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Endoscopic tumor ablation for laryngotracheal intraluminal invasion secondary to advanced thyroid cancer

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Abstract

Conclusions. Endoscopic tumor ablation is a valuable option for inoperable postoperative laryngotracheal intraluminal invasion of well-differentiated thyroid carcinoma (DTC). *Objectives.* To investigate whether DTC invasion to the laryngotracheal mucosa can be controlled by 'simple' tumor ablation considering its relatively slow-growing nature. *Patients and methods.* Twenty-two consecutive patients underwent endoscopic tumor ablation caused by DTC for local control of intraluminal lesions with no significant extrinsic laryngotracheal compression in symptomatic or asymptomatic patients in whom radical operations were contraindicated. Debulking by Nd:YAG laser was followed by electrocoagulation and microwave coagulation for the residual tumor base. *Results.* The critical complication, post-treatment supraglottic stenosis, was managed by prophylactic minitracheotomy. During the follow-up period of up to 125 months, 6 of 22 patients died (median survival 50 months), mainly of lung metastases, but all had a patent airway at death. Post-surgical extraluminal lesion growth is indolent and since relapse of the intraluminal lesion is the main cause of symptoms, satisfactory local control could be obtained by re-ablation of the mucosal lesion every few years. Lesions requiring retreatment within 1 year after initial treatment usually have high-grade malignancy, causing extrinsic compression, and prognosis is unfavorable.

Keywords: *Laser, argon plasma coagulation, microwave coagulation therapy, airway stenosis*

Introduction

Well-differentiated thyroid carcinoma (DTC) is generally considered an indolent malignant disease with an 80–95% 10-year survival rate [1,2]. Although rare, 5.7–7% of DTC invades adjacent laryngotracheal structures [3,4] and particularly if it reaches the mucosa, changes occur in clinical status. Intraluminal tumor can cause respiratory symptoms such as bloody sputum and dyspnea leading to a life-threatening condition, and requiring radical excision including laryngectomy and/or tracheal resection [5,6]. However, patients who have undergone repeated local recurrence and surgery over a long period from the initial treatment are often unable to undergo radical surgery for clinical or technical reasons. In these cases, tracheotomy has been performed subsequent to symptoms of respiratory distress to establish patent airway.

Recently, endoscopic laser treatment has become an increasingly important modality for bronchoscopic palliation of obstructing lesions of the tracheobronchial tree [7]. Particularly in low-grade malignant tumors, i.e. carcinoids and adenoid cystic carcinoma, laser ablation has achieved good local control with few complications [8]. We usually perform endoscopic tumor ablation by debulking with an Nd:YAG laser followed by argon plasma coagulation (APC) and microwave coagulation therapy (MCT) for local control of intraluminal lesions in both symptomatic and asymptomatic patients in whom radical operations are contraindicated, and retreat if required during periodic follow-up examination by fiberoptic bronchoscopy. Reports on intervention of laryngotracheal invasion of thyroid cancer are not only extremely limited but also only refer mainly to immediate achievement of airway

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maintenance with consequent symptomatic improvement [9]. Here, we present our experience with endoscopic tumor ablation for advanced thyroid cancer and investigate the extent to which DTC invasion to the laryngotracheal mucosa can be controlled by endoscopic tumor ablation, considering the relatively slow-growing nature of DTC.

Patients and methods

Patients

We performed a retrospective study of 22 patients who underwent endoscopic tumor ablation of intraluminal lesions caused by laryngotracheal invasion of DTC with a follow-up period of over a year at our university hospital during the 10-year period from April 1996 to March 2006. In all cases the lesions were assessed to have no significant extrinsic airway compression. Patient characteristics are summarized in Table I.

The average age was 71 years and there were more than three times as many women as men. Most tumors were papillary carcinomas (19 patients, 86%) and 3 (14%) were follicular carcinomas. Two were primary cases, two had undergone shaving resection with a residual intraluminal lesion due to advanced lung metastases, followed by endoscopic treatment within 2–3 months, and 18 (82%) were local recurrences after previous surgery. The median time from initial surgery to endoscopic treatment in the recurrent cases was 57 months (range 14–203 months). Symptoms at the time of treatment were dyspnea in 7 cases (32%) and bloody sputum 10 cases (45%), while 7 cases (32%) were asymptomatic. Intraluminal tumors were detected by a CT scan in all asymptomatic patients. Multiple lung metastases were seen in 16 cases (73%).

