Journal of Innovative Optical Health Sciences
Vol. 6, No. 1 (2013) 1350006 (6 pages)

DOI: 10.1142/S1793545813500065

THE EFFICACY OF MICROWAVE THERAPY VIA BRONCHOFIBERSCOPE IN THE TREATMENT OF SEVERE TRACHEA STENOSIS

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Accepted 13 December 2012
Published 31 January 2013

To evaluate the efficacy of microwave therapy via bronchofiberscope for treatment of severe trachea stenosis. Microwave tissue coagulation (MTC) and diathermy (MD) therapy via bronchofiberscope were performed on 37 patients with severe trachea stenosis diseases at least two times. The effective rate immediately after treatment was 100% in all cases. After one month, the rate remained 100% in the patients with benign diseases, but it dropped to 67% in the patients with malignant tumors. We have demonstrated that the microwave thermotherapy via bronchofiberscope is an effective method to treat patients with benign trachea stenosis non-invasively. For cancer patients with trachea soakage and blockage, it can be performed to improve their life quality by alleviating their agonies.

Keywords: Bronchofiberscope; microwave therapy; tracheal stenosis.

1. Introduction

Trachea, the only channel for the onset of breathing system, is the link of vocal cord and juga. It will cause death from suffocation when trachea is been blocked completely for 3−5 min. Actually, serious tracheal stenosis also results in complete blockage of the channel due to cough and sputum plugging. Those patients with advanced cancer located in the main endotracheal tube always suffer from life-threatening emergencies. However, the disease status usually makes them refuse surgery or does not allow them to perform radiotherapy, or chemotherapy again.

Technology advances have been seen in the endoscopic treatment of trachea — bronchial diseases as a result of the rapid development of biomedical optoelectronics in recent years. Physical methods that have been used to induce biological thermal effect include laser,[1−4] argon plasma coagulation,[5−9] microwave thermal coagulation and diathermy (MD) technology[10−12]; they have shown efficacies in the treatment of stenosis, blocking and bleeding caused by tracheal-endobronchial hyperplastic lesions (e.g., benign or malignant tumor, scar).[13−16] Of particular clinical significance, these

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techniques also offer a practical way to treat patients who are conventionally deemed unsuitable or inoperable for surgery so as to lessen their breathing difficulties, prolong their lives and improve their life quality.[17]

Laser is among the early techniques for endotracheal treatment. While being able to provide rapid cutting, cover deep and wide therapeutic range, however, it may cause unnecessary harms to surrounding normal tissues. For instance, tracheal perforation can occur when the treatment is too deep. In addition, the laser beam induced tissue vaporization produces a significant amount of harmful and irritant gas, which would result in alveolar damage and trachea burns if not removed instantaneously.[2,4] Argon plasma coagulation is a technology for tissue coagulation through using high-frequency electric energy and ionized argon gas. It makes less smoke in tissue cauterization and a thinner layer of scalding and necrosis at a faster cutting speed than using a laser beam. It is also a very effective and safe method to stop shallow bleeding of solid tumors with large areas.[18] But in cases that large tumor needs a deep cutting, it is not so effective as the standard high-frequency electric knife or laser. In addition, this procedure suffers a limitation in that it requires the suction oxygen concentration be maintained below 40% to prevent endotracheal combustion, which otherwise may cause severe complications.[19] Therefore, this technique becomes inapplicable to patients with severe tracheal stenosis who must breathe in a relatively high level of oxygen to prevent the aggravation of hypoxemia, which the patients might not be able to tolerate.

In contrast, microwave refers to the electromagnetic wave with wavelengths ranging from 1 m to 1 mm, or with frequencies between 300 MHz and 300 GHz, which fall in between the high-frequency electric-argon plasma and laser coagulation techniques. To date, microwave thermal coagulation and heat radiation have been used to treat the trachea blockage condition caused by benign and malignant tumors within the airway, intima hyperplasia of tuberculosis, polyps, granulomas and other complications.[10–12] It has been reported that microwave coagulation can often be used to address the conditions that cannot be resolved with drug treatment or for inoperable cases. Microwave coagulation is a safe procedure because it induces no tissue vaporization or requires no oxygen during the operation. In addition, it has an appreciable treatment depth.

Cases of treating tracheobronchial stenosis via microwave have been reported in the literature.[10–12,17] However few if any were conducted for the treatment of patients with severe tracheal stenosis by bronchofiberscope microwave treatment. Herein, we present our result of treating 37 patients with severe endotracheal stenosis by microwave therapy via bronchofiberscope.

