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Research article

Treatment of secondary benign airway stenosis after tracheotomy with Montgomery T-tube

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Abstract: *Objective:* With the improvement of surgical operation, increasing incidence of secondary benign airway stenosis, as a complication of long-term tracheal intubation and tracheotomy, leads to significant increases in morbidity and mortality. Previous treatment of secondary benign airway stenosis was mainly based on surgical resection and reconstruction. There is an urgent need for new treatment methods except surgery, especially for those inoperable patients. *Methods:* This study retrospectively reviewed 20 patients who had treatments of secondary benign airway stenosis after tracheotomy with Montgomery T-tube. The clinical data including clinical features, efficacy, complications and prognosis were retrospectively evaluated. *Results:* Complete airway obstruction was 12/20, partial stenosis was 8/20, combined with airway granuloma and endoscopic granulation resection was 16/20, combined with scar stenosis and endoscopic balloon dilatation was 18/20. Plugging successfully was 19/20. Complications included mucous accumulation (20/20), secondary granulation tissue formation (13/20), subcutaneous soft tissue infection (1/20), and T-tube re-implantation (3/20). *Conclusions:* Montgomery T-tube implantation under rigid bronchoscopy is a safe, feasible and effective tracheal forming method with well tolerance for patients with benign airway stenosis. Secondary benign airway stenosis after tracheal intubation and tracheotomy is an indication of Montgomery T-tube implantation. Compared with the traditional tracheotomy, the advantage of Montgomery T-tube implantation is easy to make the patient phonate, significantly improving the quality of life of patients. T-tube implantation is safe, and the postoperative complications include mucous accumulation and formation of secondary T-tube granulation tissue.

Keywords: benign airway stenosis; Montgomery T-tube; interventional therapy; bronchoscopy

1. Introduction

Benign airway stenosis refers to airway stenosis caused by airway wall damage by a variety of non-neoplastic diseases, which can lead to cough, sputum, varying degrees of dyspnea and other symptoms. Benign airway stenosis seriously affects the quality of life of patients, and even the occurrence of respiratory failure and death. The etiology includes: long-term tracheal intubation, tracheotomy, tracheal-bronchial tuberculosis, trauma and so on [1]. Previous treatment of secondary benign airway stenosis was limited, mainly based on surgical resection and reconstruction. However, surgical treatment not only requires good condition of patients, but also has many disadvantages, such as many perioperative complications and long recovery time after operation. In particular, those patients are often suffering from combined pulmonary infection, dysfunction of central nervous system and other complications, consequently leading to the loss of possibility for traditional surgical procedures. With the rapid development of interventional therapy under bronchoscopy, the endoscopic interventional therapy is becoming more and more [2], such as laser, balloon dilatation, freezing, stenting and so on. These measures provide safer and more effective treatment options for patients with benign airway stenosis after tracheotomy. Among them, Montgomery T-tube implantation under rigid bronchoscopy is considered as an effective, safe and well-tolerated method for tracheal stenosis.

2. Patients and methods

This study retrospectively reviewed 20 patients who had treatments of secondary benign airway stenosis after tracheotomy with Montgomery T-tube between September 2015 and February 2019 in Sir Run Run Shaw Hospital, affiliated with Zhejiang University. The clinical data including clinical features, efficacy, complications and prognosis were retrospectively analyzed to evaluate the value of Montgomery T-tube placement in secondary benign airway stenosis after tracheotomy.

All of the 20 patients were hospitalized, including 14 males and 6 females aged 20–71 years old. The clinical manifestations were mainly cough, sputum, varying degrees of dyspnea, and failed plugging with tracheostomy cannula. The duration of tracheotomy was 28 days to 16 months (Table 1). Twenty patients were diagnosed with benign tracheal stenosis by medical history, physical examination, and chest CT scan and bronchoscopy. Complete trachea obstruction was in 8 cases and partial tracheal stenosis was in 12 cases. After discussion, the intervention team decided that these patients were not suitable for surgical tracheal resection and reconstruction. Through the multidisciplinary (anesthesiology, ENT and cardiothoracic surgery) discussion, a suitable endoscopic interventional treatment was developed.

Table 1. Basic information of patients.