Table I. Patient characteristics.

Characteristics	Data
Gender	
Men	5
Women	17
Age (years)	71 ± 10 (52–88)
Histologic type	
Papillary carcinoma	19
Follicular carcinoma	3
Recurrence after surgery	18
Median time from initial surgery to endoscopic treatment (months)	57 (14–203)
Symptoms at time of endoscopic treatment	
Dyspnea	7
Bloody sputum*	10
Asymptomatic	7
Lung metastasis	16

Data are presented as numbers or means ± SD (range).
*Including two patients who presented both dyspnea and bloody sputum.

Indications for endoscopic laser treatment

Patients who met the following criteria were selected as suitable candidates for endoscopic tumor ablation. 1) Radical surgery for laryngotracheal invasion was surgically problematic, or difficult due to the patient's poor physical condition, or was refused by the patient, or did not seem likely to prolong survival due to advanced distant metastasis. 2) Occlusion of more than 50% of the normal airway was mainly caused by intraluminal lesion. 3) In cases of retreatment, more than 3 months had elapsed since the previous treatment. If treatment was required within 3 months, stenting was performed for control of tumor regrowth. 4) Cases clinically suspected of anaplastic carcinoma due to signs such as rapid enlargement of a neck tumor were considered as contraindications for endoscopic tumor ablation. Written informed consent for endoscopic treatment was given by each patient after description of the technical procedures, results, and possible complications.

Patient work-up

Work-up, including CT or three-dimensional CT imaging of the neck, and flexible bronchoscopy, was performed to evaluate the type of laryngotracheal stenosis (to determine whether intraluminal tumor or extrinsic compression was the main cause of obstruction), extent and length of the lesion. Bronchoscopic inspection was conducted to evaluate possible vocal cord paralysis, tumor hemorrhaging, and morphology. Biopsy of the intraluminal tumor was carried out if possible.

Bronchoscopic procedures

All procedures were performed under general anesthesia in our laser and X-ray fluoroscope-equipped operating room. Anesthesia was induced with 1–2 μg/kg of fentanyl citrate and 1.5–3.0 mg/kg of propofol. After induction, the patients were intubated with a rigid bronchoscope (Efer-Dumon bronchoscope, EFER, La Ciotat, France) through an 'open-tube' technique, which allows insertion of the flexible bronchoscope. Anesthesia was maintained with continuous i.v. propofol infusion (2–4 mg/kg), which achieved a reasonable depth of anesthesia with spontaneous breathing. The fraction of inspired oxygen (FiO_2) varied between 0.35 and 1.0 according to the transcutaneous oxygen saturation level (SpO_2). When employing Nd:YAG laser or APC, FiO_2 was lowered to ≤ 0.40.

Endoscopic treatment

All endoscopic treatments were performed by a single bronchoscopist who was properly trained in the performance of this procedure (H.T.). Treatment was carried out through the working channel of a bronchofiberscope, which was inserted through a rigid bronchoscope. Since October 2000, a video bronchoscope (EB 1970K, Pentax, Tokyo, Japan), equipped with a color CCD chip that enables visualization of the Nd:YAG laser aiming beam (650 nm, 5 mW, emitted by a semiconductor laser) was employed.

Ablation of intraluminal tumor was conducted with an Nd:YAG laser (KTP/YAG Surgical Laser System, Laserscope, San Jose, CA, USA; power setting 30–40 W; illumination time 0.5–2 s per shot; laser tip distance 10 mm) directed via a 600 μm diameter quartz fiber with a non-contact probe. Laser ablation was performed starting with the tumor surface and maintaining the beam parallel to the airway axis so that airway dilatation could be achieved without perforation. APC (APC300 and ICC350, ERBE, Tubingen, Germany; power setting 40 W, argon flow, 1.6 L/min) [10], and MCT (Microtaze HSE-8M, Azwell, Osaka, Japan; power setting 40 W) [11] using an endoscopic ball-type electrode (E-24B, Azwell) was employed as laser debulking progressed, to target the flattened residual tumor tangential to the airway. For polypoid tumors, mechanical debulking (coring-out) using the tip of the rigid bronchoscope before laser treatment was performed to achieve immediate airway dilatation [12]. Hydrocortisone sodium succinate (500 mg) was administered intravenously twice a day for 2 days after the treatment to reduce laryngeal edema.