2. Materials and Methods

2.1. *The clinical patients*

The 37 patients were chosen from 43 cases with clinical symptoms of obvious tracheal stenosis-blockage. Lesions were found in the main trachea below the glottis and before the carina branch under bronchofiberscope with naked eyes. The lesions blocked 2/3 to 3/4 of the tracheal diameter with a length of 1−30 mm. The clinical symptoms include cough, expectoration, hemoptysis, and obvious dyspnea and shortness of breath. The case classification was 3−4 according to the American Thoracic Society's standards.[20] The 37 patients and their families agreed to the bronchofiberscope microwave treatment. The patient information was summarized in Table 1.

2.2. *Techniques*

The adult bronchofiberscope (BF series, Olympus, Japan) and the microwave therapy apparatus, computer numerical control respiratory therapy device (HJ-5F, Huajie high-tech Institute, Bengbu, Anhui) were used in this work. The radiation source is the single-pole coaxial microwave antenna.

In this study, two types of microwave therapy were performed as follows:

For severe tumor proliferative lesions in the main trachea, mucous sputum/scab and thrombospondin,

Table 1. Clinical features.

Average age	51 ± 7.8
Male : Female	22:15
Trachea with a single tumor (Primary or metastatic tumors)	14
Tracheal transfer and infiltrating carcinoma (Lung cancer/Esophageal cancer)	10
Benign lesions (Sputum bolt, Thrombus, hypertrophic scar, Adhesions)	13

the microwave tissue coagulation (MTC) was used. The radiation probe was inserted from the bottom of the diseased tissue to the lesions at varying penetration depths. The microwave radiation was applied at 60 to 80 W of power for 5 to 6 s for the surrounding tissue coagulation or a slight vaporization. The probe was retrieved until the degeneration or the hardening of the eschar/gray solidification occurred. Biopsy forceps were used to clear the cavity off the tissue residues of solidification and expand the lumen of the cavity. The probe was repeatedly applied to multiple points in the lesion for vaporization or coagulation of burning. At last, the procedure was applied to the peripheral regions. The MTC procedure was performed three to four times with the treatment interval between three to seven days according to the patients' condition. The treatment of adhesion was applied at the same parameters as above to close the edge of adhesion with the probe.

For tracheoesophageal fistula or diffuse vascular proliferation zone, the MD therapeutic method was used with the same setup and radiation probe as in MTC. Since it provides a no-contact therapy to tissues with the probe staying 2 to 10 mm away from the diseased tissue through heat treatment, the procedure was performed at higher radiation dose, such as power of 80 to 100 W for 6 to 10 s.

2.3. *Clinical evaluation*

The treatment efficacy was evaluated by the bronchofiberscope by observing local lesion in the main trachea and the size of the lumen diameter before, immediately, and one month after the 2–5 times treatment: (1) Improved: the lesion size was significantly reduced and the stenosis condition was improved. The lumen became greater than 1/2 of the tracheal diameter. (2) Cured: tracheal lesions disappeared at the end of treatment and the wall was recovered. An effective therapy met either of the two outcomes.

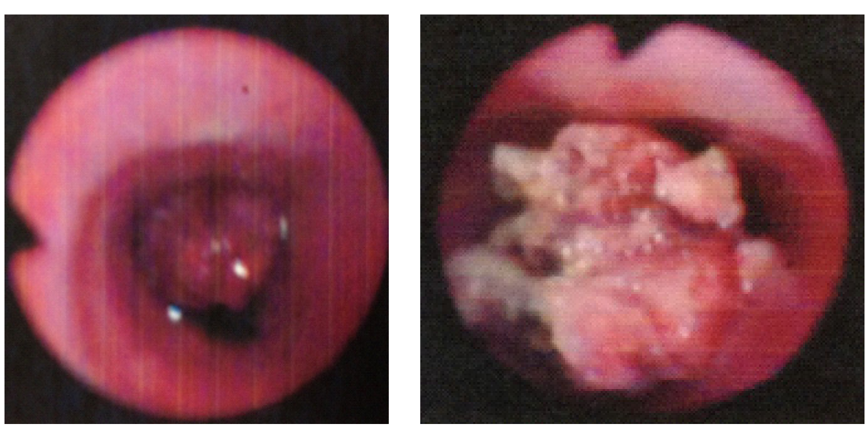
3. Results

3.1. *Endotracheal lesion morphology and treatment effect*

Figure 1 shows a series of diagrams depicting the typical result of a single malignant tumor in the lower segment of trachea, which was treated five times. Prior to treatment, the solid tumor blocked the majority of the lower segment of trachea [see Fig. 1(a)]. During the 4th MTC therapy, the tumor clearly became necrotic, pale and smaller [see Fig. 1(b)]. At the end of the 4th treatment, the lesion became a flat papillary with only one tenth of the tracheal diameter [see Fig. 1(c)]. After the 5th treatment, only a small uplift change was observed on tube wall, whose surface was presented with gray solidified tissues due to the thermal therapy [see Fig. 1(d)].

