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Original Paper

Outcome and Safety of the Montgomery T-Tube for Laryngotracheal Stenosis: A Single-Center Retrospective Analysis of 546 Cases

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Key Words
Laryngotracheal stenosis · T-tube · Efficacy · Extubation rate · Safety

Abstract
Objective: We retrospectively analyzed the surgical outcome and safety of the Montgomery T-tube for laryngotracheal stenosis. ***Methods:*** The patients with laryngotracheal stenosis who had undergone T-tube placement between 1996 and 2010 were reviewed. The severity of the stenosis was evaluated using the Cotton-Myer staging method. The primary endpoint was the rate of successful extubation and the secondary endpoint was safety. ***Results:*** 546 patients were eligible. T-tubes were successfully extubated in 342 patients 6–24 months following intubation. The initial extubation success rate was 62.3%. Laryngotracheal restenosis following extubation occurred in 192 patients, necessitating T-tube placement for a second time. The success rate for the second attempt was 58.9%. The overall success rate was 83.3%. Hemoptysis was reported in 8 patients, postoperative infection in 6 patients, wound dehiscence in 3 patients, laryngeal obstruction in 13 patients, aspiration in 12 patients, and postoperative tracheoesophageal fistula in 2 patients. ***Conclusion:*** This large clinical series demonstrated the safety and effectiveness of the T-tube for grade 1 and 2 stenosis with stenosed segments of <6 cm. For those being >6 cm, tracheal end-to-end anastomosis is not appropriate and long-term placement of a T-tube is recommended. Our findings provide useful guidance for preoperatively selecting patients with laryngotracheal stenosis of various causes and differing severity.
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Introduction

Laryngotracheal stenosis remains a therapeutic challenge clinically. One major factor is restenosis following laryngotracheoplasty in a significant proportion of patients. Laryngotracheoplasty with T-tube placement is a simple method for treating laryngotracheal stenosis. The T-tube was first developed by Montgomery [1] in 1965 for treating tracheal stenosis. According to Pereszlenyi et al. [2], common indications for T-tube placement include: (1) temporary placement before segmental tracheal resection due to complex tracheal injury, apparent tracheal inflammation, or tracheal and esophageal fistula; (2) temporary placement following segmental tracheal resection due to unreliable suture (apparent inflammation and high tension) as a precautionary measure against tracheal restenosis, inadequate anastomosis of the tracheal end, the presence of free edges, restenosis, or subglottic stenosis; (3) placement as a single measure for unresectable tumor, long stenosis, stenosis of multiple segments, or other problems that render segmental tracheal resection impossible (fibrosis and inflammation). According to Wahidi and Ernst [3], T-tubes can be placed temporarily before eventual reconstruction surgery in patients with active concurrent disease or severe systemic disease that prolongs intensive care unit stay or in patients with a recent episode of tracheal trauma or infection. T-tubes can be used as a complementary measure to promote mucosal recovery following repair including tracheal reconstruction and end-to-end anastomosis after segmental tracheal resection. Furthermore, T-tubes can be used therapeutically to prevent the occurrence of complications such as partial dehiscence and restenosis following failed surgical reconstruction. They can also be placed as a therapeutic measure for patients with a poor systemic condition that does not allow surgery or a tracheal injury that cannot be repaired because of its length and relation with adjacent structures. According to Puma et al. [4], T-tubes can be placed as a temporary support in the presence of excessive scar tissue or apparent inflammation in the tracheal mucosa until the condition of the patient allows partial tracheotomy. It is advisable that tracheotomy be not performed until the resolution of the inflammation and improvement of the overall condition of the patient. It usually takes approximately 6 months for an inflammation to be completely resolved. Liu et al. [5] believed that T-tubes can be placed for a longer period of time or permanently if there is a long segment of stenosis or if tracheal malacia is present. It has been reported that for stenosed segments >6 cm, T-tubes can be placed for a longer term. Similar indications for T-tubes have been described by other investigators [6–8].