Follow-up and assessment

Fiberoptic bronchoscopy was performed 2 days after treatment to remove airway secretion and necrotic tumor tissue, by suctioning or removal with forceps. Airway humidification by an ultrasonic nebulizer was performed in patients during hospitalization. Most of the patients were discharged within a week after treatment. All patients were exclusively followed up endoscopically by our department. Two weeks after discharge, patients underwent bronchoscopic inspection, and subsequent examinations were carried out every 1–4 months according to the patient's clinical condition. During the follow-up period, reablation was performed when there was a risk of hemorrhaging or ventilatory impairment due to intraluminal tumor regrowth. When increased extrinsic compression caused $>50\%$ occlusion of the airway and respiratory distress, airway stenting including T-tube placement was performed.

Statistical analysis

All analyses were performed using SAS V9.13 software (SAS Institute Japan, Tokyo, Japan). The survival rate was compared using the Kaplan–Meier life-table analysis and the log-rank test. A p value of <0.05 was considered to show a statistically significant difference. All results were presented as means $\pm$ SD.

Results

Bronchoscopic findings before treatment, treatment profile, clinical course after treatment, and outcome of patients are summarized in Table II.

Bronchoscopic findings

Nineteen cases (86%) presented with unilateral vocal cord paralysis. The lesions were located in the larynx ($n = 8$), cricoid cartilage (10), and trachea (4). The lesion type was intraluminal tumor in 18 cases and there were 4 cases of 'mixed type' or intraluminal tumor accompanied by extrinsic compression. The extent of airway stenosis in relation to symptom was $85 \pm 13\%$ for dyspnea (range 60–95%), $40 \pm 18\%$ for bloody sputum (range 15–70%), and $34 \pm 10\%$ for asymptomatic cases (range 25–50%). All intraluminal lesions were proved to be DTC by histologic examination.

Endoscopic treatment

Intraluminal lesions of all patients were treated with Nd:YAG laser (median energy used, 3550 J; range 527–16377 J) combined with APC, MCT, and coring-out for maximum effect. None of the cases presented severe bleeding from tumor or airway perforation during treatment. Furthermore, residual extrinsic compression did not cause more than 50% narrowing of lumen patency after treatment.

Complications

Stridor occurred in one case (patient no. 17) 4 h after treatment. Emergency bronchofiberoscopy revealed laryngeal edema and bilateral vocal cord paralysis (left vocal cord paralysis preceded treatment). Endotracheal intubation was readily carried out followed by tracheotomy. After 5 days, laryngeal edema and right vocal cord paralysis showed

Table II. Treatment profile and outcome.