N	G	Age	Underlying diseases	Duration of tracheotomy	Clinical symptoms	The degree of stenosis	Stenosis types	Stenosis length
1	M	71	Cerebral hemorrhage	1 month	Failed tracheal plugging	> 2/3	Granulation tissue combined with tracheal wall collapse	1–2 cm
2	M	39	Craniocerebral trauma	9 months	Failed tracheal plugging	Complete	Granulation tissue	1–2 cm
3	F	55	Car accident trauma	6 months	Cough, Dyspnea	> 2/3	Granulation tissue combined with scar stenosis	2 cm
4	M	41	Cerebral hemorrhage	16 months	Cough, expectoration	> 2/3	Granulation tissue	1–2 cm
5	M	36	Cerebral hemorrhage	3 months	Dyspnea	Complete	Scar stenosis	2 cm
6	M	20	Electric injury	2 months	Expectoration, failed tracheal plugging	Complete	Scar stenosis	3 cm
7	M	46	Cerebral hemorrhage	20 days	Cough, expectoration, dyspnea	> 2/3	Tracheal distortions combined with scar stenosis	2–3 cm
8	M	66	Cerebral infarction	3 months	Failed tracheal plugging	Complete	Granulation tissue combined with scar stenosis	1–2 cm
9	M	52	Craniocerebral trauma	2 months	Cough, dyspnea	Complete	Granulation tissue combined with scar stenosis	1–2 cm
10	F	51	Cerebral hemorrhage	6 months	Failed tracheal plugging	> 2/3	Tracheal distortions combined with scar stenosis	1–2 cm
11	F	69	Cerebral hemorrhage	69 days	Failed tracheal plugging	> 2/3	Scar stenosis	1–2 cm
12	M	71	Cerebral hemorrhage	28 days	Failed tracheal plugging	Complete	Tracheal distortions combined with scar stenosis	1–2 cm

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N	G	Age	Underlying diseases	Duration of tracheotomy	Clinical symptoms	The degree of stenosis	Stenosis types	Stenosis length
13	F	24	Granulomatosis with polyangiitis	36 days	Failed tracheal plugging	> 2/3	Granulation tissue combined scar stenosis	3 cm
14	M	66	Cerebral hemorrhage	3 months	Failed tracheal plugging	Complete	Tracheal distortions combined with scar stenosis	1–2 cm
15	F	55	Cerebral hemorrhage	50 days	Failed tracheal plugging	> 2/3	Scar stenosis	2 cm
16	F	47	Craniocerebral trauma	3 months	Failed tracheal plugging	> 2/3	Tracheal distortions combined with scar stenosis	2 cm
17	M	28	Craniocerebral trauma	2 months	Failed tracheal plugging	> 2/3	Granulation tissue combined with scar stenosis	3 cm
18	M	70	Cerebral infarction	1 months	Failed tracheal plugging	> 2/3	Scar stenosis	1–2 cm
19	M	48	Cerebral infarction	3 months	Failed tracheal plugging	Complete	Scar stenosis	>3 cm
20	M	59	Cerebral hemorrhage	70 days	Failed tracheal plugging	> 2/3	Tracheal distortions combined with scar stenosis	2 cm

N: number; G: gender; M: male; F: female.

The protocol of endoscopic intervention is as follows:

a. Anesthesia: Patients were given tracheotomy and indwelling metal tracheostomy cannulas before operation. After intravenous anesthesia, the metal tracheostomy cannula was replaced by a plastic tracheostomy cannula and then connected to a ventilator.

b. Airway assessment and intervention: Oral insertion of STORZ rigid bronchoscope was performed after position placed to observe the stenosis of glottic and airway. For patients with incomplete airway atresia, rigid bronchoscopic mechanical expansion, balloon dilatation, granulation tissue resection or other intervention methods can be used to dilatation the narrow airway to 10–15 mm, hence ensuring that the airway has adequate space for T-tube placement. For patients with complete airway obstruction (8/20, Figure 1), tracheostomy cannulas were replaced with size 5.5–6 tracheal tubes for ventilation. After the ENT physician's cooperation, the anatomical structure through retrograde exploration from the distal end of atresia trachea was undertaken, and electric knife or laser was used in the proximal end of trachea for airway atresia recanalization. Balloon dilatation of the stenotic trachea was then performed after successful recanalization.

