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Nd:YAG Laser Therapy in Lung Cancer: An 11-Year Experience with 2,253 Applications in 1,585 Patients

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Abstract. Between April 1982 and March 1993, 1,585 patients with significant symptoms of malignant airway obstruction were treated with 2,253 tracheobronchial neodymium (Nd):YAG laser resections performed by the first author only: 1,274 (78%) patients had non-small cell lung cancers, 91 (6%) small cell lung cancers, 105 (7%) metastatic tumors, 61 (4%) rare malignant tumors, and 81 (5%) unclassifiable carcinomas. More than 90% of the Nd:YAG laser resections were performed with rigid bronchoscopy under general anesthesia (sedation plus analgesia with spontaneous ventilation). Almost all the cases (93%) showed immediate good results based on clinical, radiological, and endoscopic follow-up. Rapid regrowth of tumor is the major limitation; in our series the median time between the first and the second treatment was 100 days. Complications have been few to date: 18 hemorrhages, 6 pneumothoraxes, and 10 deaths. The mortality rate was 0.44%. Although laser resection is a palliative treatment, since 1983 we have treated 19 carcinomas in situ and none has recurred. This is also the case for some early endoluminal metastases. Finally, 17 patients with bronchogenic carcinoma that seemed inoperable did have surgery after laser therapy and another 21 underwent less extensive surgery than initially planned. Nd:YAG laser photoresection, in experienced hands, can be used safely and successfully to open airways obstructed by tumor growth while controlling bleeding. Its primary use is in the trachea and in the main bronchi. **Key Words:** Neodymium:YAG laser—Lung cancer—Carcinoma in situ—Tracheobronchial metastasis.

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Nd:YAG, neodymium:yttrium aluminum garnet.

Lung cancer is a very aggressive neoplasm that quickly leads to death. Since fewer than 10% of these patients are cured, the other 90% must have recourse to symptomatic-palliative treatments. Many patients with advanced disease develop endotracheal and/or endobronchial obstruction by tumor growth, with ventilatory impairment and obstructive pneumonia. Before the application of laser therapy, endoscopic treatment of these patients was hazardous and often inadequate.

At present in some cases the optimal treatment may be a combination of modalities, such as neodymium:yttrium aluminum garnet (Nd:YAG) laser resection followed by radiotherapy or chemotherapy (Fig. 1). These procedures allow patency of the central airways and avoid the most distressing symptoms of the disease, enhancing the patient's quality of life.

After more than 11 years of experience with Nd:YAG laser therapy in bronchology, we can offer a well-founded critique of its role and an evaluation of its effectiveness in tracheobronchial malignant interventional endoscopy. Our experience confirms the value of this already widely used and recognized endoscopic procedure (1–20).

INDICATIONS

Nd:YAG laser resection of malignant tumors is a palliative-symptomatic treatment, that should be

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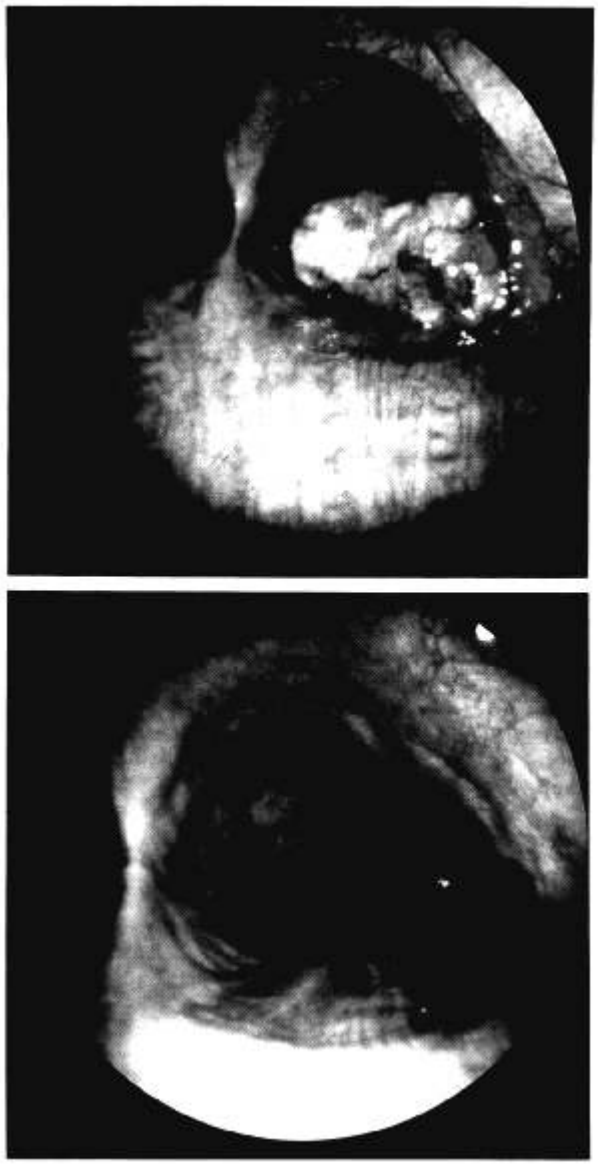

