanics and gas exchange remained extubated and were transported to the recovery room. Humidified oxygen and intravenous steroids were administered, and the patients were transferred to the intensive care unit for overnight observation.

*Data collection*

All patients had baseline heart rate and systolic and diastolic blood pressure values recorded prior to induction. Eighteen patients had pre-induction blood gas determinations. Blood pressure and heart rate were recorded at least every five minutes during the course of anaesthesia. Arterial blood gasses were obtained after the establishment of ventilation through the bronchoscope with the patients receiving 100 per cent $O_2$, and five minutes after each time the inspired concentration of oxygen was decreased for laser activation. Blood gasses were then obtained every thirty minutes if the inspired oxygen concentration remained constant.

Data were analyzed using Student's t test for unpaired data and Chi-square analysis. P values of less than 0.05 were considered significant.

**Results**

Data were obtained for fifteen patients who underwent 20 procedures. The mean patient age was 67 ± 11 years. The mean duration of the procedures was 104 ± 39 minutes. All but two procedures involved malignant lesions.

Table I compares age, site of obstruction, and pre-induction values of respiratory and haemodynamic variables between the two groups. Groups were similar in all respects. Four patients in Group I and three patients in Group II were receiving supplemental oxygen prior to induction, and one patient in each group had been intubated prior to arrival in the bronchoscopy suite because of respiratory distress.

Table II summarizes the anaesthetic technique and operative course of both groups of patients. Group II patients had a significantly longer duration of resection than did Group I. Mean lowest $pO_2$'s were higher than pre-induction values in both groups. Mean peak $pCO_2$ increased markedly over control in the Group I patients, and this increase was significantly greater than Group II. Systolic blood pressures fluctuated widely in both groups. It was our clinical impression that Group I patients tended to become hypotensive, and Group II patients hypertensive, during these procedures, but we were not able to show any statistical significance between groups in this regard. Heart rates remained within 15 per cent of pre-induction values.

Table III summarizes the incidence of critical perioperative events not described in Table II. Six patients had documented intraoperative hypoxemia. One patient had an intraoperative $pO_2$ of 3.3 kPa (25 mmHg), another a $pO_2$ of 5.6 kPa (42 mmHg). Three patients in each group had at least one $pCO_2 > 7.3$ kPa (55 mmHg) during the procedure. one patient had a peak $pCO_2$ of 16.2 kPa (122 mmHg), and two others had $pCO_2$'s of 11.2 kPa (84 mmHg) and 11.8 kPa (89 mmHg) respectively. Three patients had marked hypoxemia and hypercarbia during the procedure.

There were no intraoperative deaths and all patients were discharged from the hospital, most with subjective and objective improvement in their respiratory status. Complications were uncommon. Three patients had some recall of intraoperative events; all had been ventilated with the Sanders injector and had received only intravenous agents for maintenance anaesthesia. Two patients went into atrial fibrillation the first postoperative day; both had a history of atrial fibrillation, but were in sinus rhythm at the time of bronchoscopy. One patient sustained a corneal abrasion. There was no

TABLE II Intraoperative comparison of sidearm (Group I) vs. Sanders (Group II) patients

| *Variable* | *Group I* | *Group II* | *Statistical significance* |
|---|---|---|---|
| Maintenance anaesthetic | Inhalation* | Intravenous† | |
| Duration of procedure (minutes) | 83 ± 39 | 119 ± 32 | $p < 0.05$ |
| Lowest $pO_2$ kPa | 11.1 ± 6.0 | 9.7 ± 3.3 | NS |
| mmHg | 83 ± 45 | 73 ± 25 | |
| Highest $pCO_2$ kPa | 8.3 ± 3.5 | 5.9 ± 2.4 | $p < 0.05$ |
| mmHg | 62 ± 26 | 44 ± 18 | |
| Highest systolic blood pressure (SBP) | | | |
| kPa | 22.0 ± 2.5 | 22.7 ± 3.2 | NS |
| mmHg | 165 ± 19 | 170 ± 24 | |
| Lowest SBP | | | |
| kPa | 15.3 ± 3.7 | 15.2 ± 1.7 | NS |
| mmHg | 115 ± 28 | 114 ± 13 | |
| Highest heart rate (HR) | | | |
| (beats/minute) | 112 ± 16 | 105 ± 13 | NS |
| Lowest HR | 87 ± 16 | 87 ± 16 | NS |

Data are expressed as mean ± S.D.
*Halothane – 4 patients; Isoflurane – 3 patients; Enflurane – 1 patient.
†Enflurane was used to supplement intravenous anaesthesia in two Group II patients.

occurance of penumothorax, significant haemorrhage or airway fire in this series.