Patient no./ gender/age (years)	Histology	Respiratory symptoms	Lesion location	Airway occlusion	Procedure*	Complications	Subsequent endoscopic treatment†	Outcome, cause of death
1/F/61	Papillary	Dyspnea	Larynx	60%	YAG 3200 J	N	2nd: 34 months, 3rd: 60 months 4th: 104 months	Alive, 125 months
2/M/52	Papillary	Dyspnea; bloody sputum	Trachea	90%	Coring-out YAG 5670 J	N	2nd: 25 months, 3rd: 67 months	Alive, 78 months
3/F/84	Papillary	Bloody sputum	Cricoid cartilage	50%	YAG 1760 J	N	2nd: 34 months, T-tube	Dead, 41 months, heart disease
4/M/81	Papillary	Bloody sputum	Cricoid cartilage	20%	YAG 4145 J	N	2nd: 23 months, 3rd: 44 months, tracheotomy	Dead, 50 months, lung metastasis
5/M/66	Papillary	Bloody sputum	Larynx	15%	YAG 1427 J	N	2nd: 36 months	Alive, 59 months
6/M/77	Papillary	Bloody sputum	Cricoid cartilage	40%	YAG 7432 J	N	2nd: 10 months, 3rd: 14 months, T-tube	Dead, 23 months, lung metastasis
7/F/77	Papillary	N	Trachea	50%	Coring-out YAG 8460 J	N		Alive, 46 months
8/F/88	Follicular	N	Trachea	30%	Coring-out YAG 540 J	N		Alive, 42 months
9/F/56	Papillary	Dyspnea	Cricoid cartilage	95%	Coring-out YAG 6147 J	N	2nd: 3 months, Dumon stent, 3rd: 10 months, T-tube	Dead, 35 months, bleeding from relapsed tumor
10/F/77	Papillary	N	Cricoid cartilage	25%	YAG 4530 J	N	2nd: 34 months	Alive, 41 months
11/F/71	Papillary	Bloody sputum	Cricoid cartilage	35%	YAG 3500 J	N		Alive, 31 months
12/F/67	Papillary	N	Cricoid cartilage	25%	YAG 4320 J	N	2nd: 19 months, Ultraflex stent	Alive, 29 months
13/M/76	Papillary	Bloody sputum	Larynx	35%	YAG 820 J	N		Alive, 25 months
14/F/73	Follicular	Dyspnea	Cricoid cartilage	85%	Coring-out YAG 1300 J	N		Alive, 25 months
15/F/59	Papillary	N	Cricoid cartilage	40%	YAG 4289 J	N	2nd: 10 months, T-tube	Alive, 24 months
16/F/79	Papillary	N	Larynx	25%	YAG 1328 J	N		Alive, 22 months
17/F/70	Papillary	Dyspnea	Larynx	40%	YAG 5738 J	Bilateral VC paralysis		Dead, 4 months, carcinomatous pleuritis
18/F/53	Papillary	Dyspnea	Trachea	90%	Coring-out YAG 1008 J	N	Radical surgery: 1 month	Dead, 6 months, carcinomatous pleuritis
19/F/78	Papillary	Bloody sputum	Larynx	55%	YAG 3600 J	N		Alive, 18 months
20/F/61	Papillary	Bloody sputum	Trachea	70%	Coring-out YAG 527 J	N		Alive, 17 months
21/F/82	Papillary	N	Larynx	40%	YAG 3124 J	N		Alive, 14 months
22/F/72	Follicular	Dyspnea Bloody sputum	Larynx	90%	YAG 16377 J	Bilateral VC paralysis		Alive, 13 months

YAG, Nd:YAG laser; VC, vocal cord.
*All cases underwent argon plasma coagulation and/or microwave coagulation therapy after Nd:YAG laser treatment.
†Months after initial endoscopic treatment.

improvement, and the patient underwent stoma closure 10 days after endoscopic treatment.

After encountering this particular case, we began to perform prophylactic minitracheotomy (cricothyroidotomy: Mini-Trach II, Smiths Medical Japan, Tokyo, Japan) before removal of the rigid bronchoscope when treating laryngeal lesions. Patient no. 22 developed postoperative bilateral vocal cord paralysis but no symptoms of stridor or dyspnea. Some difficulty in sputum expectoration was seen but could be managed by aspiration via cannula. Five days after treatment, right vocal cord paralysis showed improvement, and the minitracheotomy tube was removed 2 days later. All the other cases also underwent tube removal 1 week after endoscopic treatment.

Subsequent treatments

One case (patient no. 18) without previous surgery underwent radical surgery, i.e. total thyroidectomy and circumferential tracheal resection (eight rings) with subsequent anastomosis 1 month after laser treatment. Although multiple lung metastases were seen, postoperative radioactive iodine treatment effect was expected due to the patient's relatively young age. During the follow-up period, 10 of the other 21 cases were retreated for progression of laryngotracheal lesions.

