Anesthesia for Endobronchial Laser Surgery: A Modified Technique

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We describe a technique for endobronchial surgery with the neodymium:yttium-aluminum-garnet laser, in which an insufflation catheter with side holes placed into the contralateral mainstem bronchus is used for high-frequency positive pressure ventilation. Thirty-five patients (45 procedures) were treated during general anesthesia using a rigid bronchoscope in combination with a fiberoptic bronchoscope. Perioperatively, oxygen saturation (Sao_2), mean arterial pressure, and heart rate were recorded. Sao_2 during the recovery period was comparable to that during the intraoperative period but was significantly ($P < 0.05$) higher than that before the induction of anesthesia. There was a considerable (≥5%) increase in Sao_2 at the end of the treatment in six patients, which indicates that the recanalization of the treated airway was successful. Our data support the assumption that, during endobronchial resection, selective ventilation of the nonaffected lung was adequate; in addition, subcarinal placement of the insufflation catheter with side holes was advantageous. We conclude that this technique contributes to the prevention of lung complications during endobronchial laser surgery. **Implications:** We describe a technique in which an insufflation catheter with side holes placed into the contralateral mainstem bronchus largely prevented inhalation of laser smoke and aspiration of blood and debris.

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Using the neodymium:yttium-aluminum-garnet laser during endobronchial surgery presents specific problems to the patient (1). Most authors prefer a combination of the rigid bronchoscope (RB) with the fiberoptic bronchoscope (FOB) during general anesthesia (GA) (2–6). The argument in favor of GA is that it permits the use of the RB, which provides superior control of the airways in the event of hemorrhage and allows tissue removal by mechanical means.

The main hazards during this procedure are fire, major hemorrhage, aspiration of debris into the lungs, barotrauma, pulmonary venous gas emboli, and bronchial irritation due to laser smoke inhalation (7–10). We describe a technique in which some of these complications are largely prevented.

Methods

We studied 35 patients (45 procedures), 12 female and 23 male, aged 26–83 (mean 57) yr, ASA physical status I–IV, who were scheduled for treatment of obstructive lesions distal to the carina.

The clinical indication for recanalization was a history of dyspnea, hemoptysis, coughing, or a combination of these. Criterion for the procedure was that the lesion should be endobronchial. We treated benign lesions (5 lipoma, 1 hamartoma), primary lung tumors (10 squamous cell carcinoma, 1 adenocarcinoma, 7 large cell undifferentiated carcinoma, 3 small cell lung carcinoma, 1 carcinoid), and metastatic tumors (4 hypernephroma, 1 leiomyosarcoma, 1 melanoma, 1 rectum carcinoma). Table 1 lists the topography of the lesions.

Supplementary preoperative evaluation included bronchoscopy and, if indicated, lung function tests and blood gas analysis. Premedication consisted of midazolam (2.5 mg IM) and atropine (0.5 mg IM) 30 min before the intervention; dexamethasone (20 mg IV) was administered to prevent edema of the airways and to promote detumescence of the treated lesion. After placement of standard monitors, IV anesthesia was induced with propofol at a rate of 6–9 $mg \cdot kg^{-1} \cdot h^{-1}$ after a bolus of 2 mg/kg and alfentanil 1 mg followed, as needed, by a dose of 0.5 mg. Muscle relaxation was achieved with vecuronium bromide 0.1 mg/kg. High-frequency positive pressure ventilation (HFPPV) was performed using

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Table 1. Topography of the Endobronchial Lesions in Patients Undergoing Neodymium:Yttium-Aluminium-Garnet Laser Treatment

Recanalization	Patients	Procedures
Right mainstem bronchus	21	26
Left mainstem bronchus	8	12
Left upper lobe bronchus	2	3
Left upper and lower lobe bronchus	1	1
Right upper lobe bronchus	3	3

n = 35 patients, n = 45 procedures.

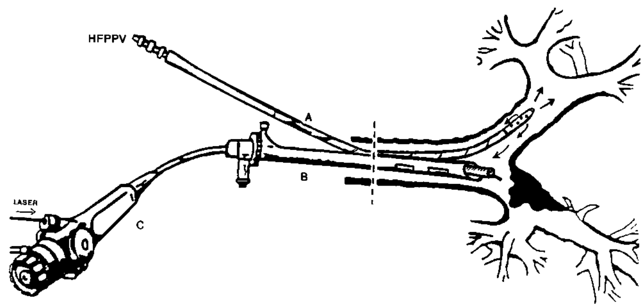

Figure 1. Ventilation during endobronchial laser surgery. A, High-frequency positive pressure ventilation (HFPPV) insufflation catheter with side holes, wrapped with aluminum tape. B, Rigid bronchoscope with suction outlet for gases. C, Flexible bronchoscope with inside neodymium:yttium-aluminum-garnet laser approaching the lesion.

an AMS 1000 Universal Jet Ventilator (Acutronic Medical System AG, Hirzel, Switzerland): driving pressure (DP) 1125–1350 mm Hg (1.5–1.8 bar), frequency (f) 100 breaths/min, inspiratory time (T_i) 30%; the end-expiratory pressure alarm limit was set at 15 cm H_2O. The fraction of inspired oxygen (FIO_2), supplied with an air-to-oxygen mixer, was set at 0.4.