## Discussion

General anaesthesia for laser resection of endobronchial tumours requires techniques particular to this patient population and surgical procedure. These patients are generally elderly and have severe respiratory disease. Additional anaesthetic considerations include the necessity for a shared airway, the elimination of nitrous oxide and high concentrations of oxygen from the inspired gas mixture because of the risk of airway fire, and the need to provide an immobile field to allow accurate use of the laser beam.

TABLE III Comparison of sidearm (Group I) vs. Sanders (Group II) patients for occurance of critical perioperative events

| *Event* | *Group I (N = 8)* | *Group II (N = 12)* |
|---|---|---|
| Intraoperative $pO_2 < 8$ kPa (60 mmHg) | 2 | 4 |
| Intraoperative $pCO_2 > 7.3$ kPa (55 mmHg) | 3 | 3 |
| Intraoperative $pO_2 < 8$ kPa and $pCO_2 > 7.3$ kPa | 1 | 2 |
| Increase in systolic blood pressure (SBP) > 25% pre-induction | 2 | 3 |
| Decrease in SBP > 25% Below pre-induction | 6 | 3 |
| Increase in heart rate (HR) > 25% pre-induction | 3 | 2 |
| Decrease in HR > 25% Below pre-induction | 1 | 0 |
| Postoperative intubation, no preop tube | 2 | 1 |
| Intraoperative recall | 0 | 3 |

Our experience with this procedure confirms the findings of others that laser resection of endobronchial tumours can be conducted successfully under general anaesthesia.[1-3] We have also shown that respiratory and haemodynamic instability occurred in some patients.

Possible explanations for the hypoxemia seen in this series includes the presence of underlying pulmonary disease, along with the well known ventilation–perfusion abnormalities induced by anaesthetic agents, positive pressure ventilation, and manipulation of the airway.[8] The bronchoscope may be passed entirely down one bronchus during the resection, thus producing one lung ventilation and possible shunting. Ventilation abnormalities may be secondary to obstruction of the bronchoscope by tumour or bronchus. This latter effect can be attenuated through the use of a ventilating bronchoscope with side vents. The consequences of these possible derangements in normal respiratory function are accentuated in this procedure because of the requirement to limit the inspired oxygen concentration during periods of laser resection. The combination of light anaesthesia, pre-existing cardiovascular disease, intraoperative blood gas derangements and continual airway stimulation all may account for the haemodynamic instability experienced by our patients.

Since our process to select the anaesthetic technique was not designed to rigourously compare side-arm versus Sanders ventilation, we cannot make definite statements about a preferred technique. Our data show comparable oxygenation and superior ventilation in the Sanders ventilated group, a finding confirmed in the literature concerning this technique.[6,9] The major disadvantage of the Sanders injector for prolonged bronchoscopy is the inability to use potent inhalation agents for maintenance anaesthesia. Recall during bronchoscopic procedures under intravenous anaesthesia and paralysis has been reported by others, and emphasizes the need for amnesia, as well as analgesia and immobility, with this technique.[6,10] Although the use of inhalation agents in these patients might decrease awareness and has been reported with the Sanders injector, we found the operating room pollution unacceptable with this technique, and have abandoned it.[7]

Based on our experiences reported here, we have adopted the following technique of general anaesthesia for this challenging group of patients:

1 Premedication consists of anticholinergics only. Intravenous doses of diazepam, droperidol, or scopolamine are given prior to induction of anaesthesia to promote amnesia and sedation, but during the preoperative visit patients are still warned about possible intraoperative awareness.
2 Anaesthesia is induced with a combination of thiopentone (2–4 $mg \cdot kg^{-1}$), fentanyl (4–8 $\mu g \cdot kg^{-1}$), lidocaine (2 $mg \cdot kg^{-1}$) and a non-depolarizing muscle relaxant, and maintained using a thiopentone infusion titrated to decrease the patient response to stimulation while maintaining a satisfactory blood pressure and heart rate. Most patients receive between 500 and 800 mg of thiopentone for a 90 minute procedure. Although this technique may result in somnolence at the conclusion of the procedure that may be greater than that seen with the use of inhalation agents,[5] we feel that the advantages of performing this procedure with Venturi ventilation and the rigid bronchoscope outweigh the small disadvantages of intravenous anaesthesia. Muscle relaxant is given as needed.
3 Ventilation is accomplished using the Sanders injector. This enables the operator to work freely through the open end of the bronchoscope without disrupting ventilation, allows adequate removal of the large quantities of smoke generated in the airway during the procedure, and eliminates the need for an endotracheal tube, thus decreasing the risk of airway fire. We ventilate between 12 and 20 times a minute, and have encountered minimal difficulty with airway motion secondary to the movement of pressurized gasses.[11]
4 Oxygenation is monitored continuously with the use of a pulse oximeter (Nellcor Inc., Hayward, CA.[12] Continuous oxygen saturation monitoring with an oximeter has been shown to be an accurate and useful indicator of arterial saturation in this procedure.[3,5] Continuous monitoring enables the anaesthetist to detect hypoxemia rapidly and to intervene without delay. Serial blood gas analysis is still useful to assess adequacy of ventilation, since end tidal gas samples for capnography are not feasable when an open ended bronchoscope is used.
5 The oxygen concentration of the gas driving the Sanders injector is decreased to about 40 per cent during periods of laser resection, even though entrainment of room air decreases the $FiO_2$ even further. Although the absence of an endotracheal tube may make an airway fire less likely, charred material in the airway may still be ignited in the presence of high concentrations of oxygen. We therefore endeavour to keep the $FiO_2$ as low as is compatible with an arterial saturation of $> 90$ per cent during periods of resection.
6 Hypertension and tachycardia not thought to be secondary to hypoxemia, hypercarbia, inadequate anaesthesia or awareness is treated with vasodilators and beta-blocking agents.

In summary, our experience in the provision of general anaesthesia for 20 of these procedures reveals that some patients will experience intraoperative episodes of hypoxemia, hypercarbia and haemodynamic instability. Airway fires, massive haemorrhage and barotrauma are all possible intraoperative catastrophes that may occur with this procedure. Successful anaesthesia for these patients requires close co-operation between bronchoscopist and anesthetist, and an appreciation by both of the surgical requirements, anaesthetic difficulties and physiologic derangements likely to be encountered during this procedure.

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## Résumé

*On a commencé depuis quelque temps à employer le laser Nd:YAG (néodymium-yttrium-aluminium garnet) pour la résection de tumeurs endobronchiques obstructives. L'administration d'anesthésie générale pour ce type de résection, qui s'effectue à l'aide d'un bronchoscope rigide, présente des problèmes particuliers pour l'anesthésiologiste. Nous avons étudié 15 patients qui ont subi 20 résections de ce type sous anesthésie générale. Deux techniques différentes ont été employées: huit patients (groupe I) ont reçu un agent d'inhalation puissant administré par l'orifice latéral du bronchoscope par où s'est aussi effectuée la ventilation. Douze patients (groupe II) ont reçu des agents anesthésiques intraveineux et des relaxants musculaires. Ils ont été ventilés à l'aide d'un injecteur à jet Sanders. Un mélange de gaz contenant de l'azote et de l'oxygène a été administré et le* $FIO_2$ *a été réduite à 0.3–0.4 durant les périodes de résection active. Les patients du groupe I ont montré une pointe de* $PCO_2$ *plus élevée que ceux du groupe II (8.3 kPa (62 mmHg) vs 5.6 kPa (44 mmHg); les* $PO_2$ *les plus basses qu'on a enregistrées étaient de valeur comparable entre les groupes et non différentes des valeurs pré-opératoires. Dans les deux groupes on a observé des variations marquées de la pression artérielle. Les fréquences cardiaques n'ont pas varié de plus de 15 pour cent des fréquences pré-opératoires. On n'a déploré aucune mort per-opératoire, ni incendie des voies aériennes, ni hémorragie massive, ni pneumothorax. Nous en concluons que ces résections peuvent s'effectuer sous anesthésie générale avec l'aide d'un bronchoscope rigide en reconnaissant que ces patients peuvent présenter une instabilité respiratoire ou hémodynamique importante durant l'intervention.*