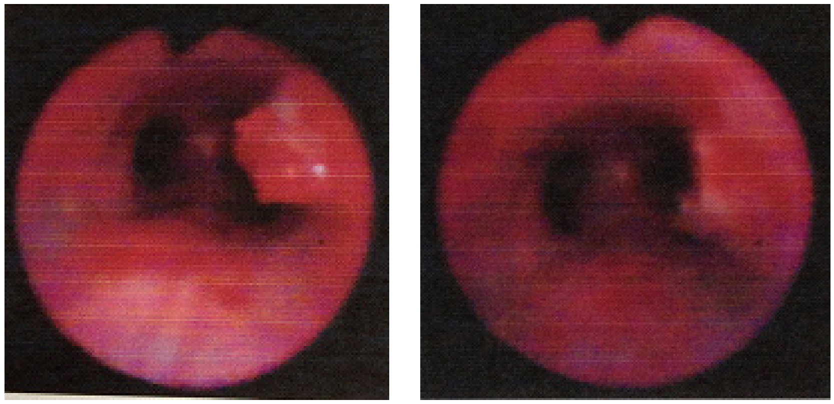
3.2. *Tumor types and treatment effects*

Of 24 cases of malignant lesions, five cases were advanced esophageal cancer that had invaded the trachea, of which four cases had tracheoesophageal fistula. The 19 other cases were involved with



(a) (b)

Fig. 1. Typical diagrams of a single malignant tumor in the lower segment of trachea before or after treatment with the MTC. (a) Before treatment; (b) During the 4th treatment process; (c) Before the 5th treatment; (d) After the 5th treatment.



(c) (d)

Fig. 1. (*Continued*)

Table 2. Treated endotracheal lesion types and therapeutic efficacies.

Endotracheal lesion types	Number of cases	Effective ratio immediately after therapy	Effective ratio one month post-therapy
Malignant:	24	100% (24/24)	67% (16/24)
A single spherical lesion	14	100% (14/14)	71% (10/14)
Infiltration, hyperplasia, swollen large	10	100% (10/10)	60% (6/10)
Benign lesions:	13	100% (13/13)	100% (13/13)
Mucus sputum bolt/scar	3	100% (3/3)	100% (3/3)
Sludged blood	3	100% (3/3)	100% (3/3)
Hypertrophic scars: the limitations and screen-like adhesion	7	100% (7/7)	100% (7/7)

tumors from the other organs or single or multiple endotracheal metastases, of which 10 cases were lung bronchogenic carcinoma that had invaded the trachea. The patients with benign lesions can be categorized into two classes: one class presented with inflammatory lesions within the trachea resulted from the limitations of hypertrophic scars, or curtain-like adhesion with a kind of scars. These conditions can be well treated with anti-inflammatory therapy in combination with microwave therapy. No surgery is necessary. The other class was frail elderly patients with debilitating conditions caused by mucus sputum/scab and blood clots (or thrombosis). These patients are not able to expectorate but no surgery is required. Usually microwave therapy is effective on them.

For all of 37 patients who underwent the microwave therapy via bronchofiberscope presented with either advanced cancer or benign lesions, the effective ratio immediately with 2–5 times treatment reaches to 100%. After one month, there was no recurrence for benign lesions, which means the benign lesions were cured completely. For the 14 cases of malignant lesions with a single spherical lesion and 10 cases with infiltration, hyperplasia, swollen large, there are four cases of restenosis, respectively. Table 2 summarizes the microwave therapy for different endotracheal lesion types and the therapeutic efficacies.

4. Discussion

This study included patients with advanced tumors that had invaded the main trachea. For all of the patients, their original tumors were unresectable. In addition, the tracheal involvements of the tumors had undergone surgery and local radiotherapy; however, there were still local tumor residuals that might lead to a large mass of necrosis and as such impose a risk of fatal hemoptysis. No external radiation therapy for palliative care could be performed on these patients because their endotracheal lesion diameters were greater than 3/4 of the tracheal diameter. The patients presented with severe breathing difficulties; some even had recurrent suffocation. Therefore, microwave treatment through bronchoscopy might be able to serve as an effective local therapy in these patients to mitigate and lift the tracheal obstruction, relieve pain and improve the quality of life.