FIG. 1. **A:** Squamous cell carcinoma of the right upper lobe bronchus extending into the right main bronchus. **B:** Impending right lung atelectasis was avoided by laser and mechanical resections of the relatively small endobronchial tumor obstructing the right main bronchus. The patient underwent transcutaneous radiotherapy, and very exceptionally, he is still tumor-free after 5 years.

performed in nonsurgical cases. Its prime indication is bulky endoluminal obstructions of the central airways, particularly the trachea and mainstem bronchi, where these lesions can cause respiratory failure. Regardless of their location and macroscopic appearance, friable tumors that produce hemoptysis can be treated with laser photocoagulation to limit this occurrence, which very often haunts patients.

The combination of rigid bronchoscopic Nd:YAG laser resection with other palliative therapies is not only possible but also extremely useful. The quick reopening of the obstructed airway by laser therapy allows patients to face radiation therapy (external beam radiation and/or brachytherapy) and/or che-

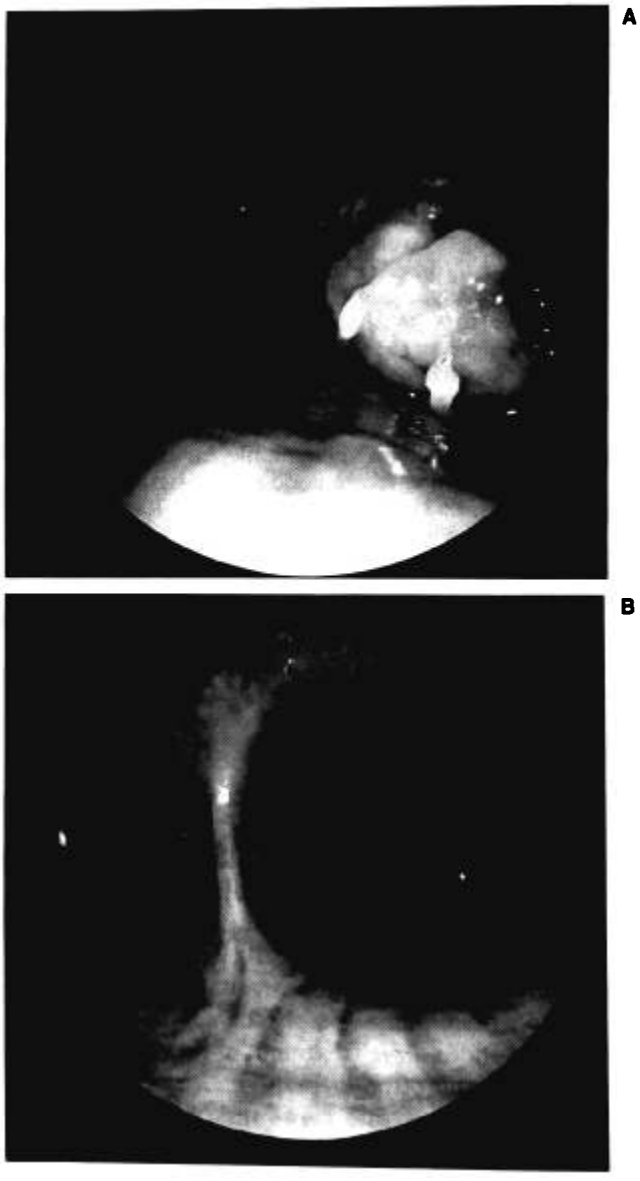