Under control of the FOB, a polyvinylchloride 14 Ch insufflation catheter with side holes and open distally was advanced orally into the contralateral bronchus 3 cm distal to the carina; to facilitate positioning and to prevent kinking and displacement, the insufflation catheter was wrapped with aluminum tape. The lesion was then approached with the RB (inner diameter 9 mm). The treatment consisted of a combination of laser coagulation and use of biopsy forceps (Figure 1). Before each use of the laser (power 20–40 W; exposure time 0.5–1s), the FIO_2 was decreased to 0.21 to reduce the risk of fire; when SaO_2 decreased to 90%, we interrupted the procedure and ventilated the lungs with 100% oxygen until a normal SaO_2 was restored. At the end of the session, a chest radiograph was taken for each patient. Patients were discharged from the postoperative care unit only when SaO_2 was equal to or higher than the preinduction values.

At various time points during the procedure, mean arterial pressure (MAP), heart rate (HR), and SaO_2 were compared using analysis of variance (ANOVA). In this analysis, proper allowance was made for inter- and intraindividual differences; a P value $\leq$0.05 was considered significant. Values are given as mean $\pm$ SEM.

Results

Anesthesia duration was 30–220 (mean 117) min. With the exception of one case complicated by massive bleeding, the procedures could be performed as planned.

Two patients required ephedrine (7.5 mg IV) after an initial decrease in blood pressure. Another patient developed atrial fibrillation, which was successfully treated with digoxin. In the peroperative period, the entire patient group was hemodynamically stable.

Compared with the preinduction value (Table 2), a significant increase in mean SaO_2 was found at all time points after the induction of GA. There was no significant difference in mean SaO_2 values during and after surgery. In 31 procedures, mean values for PaO_2 and for $PaCO_2$ during laser resection were within the normal range. In some cases, an increased $PaCO_2$ was likely caused by compression of the airways by manipulations with the RB because, in these circumstances, the ventilation automatically stops when the end-expiratory pressure reaches the alarm limit.

Postoperatively, six patients had a considerable ($\geq$5%) increase in SaO_2 compared with the baseline value. This was probably due to better ventilation of the treated lung after successful recanalization.

Two cases were complicated by a pneumothorax without significant oxygen desaturation. The first occurred on the side of the lesion and was attributed to the laser beam, the second occurred on the side of the ventilated lung and was attributed to barotrauma. In both patients, a pleural drain was inserted.

One patient suffering from a giant lung carcinoma of the right upper lobe and scheduled for recanalization of the right mainstem bronchus developed a major hemorrhage at the end of the resection. The operating table was immediately adjusted to a head-down position; the FIO_2 was set at 1. After almost 2 h, the bleeding was controlled by occluding the right upper lobe bronchus with the inflated cuff of a 7.5F thermodilution catheter and by compression with tampons soaked with epinephrine. Blood loss (1500 mL) was adequately replaced; there was no significant change in MAP and HR. During the procedure, which lasted 220 min, pulse oximetry mean SaO_2 (98%) remained unchanged. The arterial blood gas analysis performed during the period of hemorrhage showed pH 7.15, PaO_2 158 mm Hg, $PaCO_2$ 72 mm Hg, base excess −5.1 mEq/L, HCO_3 24 mEq/L, and SaO_2 98%. Because of the risk of barotrauma, we did not increase the driving pressure to correct the respiratory acidosis. During the period of hemostasis, the endoscopist confirmed that blood was blown up from the operation field and did not spread to the contralateral lung.

Table 2. Data on Mean Arterial Pressure (MAP), Heart Rate (HR), and Oxygen Saturation (SaO_2) During 45 Procedures

	A	B	C	D	E
MAP (mm Hg)	99.7 ± 2.5	84.1 ± 3.1	86.3 ± 2.2[a]	84.3 ± 2.1	92.5 ± 2.4[b]
HR (bpm)	91.3 ± 2.4	87.3 ± 2.7	86.0 ± 2.5[a]	81.2 ± 2.8	75.3 ± 2.8[b]
Sao_2 (%)[c]	94.6 ± 0.7	96.4 ± 0.6	95.8 ± 0.5[a]	96.1 ± 0.5	95.9 ± 0.4[b]
Pao_2 (mm Hg) ($n = 31$)			98 ± 8		
$Paco_2$ (mm Hg) ($n = 31$)			43 ± 2		

Values are mean ± SEM.
A = preinduction value, B = after induction of general anesthesia, C = during endobronchial laser surgery, D = end of the procedure, E = 1 h after extubation.
[a] Values obtained during endobronchial laser surgery have first been averaged for the separate procedures.
[b] One procedure was excluded from data analysis, because the patient needed mechanical ventilation.
[c] Values were obtained in A and E while breathing room air, in B and D during high-frequency positive pressure ventilation (FIO_2 0.4); in C during high-frequency positive pressure ventilation (FIO_2 0.21-1).