The microwave therapy via bronchofiberscope can be conducted in two ways — MTC and MD. The former has a direct destructive effect on tumor. Its mechanism is to control the head through a special pocket-like high-energy microwave concentrated in the tip, which results in bio-thermal effects. The MTC method can raise the local temperature to the range of 60°C to 120°C, which causes direct vaporization or degeneration of tumor tissue protein coagulation or necrosis. The cancerous tissue within the range of microwave irradiation can be potentially killed completely; but the microwave effect within the tissue decreases significantly as the distance from the probe increases. As such, so the role of MTC is limited in the treatment of large lesions. MTC treatment does not cause bleeding due to the coagulation of small blood vessels. In MTC-treated cases, a special attention was paid to the method of microwave application to lesions with huge spherical mass in the trachea. If the tumor crowded the trachea to a narrow gap, the radiation probe should be inserted from the basal part of the lesion to perform a "borehole sampling" treatment by gradually deepening the probe to penetrate the lesion all the way. The treatment must not start from the narrow gap based on facts that the formation of necrosis coagulation or eschar may block the small ventilation gap at least temporarily and the normal tracheal tissue that receives a certain amount of thermal effects can cause acute local tissue congestion and swelling, which may result in a worse local stenosis or even a complete blockade leading to the suffocation of the patient.

If fistula presents at tracheal lesions, the MTC may result in a greater degree of fistula. In such cases, MD offers an alternative way of microwave treatment, in which the radiation probe has no direct contact with the necrotic tissues of the tracheal membrane erosion. Another benefit of the MD method is that it can induce denaturation or coagulation of the infiltrated tumor surface thus inhibiting the tumor growth.

Those benign lesions can be divided into two subgroups according to the lesion's characteristics. The first subgroup is rare and the cause is unknown, in which the inflammatory lesions within the trachea are thin curtain-like adhesions or localized hypertrophic scar. For this subgroup, the use of MTC treatment can afford a complete or near complete removal of the adhesions and hypertrophic scar in combination of with an anti-infective therapy. After the treatment, trachea can return to normal and no thoracotomy is necessary. If the hypertrophic scar shows significant endotracheal hardening in a wide range, the therapeutic outcome of MTC would be poor and thus a surgical treatment should be performed. The second subgroup of patients were presented with mucous sputum/scab or clot bolt plug. Most of them were frail elderly with expectoration difficulties. The course of treatment of this subgroup was more time-consuming compared to the 1st subgroup; however, the treatment efficacy was obvious as the breathing difficulties were relieved.

Patients with severe tracheal stenosis are hard to treat and the therapeutic methods are limited. A small number of them can receive surgical treatment, but the majority of the patients lack surgical indications, because the poor efficacy of their chemotherapy or radiation therapy has caused local edema, which worsens the tracheal stenosis or even causes suffocation or other severe consequences. Emergent endotracheal intubation and nitinol stent placement can quickly relieve the obstructive symptoms, but follow-up treatments should be conducted.[21] For example, the stent placement in patients with endotracheal recurrent granuloma stenosis can lessen the narrowing of trachea and thus prolong survival if combined with the treatment of laser and endotracheal short distance radiotherapy.[22] Laser and argon plasma coagulation therapies have also shown good effects on benign and malignant tumors within large airway; but some of them have to be carried out using a rigid bronchoscope under general anesthesia and may have the risk aforementioned. The cases covered in this study yielded satisfactory results via bronchoscopy microwave treatment. The method is simple, convenient and practical with low risk. Taken together, we have shown that microwave treatment is an effective method to treat the benign or localized malignant lesions within trachea and inhibits tumor growth in patients with inoperable late-stage cancer metastases. For patients with benign lesions, it makes the stressful surgical removal unnecessary; for patients with malignant lesions, it can be performed as a palliative care to improve the quality of life or even prolong their lives. However, this method has a limited role in the treatment of long tracheal stenosis, trachea narrowing under external pressure or hardened scar.

Acknowledgment

We would like to thank Prof. Dan Zhu of Huazhong University of Science and Technology for her benefit discussion. We also appreciate Prof. Xiankai Sun of Advanced imaging research center, UT Southwestern Medical Center, USA for his help.

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