FIG. 2. **A:** Squamous cell carcinoma obstructing the right main bronchus. The tumor appeared to be unresectable by standard right pneumonectomy. **B:** After Nd:YAG laser treatment and mechanical resection, the right main bronchus and most of the right upper lobe bronchus appeared to be uninvolved with tumor. So a right upper lobectomy was performed. The patient is still tumor-free 3 years after therapy.

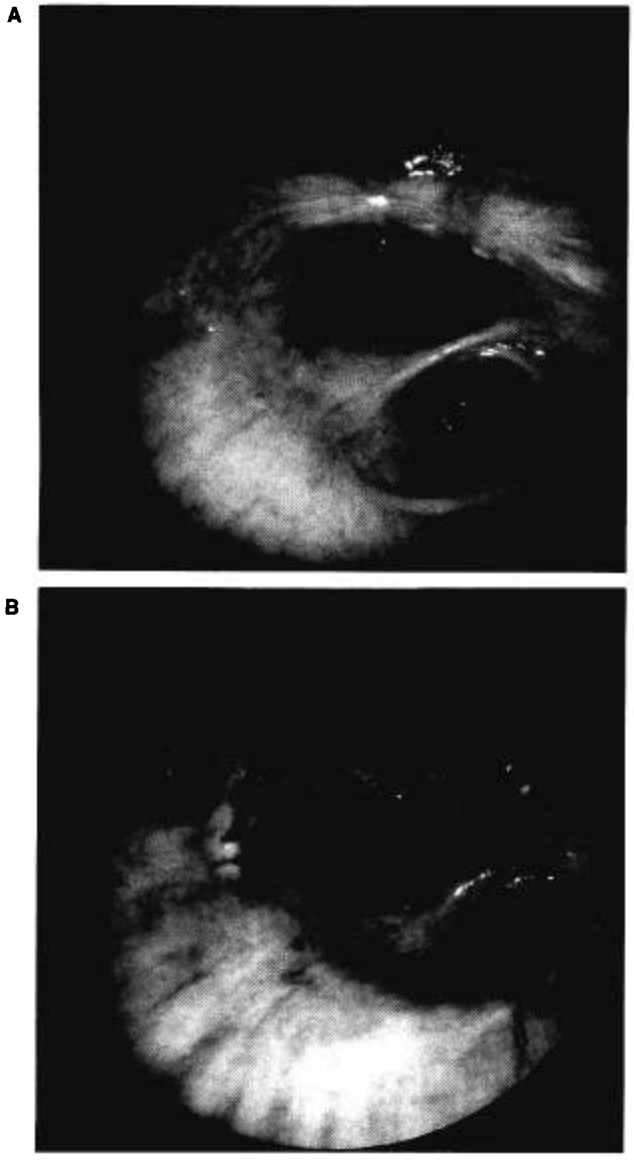

FIG. 3. **A:** Squamous cell carcinoma in situ involving the entrance of the right middle lobe. **B:** After Nd:YAG laser treatment. There has been no recurrence after 4 years.

motherapy with an improved functional status, without the risk of obstructive symptoms (10,13,18) (Fig. 1).

Some polypoid lesions, originally thought to be inoperable because of their proximal extent, proved to be resectable after Nd:YAG laser resection. In fact, laser resection sometimes can allow better preoperative delimitation, permitting surgery or less extensive resections (3,4) (Fig. 2). Laser therapy can be curative in carcinomas in situ and, locally, also in some early endoluminal metastases (4) (Figs. 3–5).