The tube is inserted into the upper trachea or larynx following trauma or surgery to serve as a means to maintain the tracheal airway as well as serving as a stent. According to the degree of the laryngotracheal stenosis, the T-tube is extubated 6–12 months after laryngotracheal placement, which could promote epithelialization of the laryngotracheal mucosa and avoid laryngotracheal stenosis. Indications for T-tube placement included temporary intubation before segmental tracheal resection, complex tracheal injury, obvious tracheal inflammation, and tracheoesophageal fistula. Puma et al. [4] believe that when there is an apparent inflammation in the mucosal tissues or when there is excessive scar tissue, a T-tube can be placed to provide temporary tracheal support until the condition of the patient has improved and tracheostomy can be undertaken. In general, it takes approximately 6 months for inflammation to subside in the tracheal mucosa. Liu et al. [5] think that T-tube placement can be regarded as a temporary measure before trachea reconstruction to lessen tracheal mucosal inflammation. If tracheal stenosis or malacia is present over an extended period of time, some investigators [6–8] may also consider permanent T-tube placement.

In the current study, we retrospectively analyzed the outcome and safety of T-tube placement for 546 patients with laryngotracheal stenosis who received treatment between May 1996 and May 2010 at our institution with extubation rate as the primary endpoint of the study.

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Patients and Methods

Patients

We retrospectively reviewed the clinical and surgical records of patients with laryngotracheal stenosis who had undergone T-tube placement between May 1996 and May 2010 at Changhai Hospital, Shanghai, China. A patient was included in the study (1) if laryngotracheal stenosis was diagnosed and if the cross-sectional area of the stenosed region was greater than 70%, (2) if the patient had progressive breathing difficulty, and (3) if apparent inflammation or granulation was observed during tracheoscopy. The study protocol was approved by the local institutional review board at the authors' affiliated institution. Patient consent was not required because of the retrospective nature of this study.

Clinical Evaluation

Tracheoscopy was performed in all patients, and tracheal CT reconstruction was carried out whenever necessary. For patients with breathing difficulties, tracheostomy was performed before evaluation. Stenosis was categorized by the location and extent of stenosis into tracheal stenosis, laryngeal stenosis, and laryngotracheal stenosis. The severity of stenosis was evaluated using the Cotton-Myer staging method [9].

Surgical Technique

T-tube placement combined with surgery was carried out in accordance with the length and extent of the laryngotracheal stenosis by a team of equally experienced surgeons (S.S., W.W., S.X., L.F.I., S.C., and Z.H.) with at least 10 years of experience in T-tube placement. T-tubes had three sizes: 10, 12, and 14 mm in diameter. The size was chosen considering age, sex, body height and preoperative bronchoscopy and tracheal CT findings to select a tube of appropriate diameter and length for the patients. Tubes of 14 mm in diameter were generally used for adult males, 12 mm for adult females, and 10 mm for youths and adolescents. The tube length was adjusted during placement and was generally 1 cm more than the length of the stenosis. The T-tube was placed after laryngotracheofissure. Normal mucosa was preserved as much as possible, scar tissue was excised, and fractured cartilage underwent anatomic reduction. The T-tube should be placed 1.0 cm beyond both sides of the stenosis. For patients with apparent laryngeal stenosis, T-tube placement was done with laryngofissure. For patients with an apparent scar in the vocal area, T-tube placement was carried out after laser removal of the scar under a laryngoscope. In case of apparent subglottic stenosis hindering T-tube placement, cricoidectomy and laryngofissure were carried out before tube placement. In cases with an inadequate transverse diameter after cricoidectomy, the cricoid cartilage arch was widened with the hyoid bone. In patients with bilateral vocal cord paralysis, arytenoidectomy was performed using laser under a laryngoscope along with T-tube placement.

Follow-Up

Patients were followed up every 3 months for the 1st year after intubation and every 6 months thereafter by clinic visits. Measures were taken according to the changes in laryngotracheal stenosis. The length of treatment and follow-up started from the time of initial T-tube placement. The primary endpoint of this retrospective study was the rate of successful extubation and the secondary endpoint was safety.

Statistical Analysis

The SPSS version 16.0 statistical software (SPSS Inc., Chicago, Ill., USA) was used for statistical analysis. Normally distributed variables are expressed as means ± SD or as a percentage, the χ^2 test was used for comparing differences between groups, and variance analysis was used for comparison among three groups. $p < 0.05$ was considered statistically significant.

