Nd:YAG Laser Bronchoscopy

A Five-Year Experience with 1,396 Applications in 1,000 Patients

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We treated 1,000 patients with the Nd:YAG laser. The rigid bronchoscope was used in 1,280 (92 percent) of the treatments, with patients almost always under general anesthesia; 116 (8 percent) treatments were performed with the flexible fiberoptic bronchoscope alone, with the use of local anesthesia. In almost all cases of benign tumors and in many carcinoid tumors, the treatment was curative. In genuine nonmalignant tracheal stenoses, laser therapy was curative in 34 out of 81 cases. In malignant tumors, the laser improved airway gauge 92 percent of the time. Cumulative survival was 50 percent (±3 percent) at six months and 26 percent (±3 percent) at one year. Following palliative laser therapy, eight patients with bronchogenic carcinoma appearing to be inoperable did have surgery and ten underwent less extensive surgery than expected. Results confirm the usefulness and safety of this relatively new method in the treatment of obstructive lesions of the tracheobronchial tree.

Before the application of laser therapy, the endoscopic management of airway neoplasms and stenoses was not entirely satisfactory. The use of forceps for removing tumors, which was attempted in the past in desperate cases, is potentially dangerous due to the high frequency of uncontrollable hemorrhage. Endoscopic application of electrocautery and cryosurgery, though effective, may damage the normal adjacent tissue.[1] The carbon dioxide laser is precise in its soft tissue interaction but lacks an efficient fiberoptic delivery system, and its ability to achieve hemostasis is limited when compared to the Nd-YAG laser.[2]

After animal experiments by Toty et al[3] and others at the end of 1978 the YAG laser was first applied clinically. This led to the beginning of modern endoscopic tracheobronchial surgery.[3-12] The growing problem of neoplastic airway obstruction and, to a smaller extent, iatrogenic benign stenoses, provides an opportunity for widespread application of this new technology. In this article, we will review our clinical experience with laser bronchoscopy during the last five years to reaffirm the application of this new therapy.[13,14]

Materials and Methods

Almost all the patients treated had significant symptoms of airway obstruction due to a malignant or benign process. In some patients with lesions such as benign endoluminal tumors, selected carcinoids, early cancers, tracheobronchial granulomas, *etc*, laser therapy was performed for cure. In most instances, however, the laser was used as a palliative therapy for patients with endoluminal tracheobronchial lesions in whom conventional therapy had failed or had not been considered possible or useful. The laser used was the Nd:YAG (YM 100 Cilas, Paris) whose technical features are well known.[4] Normally, we used power settings ranging from 40 to 50 W with pulse duration of 0.7-1.2 s. With large tumors we often used longer exposure times (several seconds) at 35 to 40 W, and with nonmalignant tracheal stenoses, shorter exposure (0.5 s) at 70 to 80 W. The flexible bronchoscope was used alone in 116 (eight percent) treatments, all with patients under local anesthesia. The rigid bronchoscope was used for 1,280 (92 percent) procedures, 1,088 with patients under general and 192 with patient under local anesthesia. The latter mostly refer to our first year of activity when, unlike today, anesthetists were not available on a regular basis. We frequently used the rigid bronchoscope to dilate some types of tracheal stenoses and, in polypoid tumors, to scoop out the endoluminal mass, following Dumon's technique.[8,15] With neoplasms, the laser was used initially to coagulate the mass with low power (25 to 30 W) and long pulse times (5 s). After mechanical removal of the tumor, the airway wall was photocoagulated for hemostasis. The fiberoptic bronchoscope was used for minor, minimally vascular lesions and, inserted through a rigid bronchoscope, for bronchial lesions that were inaccessible. Survival distribution was estimated by the product-limit method,[16] with time computed beginning from the first laser treatment.

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Results

From April 1982 to July 1987, 1,000 patients were treated with the YAG laser for a total of 1,396 procedures performed by the first author only. The number of treatments per year increased constantly: 64 in 1982, 205 in 1983, 256 in 1984, 308 in 1985, and 342 in 1986.