Three patients (nos 6, 9, and 15) were retreated within 1 year (ranging from 3 to 10 months) from the initial endoscopic treatment. Patient no. 6 presented regrowth of intraluminal tumor extending from the cricoid cartilage to the larynx 10 months after treatment, thus Nd:YAG laser treatment was performed. Subsequently, due to increased extrinsic obstruction during the following 4 months, a T-tube was placed. Patient no. 9 developed intraluminal tumor regrowth in 3 months, which was then implanted with a Dumon stent (Novatech, Aubagne, France). However, 7 months after stenting, tumor overgrowth occurred at the distal end of the stent, so a longer T-tube was placed. Patient no. 15 received placement of a T-tube as a result of increased extrinsic compression and bilateral vocal cord paralysis due to extraluminal tumor progression 10 months after laser treatment. Biopsy results revealed dedifferentiation to poorly differentiated carcinoma in patient nos 6, 9, and 15 mentioned above, 14 months after initial endoscopic ablation (extraluminal tumor), 3 months (intraluminal tumor), and 10 months (extraluminal tumor), respectively.

Seven patients underwent retreatment more than 1 year after the initial endoscopic treatment, the time between the initial and second treatment being 29 ± 7 months (range 19–36 months). Patient no. 3, who did not undergo previous surgery, received a T-tube 34 months after laser treatment due to increased extrinsic airway compression. In patient no. 12, endoscopic tumor ablation provided satisfactory local control of the lesion in the cricoid cartilage, but severe extrinsic tracheal compression due to metastic bulky mediastinal lymph node occurred 19 months after treatment, resulting in the placement of a non-covered ultraflex stent (Boston Scientific, Natick, MA, USA). Of the remaining five cases, three underwent a third endoscopic treatment, the time from the previous treatment being 30 ± 11 months (range 21–42 months). In patient no. 4, intraluminal lesion was well controlled, but extrinsic compression increased, resulting in tracheotomy 21 months after the second treatment (44 months after the initial treatment). Stent or T-tube insertion was not possible due to laryngeal stenosis and severely deformed airway. Patient no. 1, who underwent four endoscopic treatments, had satisfactory local control of the intraluminal lesion and currently, even after more than 10 years, 80% airway patency is maintained, despite continued extrinsic compression of the membranous portion (Figure 1).

Outcome

During a follow-up period of 4–125 months (median 27 months), 6 of 22 patients died. Median survival time after initial endoscopic treatment was 50 months. The cause of death was respiratory insufficiency due to multiple lung metastases and/or malignant pleural effusion (four cases), bleeding from locally relapsed tumor (one case), and other diseases (long-standing heart disease, one case). None died as a result of bleeding from the intraluminal lesion or airway occlusion. The patient survival curve after the initial endoscopic treatment is shown in Figure 2.

The cause of death of patients who died within 6 months after treatment (patient nos 17 and 18) was carcinomatous pleuritis. In patient no. 18, who underwent radical surgery after laser treatment, exacerbation of multiple lung metastases and malignant pleural effusion occurred 3 months after surgery. Although the histological type of intratracheal tumor at the time of laser treatment was differentiated papillary carcinoma, cytology of the malignant pleural effusion revealed poorly differentiated carcinoma.

The patient survival curve after initial treatment of three cases (group A) that required retreatment within 1 year, and seven cases (group B) that required retreatment after 1 year or longer, are