Results

Demographic and Baseline Characteristics of the Study Subjects

Totally, 546 patients met the inclusion criteria and were eligible for the final analysis. The demographic and baseline characteristics of the study subjects are shown in table 1. The median age of the patients was 35 (range, 12–65) years, including 337 (60.6%) male patients and 209 (39.4%) female patients. Three hundred and thirty-two (60.8%) patients had laryngotracheal stenosis due to a neck trauma, 146 (26.7%) patients developed subglottic or tracheal stenosis

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Table 1. Demographic and baseline characteristics of the study subjects

Patients, n	546
Age, years	
Median	35.65
Range	12–65
Gender	
Male	337 (61.7)
Causes of stenosis	
Neck trauma	332 (60.8)
Tracheal intubation	146 (26.7)
Laryngotracheal tumor	35 (6.4)
Chemical burns	25 (4.6)
Unknown	8 (1.5)
Site of stenosis	
Tracheal stenosis	319 (58.4)
Laryngeal stenosis	155 (28.4)
Laryngotracheal stenosis	72 (13.2)
Cotton-Myer grades	
I	338 (61.9)
II	118 (21.6)
III	69 (12.6)
IV	21 (3.9)

Figures are numbers with percentages in parentheses, unless indicated otherwise.

following trachea intubation, and 35 (6.4%) patients had laryngotracheal stenosis following surgical resection of laryngotracheal tumors. In addition, 25 (4.6%) patients developed laryngotracheal stenosis due to chemical burns, and the causes of stenosis were unknown in 8 (1.5%) patients. The time from injury to hospitalization was 3 months to 5 years. According to the Cotton-Myer staging method, 338 (61.9%) patients had grade I stenosis, 118 (21.6%) had grade II stenosis, 69 (12.6%) had grade III stenosis and 21 (3.9%) had grade IV stenosis.

Surgical Outcomes

The patients were followed up for a mean duration of 13 months (range, 6–24). Twelve (2.2%) patients were lost to follow-up. T-tubes were successfully extubated in 342 (62.6%) patients 6–24 months following intubation. The initial extubation success rate was 62.3%. Laryngotracheal restenosis following extubation occurred in 192 (35.2%) patients, necessitating T-tube placement for a second time. One hundred and thirteen patients were successfully extubated with the success rate for the second attempt at 58.9%. The overall success rate was 83.3%.

We further analyzed the surgical outcome of T-tube placement according to the causes of laryngotracheal stenosis. The successful initial extubation rate was 78.6% for laryngotracheal stenosis due to neck trauma, 63% for that due to tracheal intubation, 74.3% for that due to laryngotracheal tumor, and 32.0% for that due to chemical burns, and a statistically significant difference in the extubation rate was observed among the five groups ($p < 0.05$) (table 2). The successful second extubation rate was 52.1% for laryngotracheal stenosis due to neck trauma, 53.7% for that due to tracheal intubation, 66.7% for that due to laryngotracheal tumor, and 11.8% for that due to chemical burns. Furthermore, the successful initial and second extubation rates were significantly lower for laryngotracheal stenosis due to chemical burns than those for that due to neck trauma, tracheal intubation or laryngotracheal tumors ($p < 0.05$). In addition, the successful second extubation rate was markedly lower than the initial extubation rate for laryngotracheal stenosis due to neck trauma or chemical burns ($p < 0.05$ in both).

We additionally analyzed the surgical outcome of T-tube placement according to the site of stenosis. The successful initial extubation rate was 76.2% for tracheal stenosis, which was

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Table 2. Extubation rate in laryngeal, tracheal and laryngeal stenosis patients by causes of stenosis

	Trauma	Tracheal intubation	Laryngotracheal tumor	Chemical burns	Unknown causes	χ^2	p
All patients, n	332	146	35	25	8		
Successful initial extubation	261 (78.6)[a]	92 (63)[a]	26 (74.3)[a]	8 (32)[a]	4 (50)[a]		
Successful second extubation	37 (52.1)[a,b]	29 (53.7)[a,c]	6 (66.7)[a,c]	2 (11.8)[a,c]	1 (25)[a,c]		
Total extubation	298 (89.8)[a]	121 (82.9)[a]	32 (91.4)[a]	10 (40)[a]	5 (62.5)[a]		
Tracheal stenosis							
Patients, n	213	86	18	0	2		
Successful initial extubation	164 (77.0)	65 (75.6)	14 (77.8)	0	1 (50)	0.8667	0.833
Successful second extubation	21 (9.9)	10 (11.6)	2 (11.1)	0	1 (50)	1.407	0.704
Laryngeal stenosis							
Patients, n	90	48	11	4	2		
Successful initial extubation	50 (55.6)	22 (45.8)	6 (54.6)	2 (50)	2 (100)	3.023	0.554
Successful second extubation	15 (17.5)	12 (20.7)	3 (27.3)	1 (25)	0	1.224	0.747
Laryngotracheal stenosis							
Patients, n	29	12	6	21	4		
Successful initial extubation	13 (44.8)	5 (41.7)	3 (50)	7 (33.3)	2 (50)	16.094	0.003
Successful second extubation	6 (20.7)	2 (16.7)	1 (16.7)	6 (28.6)	2 (50)	3.508	0.477

[a] $p < 0.05$ among the five groups; [b] $p < 0.05$ versus initial extubation; [c] $p > 0.05$ versus initial extubation. Figures are numbers with percentages in parentheses unless indicated otherwise.