There were 772 tracheobronchial tumors, 139 nonmalignant tracheal stenoses and 89 miscellaneous conditions (Table 1).

Tracheobronchial Tumors

Tracheobronchial neoplasms were the most common lesions treated, representing about three quarters of

Table 1—*Pathology and Laser Treatment (April 1982-July 1987)*

Conditions	Patients	Treatments	Anesthesia	
			General	Local
Malignant tumor	649 (64.9%)	895	762	133
Tumor with uncertain prognosis	64 (6.4%)	95	70	25
Benign tumor	59 (5.9%)	77	57	20
Tracheal stenosis	139 (13.9%)	211	141	70
Miscellaneous conditions	89 (8.9%)	118	56	62
Total	1,000 (100%)	1,396	1,086 (78%)	310 (22%)

the total number of patients. We divided them into malignant, uncertain prognosis and benign tumors.

Malignant Tumors

We treated 649 malignant tumors in 895 procedures, 41 with the flexible fiberoptic bronchoscope alone with patients under local anesthesia and 854 with the rigid bronchoscope (762 were done with patients under general and 92 with patients under local anesthesia) (Table 2). Of the 593 patients with bronchogenic carcinoma, 87 were treated two or more times for recurrence. The median time between first and second treatment was 111 days. Occasionally after laser resection, neoplastic infiltration of the bronchial wall was sometimes seen to be more distal than had originally been thought. This allowed resective surgery in eight cases originally felt to be inoperable, and in another ten patients it allowed less extensive surgery than planned.

By far, the most common malignant cell type was squamous cell carcinoma (451, 69.5 percent), followed by adenocarcinomas (48, 7.4 percent), small cell carcinomas (36, 5.5 percent) and large cell carcinomas (24, 3.7 percent). There also were 19 rare tumors: five carcinosarcomas, five carcinomas *in situ*, two sarcomas, two malignant plasmocytomas, one teratoma and four malignant lymphomas (two Hodgkins and two non-Hodgkins). Metastatic tumors included 15 from the thyroid, seven from the kidney, five from the bowel, four from the esophagus, two from the breast, one from the thymus, one from the ovary, one from the testicle and one melanoma. Finally there were 34 unclassified tumors.

Table 2—*Malignant Tumors (April 1982-July 1987)*

Tumor Type	Patients	Treatments	Anesthesia	
			General	Local
Squamous cell carcinoma	451 (69.5%)	620	523	97
Adenocarcinoma	48 (7.4%)	56	53	3
Small cell carcinoma	36 (5.5%)	41	37	4
Large cell carcinoma	24 (3.7%)	34	30	4
Unclassifiable	34 (5.2%)	44	39	5
Metastatic	37 (5.7%)	71	56	15
Rare tumors	19 (2.9%)	29	24	5
Total	649 (100%)	895	762 (85%)	133 (15%)

Results depended more on the location and macroscopic appearance of the tumor than on the histologic studies. As to location, trachea and main stem bronchi are the most favorable. Polypoid tumors were readily removed (Fig 1).