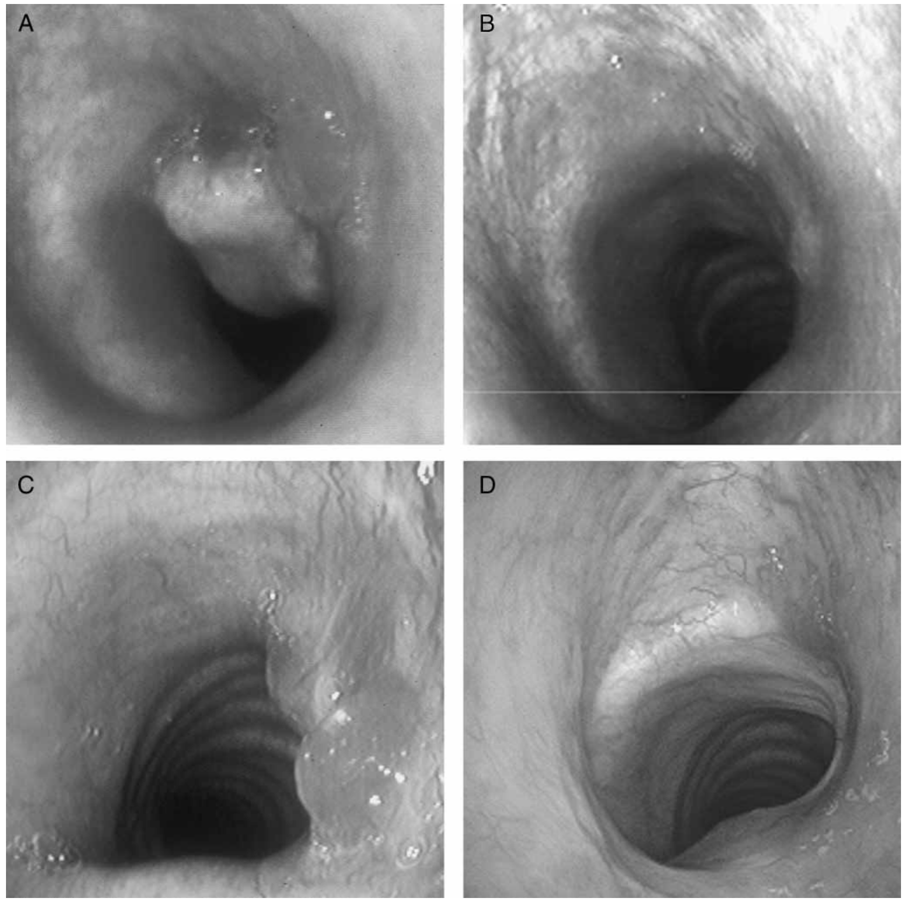

Figure 1. Typical bronchoscopic images of intraluminal laryngeal invasion by papillary thyroid carcinoma (patient no. 1). The patient suffered from dyspnea on exertion. During the follow-up period of over 10 years, the patient has undergone four endoscopic tumor ablations. (A) October 1996. Before endoscopic treatment. The tumor, with a superficial white necrotic area above the cricoid cartilage, obstructed 60% of the airway. Another edematous reddish small tumor was located just below the right vocal cord. (B) October 1998. Two years after initial treatment. (C) October 1999. Before the second treatment. (D) April 2007, 10.5 years after initial treatment. Satisfactory local control of the intraluminal lesion and 80% airway patency was obtained despite continued extrinsic compression of the membranous portion.

shown in Figure 3. Although it is difficult to interpret the results, due to the limited sample size, it should be noted that the survival time of group B is significantly longer ($p = 0.009$) than that of group A. Patients (nos 5 and 10) who underwent shaving resection without removal of the intraluminal tumor followed by laser treatment, were retreated 3 years after the initial laser treatment. Subsequently, local control is satisfactory and both patients remain alive after 59 and 41 months, respectively.

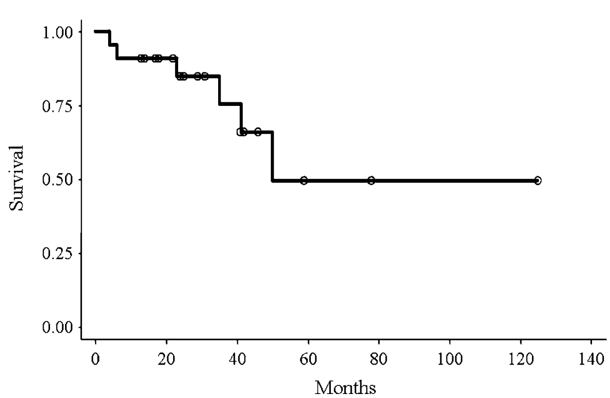

Figure 2. Survival curves after initial endoscopic tumor ablation. The median survival time was 50 months.