TECHNIQUE

It is consensual that Nd:YAG is the most suitable laser for endoscopic resection, having power enough to vaporize tissue while producing a good coagulation effect. The ability to deliver the laser energy via a flexible quartz fiber is also very important in bronchoscopic application.

Our technique, based on the use of the rigid bron-

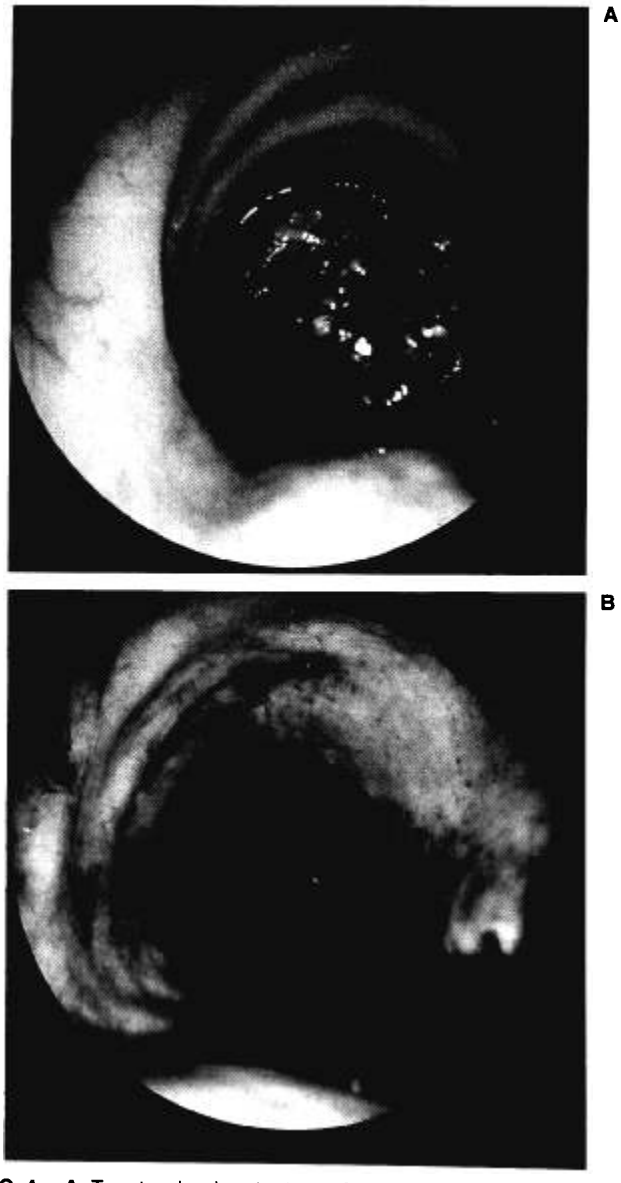

FIG. 4. **A:** Two tracheal metastases from squamous cell carcinoma arising in the left lower lobe bronchus. **B:** After Nd:YAG laser treatment and mechanical resection. Recent case.