The immediate results of treating malignant tumors,

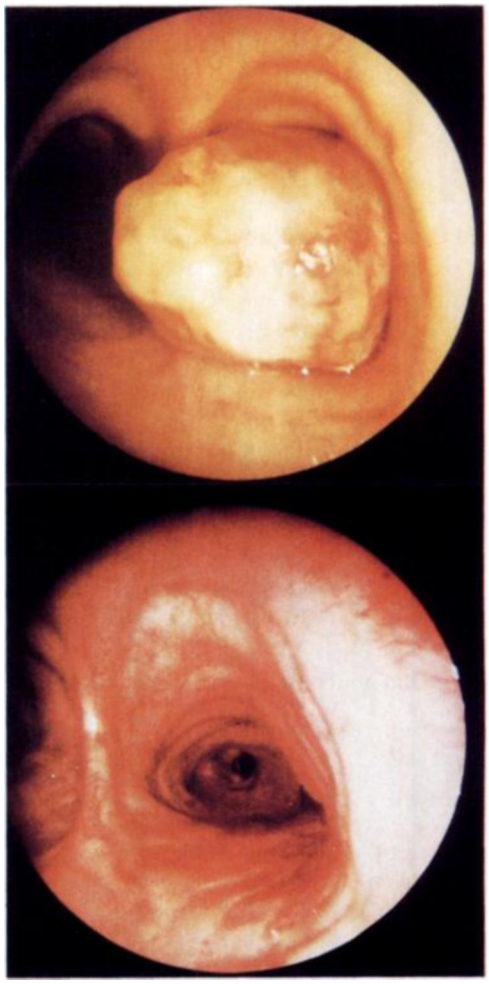

FIGURE 1. *Top*, Polypoid squamous cell carcinoma obstructing the right main stem bronchus arising in the right upper lobe bronchus. *Bottom*, Endoscopic control a week after a single laser treatment shows a normal right main stem bronchus.

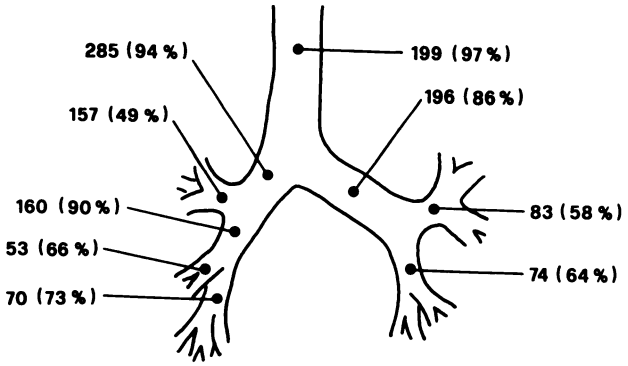

FIGURE 2. Bronchogenic carcinoma. Immediate results in various locations. Number of lesions in each region and corresponding percentage of satisfactory results after first treatment in parentheses.

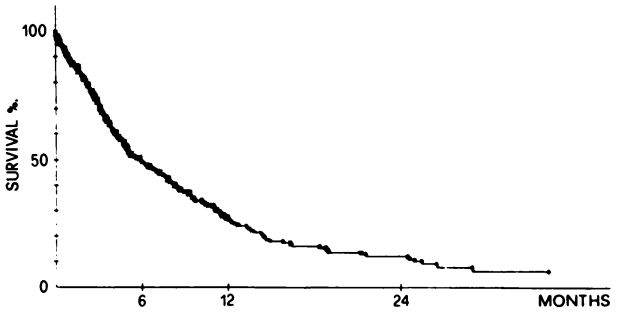

FIGURE 3. Estimated survival from time of first treatment to death in 333 patients with bronchogenic carcinoma.

almost always achieved in a single laser session, were invariably good and often spectacular. In the 592 bronchogenic carcinomas alone, we achieved a normal airway lumen gauge or a significant improvement in ventilation in 548 (92.4 percent). In only 45 (7.6 percent) did the laser have no effect; these were mainly obstructions due to external compression or extensive tumor extending distally. Histologic tumor cell type had no important bearing on results; normal airway lumen or significant improvement in ventilation was obtained in 93 percent of patients with squamous cell carcinoma, 92 percent with large cell carcinoma, 90 percent with adenocarcinoma and 90 percent with small cell carcinoma. Location of the tumor was a major determinant of outcome (Fig 2).

It is difficult to draw conclusions regarding long-term results, since TNM restaging and performance status cannot be determined. Also, other therapies prior to and following laser treatment varied considerably.

The cumulative survival percentages after the first laser treatment for 333 patients with bronchogenic carcinoma was 50 percent (±3 percent) at six months and 26 percent (±3 percent) at one year (Fig 3). Follow-up information was not available in 242 patients. Those who underwent surgery after laser resection are not included in the survival data. More important than length of survival was the obvious improvement in quality of life. It is worth noting that almost all patients with known data and cause of death died without recurrent obstructive symptoms.

Tumors with Uncertain Prognosis

This heading lumps together several tumor types characterized by slow growth and rare tendency to metastasize (Table 3).