When the bleeding stopped, a cuffed endotracheal tube (size 8) was inserted into the left main bronchus. Postoperative arterial blood gas analysis showed restored ventilation. The left lung was mechanically ventilated for 3 days; during this period, the right bronchial artery was embolized, followed by extubation. Unfortunately, 4 days later, during a coughing attack, the patient died from hemoptysis. Autopsy was not allowed.

Discussion

Eriksson and Sjöstrand in 1977 (11) and Sjöstrand in 1980 (12) described the gas flow pattern of the insufflation catheter with side holes and its clinical application during HFPPV.

An interesting observation of their studies was that the flow of the gases through the side holes generates an upward stream. Consequently, placement of the insufflation catheter into the trachea during upper airway surgery prevents aspiration of blood and debris and clears the operation field from laser smoke. This phenomenon is not present during high-frequency jet ventilation, in which, on the contrary, the flow through the injector causes air entrainment (Venturi effect).

During endobronchial laser surgery, protection of the nonaffected lung is a *sine qua non* condition to prevent deterioration of the lung function. The upward stream of the gases through the side holes of the insufflation catheter prevents entrainment of smoke and aspiration of blood and debris. Smoke irritates the bronchial mucosa and can provoke bronchospam or aspiration of blood or debris and can cause death from asphyxia.

In the case of a major hemorrhage, the anesthesiologist should immediately adjust the operating table to a head-down position. With regard to ventilation, there are two options: to continue or to stop. Continuing ventilation will facilitate the spread of blood to the distal airways; if ventilation is discontinued, the patient will develop hypoxemia. An insufflation catheter with side holes placed into the mainstem bronchus anticipates this complication.

One point of discussion concerning this method is that the subcarinal position of the insufflation catheter allows gas exchange in the contralateral lung mostly by diffusion. For tumors that obstruct the mainstem bronchus, the choice to introduce the insufflation catheter proximal or distal to the carina has no clinical significance because the affected lung does not participate in the gas exchange; when the lesion involves a lobar bronchus, the RB advanced into the mainstem bronchus, together with the FOB, occupies the airway such that convection of gases to the affected lung is impeded.

The subcarinal position of the insufflation catheter increases the risk of barotrauma in the ventilated lung because, maintaining the same ventilatory pattern, dead space will be reduced and the alveolar volume enlarged. In addition, the air trapping characteristic of high-frequency ventilation techniques causes lung hyperinflation by an increase of the functional residual capacity above the apneic period. This phenomenon, which is more sustained in patients with large lung compliance and high airway resistance, can be limited by lowering the DP, f, and T_i, because these reduce the tidal volume and prolong the expiratory time (13). To minimize the risk of barotrauma, we adjusted the DP to a lower level (we routinely ventilate the lungs at a DP of 1350–1800 mm Hg or 1.8–2.4 bar) and reduced T_i from 40% to 30% at an f of 100 breaths/min. Nevertheless, in one patient suffering from chronic obstructive pulmonary disease, we could not prevent the development of pneumothorax. This again stresses that patients with chronic obstructive pulmonary disease are at risk of barotrauma using high-frequency ventilation techniques.

The development of bronchoconstriction from laser smoke (8,10) is speculative; it is well established that this inhalation depresses mucociliar function and decreases Pao_2. Aspiration of small debris is a minor complication because debris can be easily removed with biopsy forceps; in contrast, a dislodged tumor into the bronchus can seriously impede ventilation (4). In large and small studies using different techniques, patients have died on the operating table during massive hemorrhages (2,3,5). In our study, we observed that the ventilated lung is kept clean from laser smoke and debris; in one case complicated by massive hemorrhage, we could prevent asphyxia.

During endobronchial laser surgery, lungs are ventilated with high-frequency jet ventilation or conventional mechanical ventilation, and the treated area is distal to the source of the gases with both techniques. In contrast, the method described herein uses an insufflation catheter with side holes placed subcarinal and contralateral to the lesion. This technique should be considered as an alternative form of ventilation because it enables increased protection of the nonaffected lung from aspiration and smoke.

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