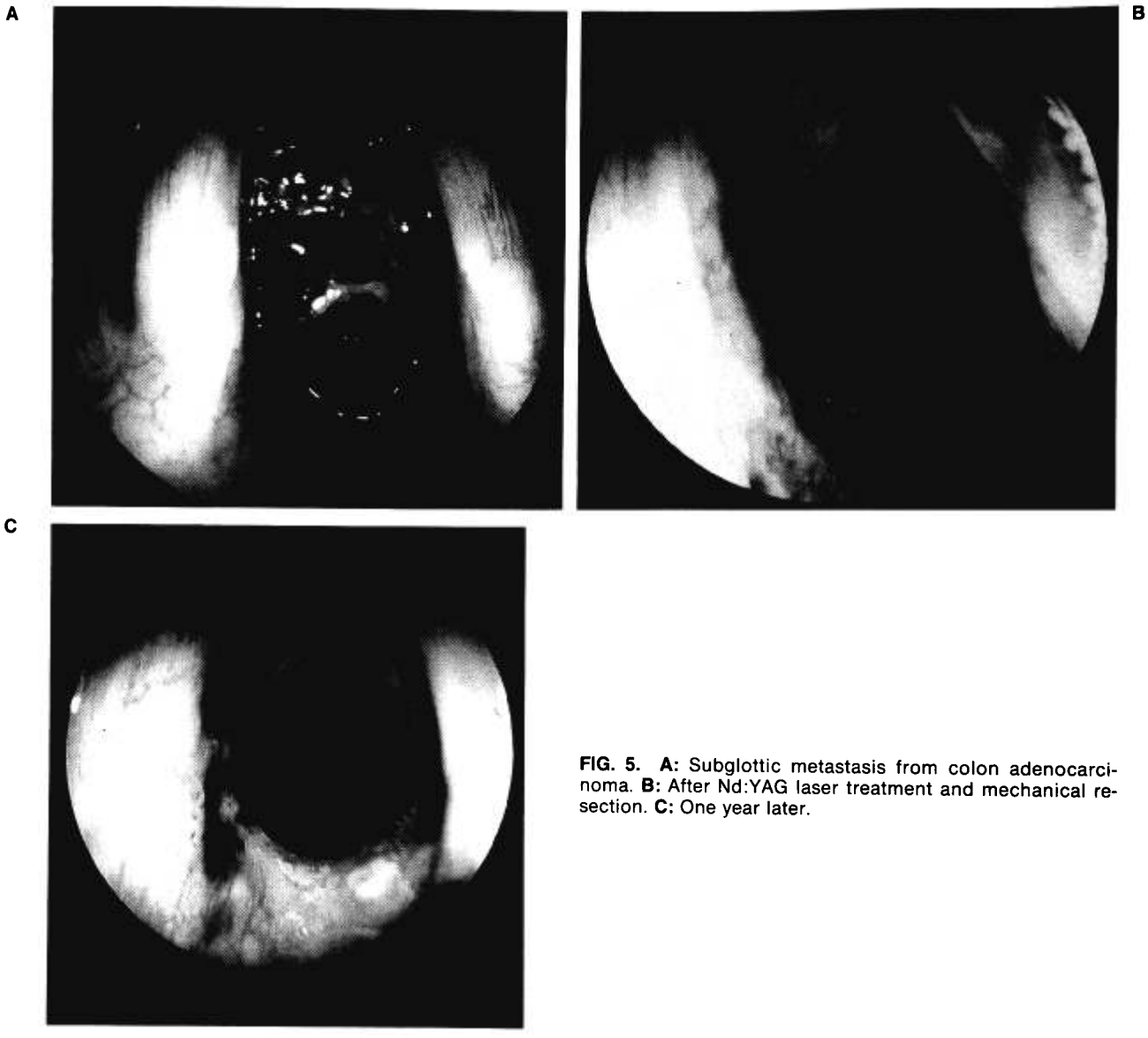

FIG. 5. **A:** Subglottic metastasis from colon adenocarcinoma. **B:** After Nd:YAG laser treatment and mechanical resection. **C:** One year later.

choscope under general anesthesia, is the following: coagulation of the tumor at a low power density, mechanical resection of the endoluminal mass with the tip of the bronchoscope, vaporization of the tumor stump at a high laser power, and finally, treatment of the surrounding wall at a low laser power and long exposure times (20–30 W, 4- to 5-s pulse duration, 1,000–3,000 J) to obtain a cytocidal effect in depth (4). To avoid perforation, the tip of the fiber is not aimed at a single point, but moved along the target, firing the laser nearly parallel to the airway wall.

We use the following anesthesic protocol: premedication with 0.15 mg/kg diazepam and 0.01 mg/kg atropine and induction with 2.5 μg/kg fentanyl and 125 μg/kg droperidol followed by 2.5 mg/kg propofol. Ventilation is administered by mask at $FiO_2 = 1$. After the administration of 0.7 mg/kg succinylcholine, laryngotracheal local anesthesia is performed under direct laryngoscopy with 3–5 ml 4% lidocaine. A No. 8.5 Storz or Efer–Dumon–Harrel rigid bronchoscope is then introduced. Spontaneous ventilation is reinitiated 2 min later. General anesthesia is maintained with 6 mg/kg/h propofol and a 2-μg/kg fentanyl bolus when necessary (6).