Some carcinoids deeply infiltrated the bronchial wall and appeared similar to bronchogenic carcinomas. In these cases, recurrence was relatively rapid, requiring further treatment. Other carcinoids appeared polypoid with endoluminal growth. Their macroscopic and microscopic presentation was benign. So far, 11 of the 12 carcinoids of this type have not recurred (follow-up of 10 to 50 months). Adenoid cystic carcinomas are often complex tumors, frequently widebased with a tendency to recur. Many of these required repeated treatment.

One mucoepidermoid carcinoma has not recurred after 40 months. Mixed tumors and particularly spindle-cell carcinomas tend to recur and require more than one treatment.

Benign Tumors

These are the best indication for laser therapy, being mostly polypoid tumors and mainly localized. This means they are easy to resect with laser therapy and, most important, they rarely recur (Fig 4).

Fifty-nine patients were treated in 77 procedures. There were 14 hamartomas, 11 papillomas, seven amyloidoses, four osteoplastic tracheopathies, four polyps, four angiomas, two plasmocytomas, two schwannomas, two chondromas, two lipomas, two endometrioses and one of each of the following: fibroma, scleroma, fibroleiomyoma, fibrohistiocytoma and tracheobronchial syphilis. In amyloidosis and osteoplastic tracheopathy, the laser cannot be curative, but the growth process is very slow and our cases have not required further treatment thus far. One patient with amyloidosis has not required treatment since 1982. Among the other cases, only endometriosis and one papillomatosis required further treatment.

Table 3—*Tumors with Uncertain Prognosis (April 1982-July 1987)*

Tumor Type	Patients	Treatments	Anesthesia	
			General	Local
Carcinoid	32	41	31	10
Adenoid cystic	23	40	27	13
Spindle cell	5	9	8	1
Mixed	2	3	2	1
Mucoepidermoid	2	2	2	0
Total	64	95	70	25

Non-tumoral Tracheal Stenoses

This group includes very simple cases together with decidedly difficult ones. We followed the classification