Table 3. Extubation rate in laryngotracheal stenosis patients by stenosis site

	Tracheal stenosis (n = 319)	Laryngeal stenosis (n = 155)	Laryngotracheal stenosis (n = 72)
Successful initial extubation	243 (76.2)[a]	82 (52.9)[a]	30 (41.2)[a]
Successful second extubation	35 (46.1)[b,d]	31 (42.5)[c,d]	15 (35.7)[c,d]
Total extubation	278 (87.1)[a]	113 (72.9)[a]	45 (62.5)[a]

[a] $p < 0.05$ among the three groups; [b] $p < 0.05$ versus initial extubation; [c] $p > 0.05$ versus initial extubation; [d] $p > 0.05$ among the three groups. Figures are numbers with percentages in parentheses.

markedly higher than that for laryngeal stenosis (52.9%) and laryngotracheal stenosis (41.2%; $p < 0.05$) (table 3). The successful second extubation rate was 46.1% for tracheal stenosis, 42.5% for laryngeal stenosis and 35.7% for laryngotracheal stenosis. The successful second extubation rates were significantly lower for tracheal stenosis and laryngotracheal stenosis than those for initial extubation rates ($p < 0.05$). In addition, there was no marked difference in successful second extubation rates for stenoses of different sites ($p > 0.05$ in both).

Moreover, we analyzed the surgical outcome of T-tube placement according to the Cotton-Myer grades. The successful initial extubation rate gradually declined with an increase in Cotton-Myer grades and remained at 70.4% for grade I laryngotracheal stenosis, which was markedly higher than that for grade II (56.8%), III (44.9%) and IV stenosis (28.6%; grade I vs. grades II–IV, $p < 0.05$; grade II vs. grades III and IV, $p < 0.05$; grade III vs. IV, $p < 0.05$) (table 4). Similar findings were observed for successful second extubation rates for different Cotton-Myer grades (grade I vs. grades II–IV, $p < 0.05$; grade II vs. grades III and IV, $p < 0.05$; grade III vs. IV, $p < 0.05$). In addition, there was no marked difference in the successful initial and second extubation rates for stenoses of different grades ($p > 0.05$ in all).

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Table 4. Extubation rate in laryngotracheal stenosis patients by Cotton-Myer grades

	I (n = 338)	II (n = 118)	III (n = 69)	IV (n = 21)
Successful initial extubation	238 (70.4)[a]	67 (56.8)[a]	31 (44.9)[a]	6 (28.6)[a]
Successful second extubation	72 (72)[a,c]	33 (64.7)[a,c]	8 (21.1)[a,b]	0 (0)[a,b]
Total extubation	310 (91.2)[a]	100 (84.7)[a]	39 (56.5)[a]	6 (28.6)[a]

[a] $p < 0.05$ among the four groups; [b] $p < 0.05$ versus initial extubation; [c] $p > 0.05$ versus initial extubation. Figures are numbers with percentages in parentheses.

Complications

Hemoptysis was reported in 8 patients (1.5%), postoperative infection in 6 patients (1.1%), wound dehiscence in 3 patients (0.5%), laryngeal obstruction in 13 patients (2.4%), aspiration in 12 patients (2.2%), and postoperative tracheoesophageal fistula in 2 patients (0.4%).