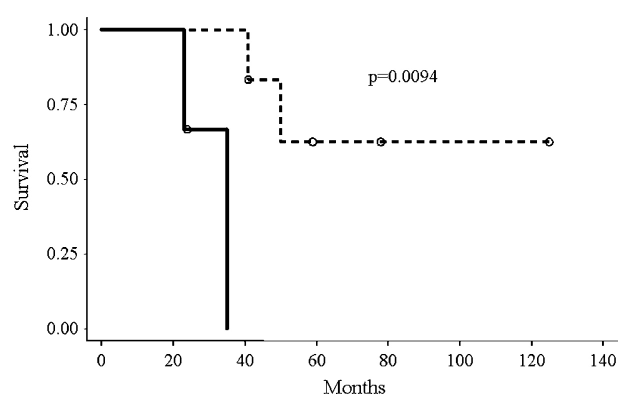

Figure 3. Comparison of survival curves of patients who required retreatment within 1 year (—) and after 1 year or longer (---).

Discussion

In this study, we investigated the extent to which DTC invasion to the laryngotracheal mucosa can be controlled by endoscopic tumor ablation, and how the airway is compressed due to the progression of the extraluminal lesion during the follow-up course, and the resulting effect on patient survival time. To control intraluminal lesions, appropriate and effective tumor ablation is essential. The mean interval between the first and second endoscopic treatment for airway obstruction caused by bronchogenic carcinoma was investigated, comparing different tumor debulking methods. The results were 29 days for mechanical coring-out by rigid bronchoscope followed by residual tumor removal with forceps, and 102 days for Nd:YAG laser [7]. These results can be attributed to the residual tumor base liable to remain after mechanical debulking, and to the cytocidal effects of laser energy penetrating deep into the tumor.

However, laser treatment also has its limitations. The light emitted from the fiber tip travels in a straight line, which can damage the tracheal wall when treating increasingly flattened tumors as ablation progresses. For such superficial residual lesions on the airway mucosa, we employed APC and MCT, which enable safe treatment in a lateral direction through the flexible probe. APC is a form of non-contact electrocoagulation, and the argon plasma beam not only acts in a straight line along the axis of the probe but also laterally, maintaining a limited depth of penetration. MCT is recognized as a percutaneous thermal ablation technique for hepatic malignancies [11]. While a needle-type electrode is utilized for liver tumor treatment, a ball-type electrode has recently been developed for interventional bronchoscopy. For thermal coagulation of tissues, an electrode 2.4 mm in diameter is positioned directly on the tumor, enabling lesions tangential to the airway to be treated without difficulty. In MCT, tissue coagulation is achieved by the 'dielectric heating effect', which refers to the friction heat induced by microwaves stimulating the water molecules in tissues. This means that heat is not transferred from the outside but generated within the tissue itself, thus preventing tissue carbonization and eliminating the risk of ignition under administration of highly concentrated oxygen. Similar to APC, MTC has significant hemostatic effects, but is less effective in reducing tumor volume compared with the Nd:YAG laser. We succeeded in achieving efficient tumor debulking with minimal damage to the normal airway mucosa by utilizing Nd:YAG laser, which can achieve remarkably effective tumor regression, to ablate a large portion of the intraluminal tumor followed by APC and MCT combined to treat the residual tumor base.

The most critical complication of interventional bronchoscopy for advanced thyroid cancer is supraglottic stenosis caused by laryngeal edema and temporary bilateral vocal cord paralysis [13]. Especially during the treatment of laryngeal lesions, the tip of the rigid bronchoscope needs to be positioned adjacent to the vocal cords, and furthermore, most patients suffer from pre-existing unilateral vocal cord paralysis, thus there is a high occurrence of temporary paralysis of the unaffected vocal cord. Supraglottic stenosis is a life-threatening condition that requires emergency airway control, but once laryngeal edema occurs, re-insertion of a rigid bronchoscope or endotracheal intubation is often difficult. Minitracheotomy is performed with a percutaneous cricothyroidectomy device with an internal diameter of 4 mm, which has been reported to be effective not only for treatment of sputum retention but also as a ventilatory support for upper airway obstruction in recent years [14]. However, since the introduction of minitracheotomy, serious complications such as misplacement and bleeding have been reported [15,16]. We performed minitracheotomy before removing the rigid bronchoscope for preventive airway control. By cannulating during endoscopic observation of the airway lumen, a safe and reliable treatment without misplacement was feasible even in cases of laryngotracheal deformation/deviation caused by tumor invasion. Given that the minitracheotomy tube can be removed 1 week after recovery of temporary supraglottic stenosis and fistula formation, minitracheotomy should be performed as a minimally invasive technique – especially after treating laryngeal lesions.