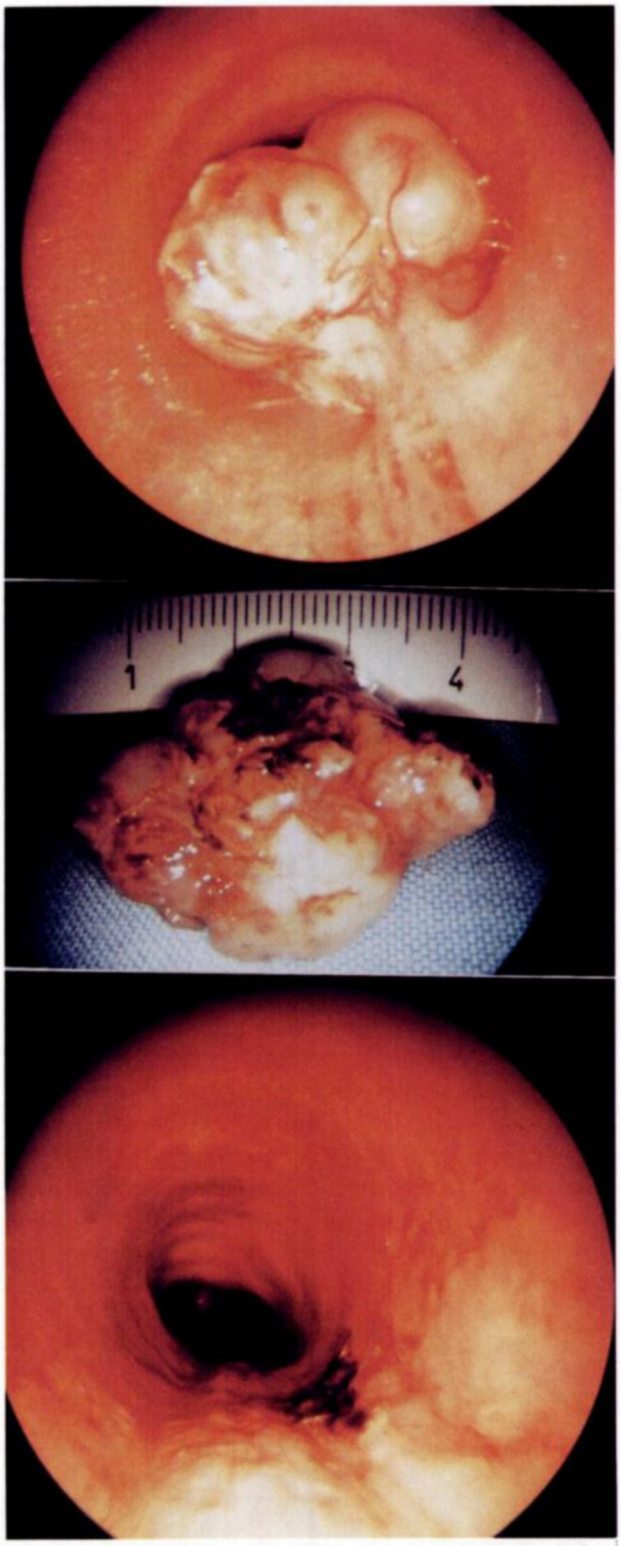

FIGURE 4. *Top,* Tracheal schwannoma with origin on the right posterolateral wall. *Center,* Tumor removed by mechanical resection. *Bottom,* Tumor base was treated with a lower setting, thus avoiding tissue loss while still obtaining a cytocidal effect. No recurrence after 17 months.

Table 4—*Nonneoplastic Tracheal Stenoses (April 1982-July 1987)*

Type of Stenosis	Patients	Treatments	Anesthesia	
			General	Local
Genuine stenosis	81	132	106	26
Tracheal granuloma	37	45	16	29
Granuloma after sleeve resection	21	34	19	15
Total	139	211	141 (67%)	70 (33%)

used by Dumon et al[4] and subdivided our 139 cases into genuine tracheal stenoses (81) and tracheal granulomas (58) (Table 4).

Tracheal Granulomas

The most common etiology of tracheal granulation tissue was the presence of a metallic tracheostomy tube. In 21 cases, the granulation was induced by suture threads after sleeve resection. The use of reabsorbable suture material has now reduced the frequency of this complication. Results were almost always curative. The few recurrences were due to the appearance of other suture threads and, in patients with permanent tracheostomy tubes, to the persistence of mechanical irritation.

Genuine Stenoses

Our 81 cases were almost all iatrogenic, caused by endotracheal intubation or closure of a tracheal stoma. There also were six postdiphtheritic and three posttraumatic stenoses, and two of unknown origin. Except for the five concentric stenoses, the obstruction extended over several cartilage rings and the tracheal wall appeared to be involved with inflammation.

Immediate results were almost always good (Fig 5). In 76 of 81 cases, there was immediate significant improvement. Three of the five poor results involved patients with total suprastomal stenosis (we treated six complete stenoses). The other two poor results were cases of postdiphtheritic tracheal stenosis also involving the larynx.

Genuine tracheal stenoses tend to recur following laser therapy. A stable result for over six months was achieved in 34 patients. Of the rest, sleeve resection was needed in 20; five died; eight were unavailable for follow-up; nine are recent and five had no lasting improvement but were not retreated. A silicone T-tube was used in 18 cases.

Miscellaneous Conditions

Besides obstructing tumors and tracheal stenoses, there are other clinical situations treatable by endobronchial laser therapy. We treated 89 cases in 118 procedures, using the flexible fiberscope under local

anesthesia in 23 procedures (Table 5). Resection of suture threads and bronchial granulomas and control of mild hemorrhages is normally easy and complete. On the other hand, bronchial stenoses following sleeve resection are very difficult to treat and frequently recur: five out of 12 in this series.

With fistulas, the laser was used to clean the fistulized zone of suture threads and necrotic tissue. Using this technique, four small fistulas closed spontaneously, four medium-gauge ones closed after repeated silver nitrate treatment, and one remained open.