TABLE 1. *Tracheobronchial tumors (April 1982–March 1993)*

	Patients	Treatments
Lung cancer	1,585 (84%)	2,253
Tumor with uncertain prognosis	143 (8%)	218
Benign tumor	156 (8%)	221
Total	1,884	2,692

This technique saves considerable time and allows a better approach to the lesion as well as maximal control of ventilation and intervenient complications (8). Flexible bronchoscopic laser therapy should be reserved for small and nonvascular tumors or used in combination with the rigid mode to reach a more distal lesion.

In some cases with predominant extrinsic compression and endoluminal growth, after endoscopic laser resection and mechanical dilation, it is advantageous to insert an endobronchial stent. We usually place silicone Dumon's prostheses, which, in our experience (>400 cases), have proven to be effective, without any serious complications (4).

RESULTS

Between April 1982 and March 1993 we treated 1,884 tracheobronchial tumors by Nd:YAG laser: 1,585 of these lung cancers (data given here), 143 tumors with an uncertain prognosis (carcinoids, adenoid cystic carcinomas, etc.), and 156 benign tumors (data to be published) (Table 1).

By far the most numerous type of bronchogenic carcinoma was squamous cell carcinoma (1,072; 67%), followed by adenocarcinoma (125; 8%), then small cell (91; 6%), large cell (50; 3%), and unclassifiable (81; 5%) carcinomas (Table 2). There were also 105 metastatic tumors (Table 3) and, finally, 61 rare malignant tumors (Table 4). For the 1,419 bronchogenic carcinomas we were able to report 1,314 (93%) very good immediate results based on clinical, radiological, and endoscopic follow-up according to the classification system reported by Dumon and Unger (Table 5) (9,20). The unsatisfactory results were usually obtained in cases with a predominant extrinsic compression of the airway or in very extensive tumors.

TABLE 2. *Bronchogenic carcinomas (April 1982–March 1993)*

Tumor type	Patients	Treatments
Squamous cell	1,072 (67%)	1,526
Adenocarcinoma	125 (8%)	170
Small cell	91 (6%)	103
Large cell	50 (3%)	70
Unclassifiable	81 (5%)	98
Total	1,419	1,967

TABLE 3. *Metastatic tumors (April 1982–March 1993)*

Thyroid	33
Kidney	22
Colon	20
Esophagus	15
Breast	4
Melanoma	4
Ovary	2
Thymus	1
Uterus	1
Testicle	1
Jaw	1
Liver	1
Total	105 patients (199 treatments)

The results depend more on the location and macroscopic appearance of the tumor than on the histological type. Very good immediate results were almost always obtained for tracheal tumors, and progressively less satisfactory results for main bronchi, lower lobe bronchi, and upper lobe bronchi (Fig. 6).

For the patients treated with laser therapy, the median time between the first and the second treatment was exactly 100 days, whereas it was 29 days for 33 patients of ours treated previously only with mechanical resection, using a method similar to that described by Mathisen and Grillo (21). We are persuaded that the considerably better results in the patients treated by laser were due mainly to our technique of treating the wall in depth. In situ carcinomas and some early endoluminal metastases

TABLE 4. *Rare tumors (April 1982–March 1993)*

Carcinoma in situ	19
Lymphoma	
Non-Hodgkin's	10
Hodgkin's	5
Carcinosarcoma	12
Sarcoma	4
Malignant plasmacytoma	3
Leiomyosarcoma	2
Fibrosarcoma	2
Teratoma	1
Myeloma	1
Basaloid tumor	1
Glomic tumor	1
Total	61 patients (87 treatments)

TABLE 5. *Bronchogenic carcinoma: Immediate results per histology (April 1982–March 1993)*

Tumor type	Patients	Results	
		Satisfactory[a]	Unsatisfactory
Squamous cell	1,072	1,004 (94%)	68 (6%)
Adenocarcinoma	125	112 (90%)	13 (10%)
Small cell	91	79 (87%)	12 (13%)
Large cell	50	45 (90%)	5 (10%)
Unclassifiable	81	74 (91%)	7 (9%)
Total	1,419	1,314 (93%)	105 (7%)

[a] Significant improvement in ventilation.

were treated with curative intent using the same technique. None of the former and few of the latter have recurred (Figs. 3–5).