Excluding the 2 cases who died of carcinomatous pleuritis within 6 months after treatment, follow-up of the remaining 20 cases continued during a period of over 1 year after the initial endoscopic treatment. The clinical course differed significantly between those who required retreatment within 1 year (three cases) and the remaining cases. In all of those three cases, well-differentiated carcinoma diagnosed at the time of the initial treatment underwent malignant transformation to poorly differentiated carcinoma (within 3–14 months), which necessitated airway management by a T-tube as a result of extrinsic compression caused by extraluminal tumor progression, of which two cases died within 3 years. In another case without previous surgery, endoscopic treatment was performed for hemorrhagic tumor control but required T-tube placement to manage advanced extrinsic compression 3 years later. All remaining cases had a history of thyroid surgery, and the majority showed very gradual extrinsic compression after ablation treatment, but because the main cause of disease progression was intraluminal tumor, local endoscopic tumor ablation performed at an average of 30 months after the previous treatment maintained satisfactory airway patency.

The question is why lesion progression occurs predominantly inside the lumen in postoperative patients? A pathological study of the 22 cases of papillary carcinoma with tracheal invasion indicated that tracheal invasion occurs directly from the primary thyroid cancer extending between the cartilaginous rings, the annular ligaments of the trachea, where the vessels penetrate perpendicular to the lumen, allowing an invasion pathway [17]. Cicatricial formation and adhesion following an effective surgical resection of the extraluminal lesion may prevent anterior (extraluminal) proliferation of the existing DTC of the tracheal wall. Therefore, it can be speculated that tumor slowly penetrates into the airway lumen through the potential lines of weakness in the laryngotracheal wall, and once it reaches the mucosa, it can grow to involve portions of the airway where tissue resistance is weak. Dedifferentiated tumors may grow extraluminally due to the aggressive growth potential, resulting in extrinsic compression.

In interventional bronchoscopy for lung cancers, airway stenting is often performed to suppress relapse of residual intraluminal tumor after ablation [7]. In our highly selected series, $>80\%$ of lesions were located in the larynx and cricoid cartilage, a region where stenting is difficult due to its close proximity to the vocal cords and there is the risk of stent migration. DTC generally exhibits slower progression than lung cancer, thus post-stenting survival time is generally longer (years vs months) [7,13,18]. Given these factors, we consider that prophylactic stenting for DTC patients should not be performed because of the possible stent-related clinical symptoms that would interfere with activities of daily living. Consequently, even in 'mixed type' cases accompanied by extrinsic compression, ablation of the intraluminal lesion was our first-line procedure. However, stenting was employed in cases in which symptomatic airway stenosis occurred due to increased extrinsic compression, or which required control of the intraluminal lesion at short intervals due to a fast-growing tumor. As a result, we succeeded in maintaining airway patency, and the cause of death in two-thirds of patients was exacerbation of pre-existing multiple lung metastases or carcinomatous pleuritis.

In conclusion, endoscopic tumor ablation for laryngotracheal intraluminal invasion caused by DTC can be a safe and effective procedure with Nd:YAG laser vaporization accompanied by a combination of APC and MCT, taking full advantage of their individual characteristics. For patients undergoing surgery with lesions that exhibit no significant extrinsic compression, the extraluminal lesion tends to grow at an extremely gradual pace after treatment, but since the relapse of the intraluminal lesion is the main cause of disease, satisfactory local control can be obtained by re-ablation of the mucosal lesion every few years. As for lesions requiring retreatment within 1 year after the initial endoscopic treatment, the prognosis is often unfavorable since the high-grade malignancy of the tumor causes extrinsic compression, which necessitates stent insertion. Endoscopic tumor ablation, which takes into account the relatively slow-growing biologic behavior of DTC, is well worth considering as an alternative to surgery for patients with postoperative laryngotracheal intraluminal invasion in whom radical surgery is contraindicated.

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