The tubercular bronchial stenoses were particularly difficult to treat. We never managed to obtain a normal bronchial lumen caliber. But ventilation did appear to improve and was maintained.

Dysplasias were treated in an attempt to arrest their evolution into frank cancer. We used low-power (25 W) to kill the atypical cells without damaging the bronchial wall. Follow-up biopsies of the treated areas at three and 12 months showed fibrous tissue.

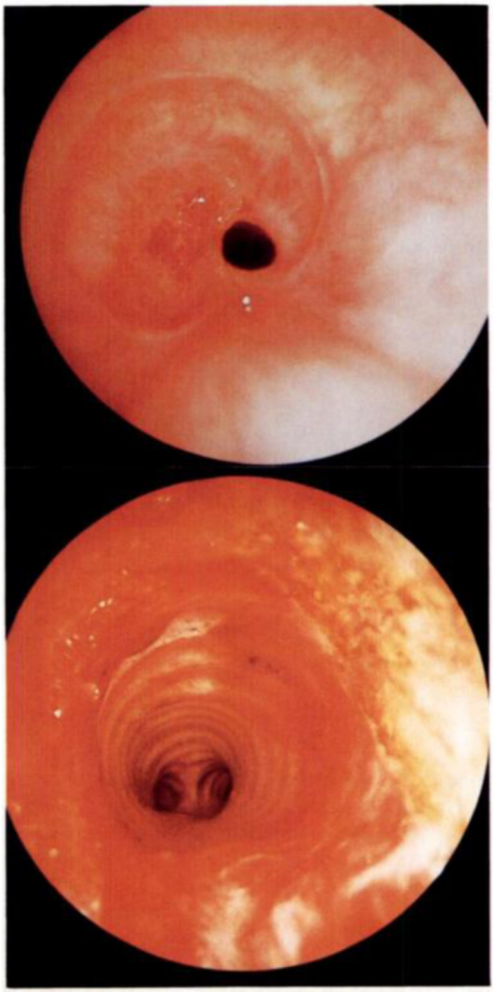

FIGURE 5. *Top*, Postintubation tracheal stenosis. *Bottom*, Immediately after one laser treatment. Stable result after three years.

Table 5—*Miscellaneous Conditions (April 1982-July 1987)*

Conditions	Patients	Treatments	Anesthesia	
			General	Local
Hemorrhage	27	31	9	22
Bronchial granuloma	25	29	10	19
Bronchial stenosis after sleeve resection	12	27	23	4
Bronchial fistula	9	11	4	7
Suture thread	8	9	0	9
Tubercular bronchial stenosis	6	9	8	1
Dysplasia	2	2	2	0
Total	89	118	56 (47%)	62 (53%)

Complications

The main complications were hypoxemia and related cardiovascular disorders induced by general anesthesia or severe hemorrhage (Table 6). In 1,396 treatments, we had ten hemorrhages of over 250 ml, all during surgery. All were managed without excessive difficulty and did not extend hospitalization times. Two mediastinal emphysemas cleared spontaneously in five and six days. Four pneumothoraxes developed, probably due to reexpansion of atelectatic lung. Two cleared spontaneously in three and five days. The other two cleared in six and eight days with pleural drainage.

There were five deaths, giving a mortality rate of 0.35 percent (5 of 1,396). One patient with recurrent bronchogenic carcinoma died of myocardial infarction during treatment under local anesthesia. The other four deaths occurred in patients treated under general anesthesia. One patient with bronchogenic carcinoma died at the end of the treatment from a cardiac arrest. In the other patient with Hodgkin's lymphoma, previously treated with radiotherapy, the laser did not improve the tracheobronchial lumen, which was severely reduced mainly due to extrinsic compression. The patient died from respiratory failure 18 hours after treatment. Another had tracheobronchial stenosis after left tracheal sleeve pneumonectomy. Although good improvement of the stenotic airway was achieved, the patient died five hours later from respiratory failure. One patient with bronchogenic carcinoma suffered a severe myocardial infarction during laser treatment and died five days later despite intensive care.