Discussion

Laryngotracheal stents keep the airway expanded after surgical reconstruction or trauma by providing support and immobilization of cartilage grafts and mucosal flaps to the recipient site and maintaining the lumen in the reconstructed airway that temporarily lacks adequate support. On the other hand, laryngeal stents act as foreign bodies in the reconstructed airway and may cause mucosal injuries, ulcerations, granulation tissue formation and subsequent restenosis. If a laryngotracheal stent does not conform anatomically to the inner laryngeal contours or if it is inadvertently damaged and not promptly repaired, granulation and scar formation will ensue, leading to laryngotracheal stenosis. A great majority of our patients in the current series suffered laryngotracheal stenosis due to trauma. In such patients, prompt cricotracheal resection and laryngeal mucous membrane reduction are frequently not performed, leading to laryngotracheal granulation and scar formation and ultimately laryngotracheal stenosis. In some neck trauma patients who develop severe breathing difficulty or even asphyxiation, the laryngotracheal stent may be inadvertently damaged during emergency tracheostomy and cricothyrotomy, but laryngotracheal repair is not promptly carried out after the breathing difficulty is alleviated. Therefore, for patients with neck trauma or laryngeal injury, prompt reduction of laryngeal cartilages and mucous membrane should be undertaken to prevent the development of laryngotracheal stenosis. In addition, regardless of the causes of laryngotracheal stenosis, the second extubation rate in our patients was lower than the initial extubation rate. This may be due to granulation in patients receiving a second intubation. T-tube placement represents a surgical insult; granulation may occur as a result, and second intubation may aggravate granulation in the patients, rendering extubation difficult.

Management of laryngotracheal stenosis includes dilation, laser therapy, and laryngotracheal reconstruction. However, there is currently a lack of an effective method for severe laryngotracheal stenosis. Laryngotracheoplasty with T-tube placement is a simple method for treating laryngotracheal stenosis. A large number of investigators consider that partial tracheostomy and end-to-end anastomosis should be undertaken first if the condition of the patients permits it [10, 11]. When there is active local laryngotracheal granulation or the general condition of the patients does not permit it, T-tube placement can be an effective temporary measure before trachea reconstruction. Recently, some investigators have reported that T-tube intubation can be a long-term or permanent measure. In our laryngotracheal stenosis patients, the higher the Cotton-Myer staging grades, the lower the successful

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extubation rates. Among various types of stenosis, tracheal stenosis had the highest extubation rate, laryngeal stenosis had the second highest extubation rate, and laryngotracheal stenosis had the lowest extubation rate. Among cases of stenosis of various causes, chemical burn-induced laryngotracheal stenosis had the lowest extubation rate, which may be related to the extent of the stenosis and scar growth. That patients with laryngotracheal stenosis due to chemical burns, patients with laryngotracheal stenosis and patients with higher Cotton-Myer grades exhibited a lower extubation rate may be explained by the fact that the stenosed segments were longer, or that there was more extensive mucosal injury, hindering epithelialization. As a result, even after 1 year of intubation with a T-tube, granulation tended to occur following extubation. A longer segment of stenosed trachea or malacia may also be present in chemical burn-induced laryngotracheal stenosis. If the stenosed segment is longer than 6 cm, if there is apparent inflammation of the tracheal mucosa or if there is excessive scar tissue, a T-tube can be placed to provide temporary support for the trachea until the condition of the patients allows tracheostomy. It may be prudent to wait until the inflammation around the tracheal stenosis has lessened and the general condition of the patients has improved.

T-tube placement is not a complicated procedure and inadvertent maneuvering may result in obvious discomfort of patients and even death if the procedure fails. One serious complication of the procedure is laryngeal obstruction, which could lead to asphyxiation. One major cause of laryngeal obstruction is laryngotracheal granulation, which is due to an inappropriate diameter of the T-tube, improper positioning of the T-tube or lack of perfect anatomical conformity. Laryngotracheal granulation is also an important cause of ineffective control of laryngotracheal stenosis following extubation. Displacement of the T-tube also causes laryngeal obstruction as the tube moves up or down in the trachea, mechanically irritating the tracheal mucosa, which can lead to recurrent coughing and tracheal bleeding. Fifteen (8%) patients in our series had apparent hemoptysis, and 3 of them required a second surgery. Common bleeding sites include the mucosa of the stenosed segment or the mucosa at the inferior end of the T-tube.

In conclusion, this large clinical series demonstrates the safety and effectiveness of T-tubes for grade 1 and 2 stenosis with stenosed segments being <6 cm. For those being >6 cm, tracheal end-to-end anastomosis is not appropriate and long-term placement of a T-tube is recommended. Our findings provide useful guidance for preoperatively selecting patients with laryngotracheal stenosis of various causes and differing severity. However, given the retrospective and single-center nature of our study, these findings need to be further confirmed by prospective multicenter studies involving a larger patient population.

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