In our series 17 patients with bronchogenic carcinoma that seemed inoperable did have surgery after laser therapy, and another 21 underwent less extensive surgery than initially planned (Fig. 2).

In our opinion, survival should not be the main criterion in evaluating these patients. The main goal of any palliative therapy is to improve the quality of life. To our knowledge, in very few of our patients was the recurrence of obstruction the eventual cause of death.

COMPLICATIONS

Hypoxia, hemorrhage, and related cardiovascular problems are the major risks of Nd:YAG laser bronchoscopic resection. Other possible complications are perforation of the airway and subsequent mediastinal emphysema, pneumothorax, and/or infection. Airway fires have also been reported in flexible laser bronchoscopy series.

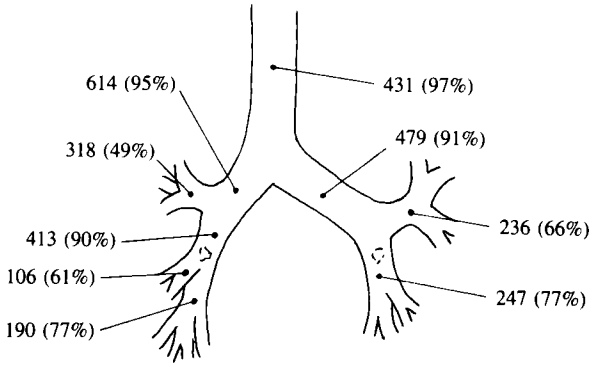

FIG. 6. Bronchogenic carcinoma: immediate results in various locations (April 1982–March 1993). The number of lesions in each region is indicated, with the corresponding percentage of satisfactory results after the first treatment in parentheses.

TABLE 6. *Complications: 2,253 treatments (April 1982–March 1993)*

Hemorrhage >250 ml	18
Transient pneumothorax	6
Respiratory failure	12 (3 deaths)
Cardiac arrest	10 (4 deaths)
Myocardial infarction	4 (2 deaths)
Pulmonary embolism	1 (1 death)

Of 2,253 malignant tumoral resections, we had 18 cases of hemorrhage >250 ml, 6 cases of transient pneumothorax, and 10 deaths (mortality rate, 0.44%): 5 of these patients died during laser resection, 4 of cardiac arrest under general anesthesia, and 1 of myocardial infarction under local anesthesia.

Three patients with very extensive tumors underwent emergency laser therapy that was not effective and died a few hours later of respiratory failure. One patient with a recent history of myocardial infarction had another infarction and died 5 days later in the intensive care unit. One patient came to our center for a second laser treatment because of acute dyspnea and, despite a good bronchial recanalization, died a few hours later. The autopsy showed a massive pulmonary embolism (Table 6).

CONCLUSIONS

In conclusion, in our 11-year series of 2,253 treatments in 1,585 patients with lung cancer, rigid bronchoscopic Nd:YAG laser resection proved to be an excellent palliative-symtomatic therapy, being rapid, immediately effective, repeatable, and complementary to other treatments.

We arrived at about the same conclusions after our 5-year series, on which we published a more detailed report (3). But although the panorama has not changed very much, our further experience enables us to point out a closer connection with other endoscopic maneuvers—such as stent placement and brachytherapy—and with classic therapies—such as transcutaneous radiotherapy and surgery.

Laser therapy is no longer considered just the last resort, when all other therapies have proved to be ineffective, but a weapon with its own peculiar role in the therapy of lung cancer.

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