Table 6—*Complications in 1,396 Treatments (April 1982-July 1987)*

Type of Complication	No.
Hemorrhage >250 ml	10
Mediastinal emphysema	2
Pneumothorax	4
Myocardial infarction	3 (2 deaths)
Respiratory failure	6 (2 deaths)
Cardiac arrest	2 (1 death)

Discussion

Technique

Two different methods of laser application in bronchology have been developed: via the rigid or the fiberoptic bronchoscope. In general, the flexible method is opted for by bronchoscopists who have little or no experience with the rigid bronchoscope.

The preference for the rigid bronchoscope by authors with the largest series of cases[8] and by ourselves is essentially for safety reasons: using the wide operating channel, the patient can be ventilated, blood and secretions aspirated, and laser coagulation utilized. Furthermore, the rigid bronchoscope allows instrumental dilatation of nonneoplastic tracheobronchial stenoses and mechanical resection of polypoid tumors with considerable savings of time.

In regard to our personal preference in using the laser on a continuous basis with pulses as long as 5 to 6 s at 35 W on large tumors, it must be pointed out that the laser is not directed onto a single point but is waved slowly over the surface of the tumor always on a course nearly parallel to the tracheobronchial walls. With this technique, we have never produced the dangerous "popcorn" effect due to vaporization of submucosal tissues or postoperative hemorrhage. During the days immediately after therapy, we have noted at the site of laser treatment a moderate production of fibrin debris, which is expectorated spontaneously in seven to ten days. Endoscopic removal can be symptomatologically useful but we have never found it really indispensable.

Results

The results appear to be more than satisfactory, which enables us to confirm the utility of the laser in treating various tracheobronchial lesions. With inoperable malignant tumors, the laser has proved to be of valuable help, mainly in improving quality of life. Particularly suitable for laser therapy are tumors blocking the main stem bronchi and/or the trachea, *ie*, those causing severe dyspnea not likely to be tolerated for long. Laser treatment in these cases offers a number of advantages: it is rapid, immediately effective, repeatable and complementary with other therapies. Radiotherapy is useful after laser in cases of widespread intramural infiltration with an extraluminal component.

The possibility of more accurately assessing the actual extent of neoplastic infiltration after reductive laser therapy is extremely interesting, since some patients originally thought to be inoperable can be sent to surgery while others can undergo less extensive surgery than expected.

The laser has also proved to be extremely useful in allowing drainage of purulent secretions distal to airway obstruction. This can prevent the serious complications of postobstructive sepsis, often improving the patient's overall condition even if there is little or no improvement in lung function.

It is difficult to make a judgment of the long-term results. While we feel it may not be correct to state this as a criterion for evaluating the effectiveness of laser therapy, we are in agreement with Brutinel et al[17] in believing that it extends the duration of life.

In regard to bronchial carcinoids, we wish to point out that laser therapy can be curative in exclusively endoluminal polypoid forms. In an attempt to eradicate all tumor in these cases, as for benign polypoid tumors, we treat the base with a lower power setting, thus avoiding tissue loss while still obtaining a cytocidal effect.

For many benign tumors that are exclusively endoluminal and polypoid, total removal with laser is often possible. Laser therapy for such lesions must be considered in preference to surgery.

In nonmalignant tracheal stenoses, though we did not obtain particularly extraordinary results, we are convinced that the laser is extremely useful for restoring ventilation rapidly, particularly in emergencies. With recurrent tracheal stenoses the laser affords time for assessment of more definitive therapy such as silicone T-tube insertion or sleeve resection.

In summary, we have treated 1,000 patients with the Nd-YAG laser in 1,396 applications during five years. Ninety-two percent of the treatments were performed via the rigid bronchoscope, the other eight percent with a flexible fiberoptic bronchoscope. Our experience confirms the usefulness and safety of this relatively new technique for treating benign and malignant obstructing lesions of the tracheobronchial tree.

Addendum

A total of 1,751 treatments in 1,261 patients has now been performed. This additional experience has not modified our judgment on procedure.

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