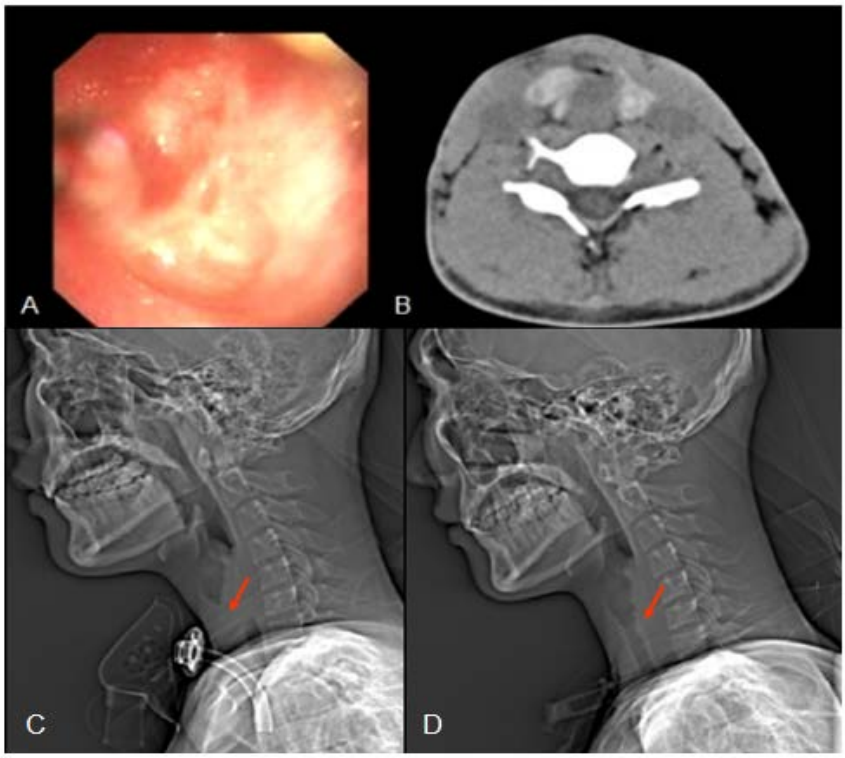

Figure 1. The bronchoscopic result indicated the complete atresia of upper trachea (A). The CT result suggested the complete atresia of cervical trachea (B). Complete atresia of cervical trachea and indwelling metal tracheostomy cannula were found before the operation (C). Airway atresia recanalization was achieved and the indwelling T-tube was observed after the operation (D).

c. T-tube placement: T-tubes with appropriate diameter were selected according to the chest CT measurement results, and then were pruned and polished when the length of T-tube proximal and distal branch was determined by bronchoscopic labeling and measurement (Table 2). The distal branch of T-tube was clamped by a vessel forceps and inserted into the airway, and the proximal branch was pulled into the proximal airway by foreign body forceps through the rigid bronchial duct, and then the position was adjusted.

d. Off-line recovery and care: The external branch of T-tube was closed, and the laryngeal mask was inserted for ventilation. The patients can be taken off the ventilator and returned back ward after spontaneous breathing was restored. 18 patients restored oral ventilation in the recovery room; 2 patient was unable restore oral ventilation and was failed in tracheal plugging; blood oxygen saturation decreased in 2 patients after returning to the ward, which was ameliorated by opening the external branches of T-tubes; tracheal plugging was successful after 24 hours, and the possible vocal cord edema was observed as a considerably postoperative complication. The routine doctor's advice includes: reducing mucous (ambroxol), atomization (saline + ipratropium bromide), the use of prophylactic antibiotics, cervical and chest CT review 3 days after operation; the patients were admitted to hospital for assessments respectively at 1, 3 and 6 months after the operation.

Table 2. Information of Montgomery T-tube implantation.

	Cases	Rate
T-tube model (diameter mm)	13 mm: 3	8/20
	14 mm: 5	9/20
	15 mm: 3	3/20
Combined with balloon dilatation	18	18/20
Combined with rigid bronchoscopic mechanical expansion	13	13/20
Combined with granulation tissue resection	13	13/20
Retrograde tracheal blunt separation	8	8/20
Rate of postoperative tracheal plugging	19	19/20

3. Results

Eighteen patients successfully restored oral respiration after closing external branches of T-tubes, and were able to phonate with significant improvement in quality of life. CPAP-assisted ventilation was performed after the surgery in 1 patient due to the combined OSAS (sleep apnea syndrome). One patient still failed to restore oral breathing after the operation, considering as bilateral vocal cord paralysis caused by cerebrovascular accident after ENT assessment. And another patient failed was due to pulmonary infection. Mild mediastinal emphysema in mediastinum and neck was observed in 1 patient in routine examination of chest CT after the operation, which was self-absorbed after oxygen inhalation (Figure 2); different levels of increased sputum were found in all 20 patients; obstruction in partial lumen due to phlegm scab formation was found in only 4 cases by bronchoscopy, which was extracted by repeatedly douching of normal saline. Granulation tissue formation on the edge of T-tubes was found in 13 patients at 3 and 6 months respectively after the operation (Figure 3), and granulation tissue resection was then performed in 5 cases among them. Increases in cough and expectoration were found in 1 patient with cerebral infarction at 1 month after the operation; no fever was observed; the chest CT result indicated the right lower lung infection, considering as aspiration pneumonia, which was improved after anti-infection treatment. Dyspnea appeared in 1 patient at 15 days after the operation, and then ventilation by opening external branches of T-tubes was performed; the neck and chest CT examination showed that the T-tube moves down about 1 cm due to the large incision stoma in the patient, consequently leading to stenosis in the upper edge of T-tube caused by the shorter length of superior T-tube branch. Thus, T-tube replacement was scheduled to perform by a bronchoscope under general anesthesia, and partial of the incision stoma was sutured to prevent T-tube displacement. Two patients accepted the T-tube re-implantation due to the re-stenosis after removing the T-tube (Table 3).

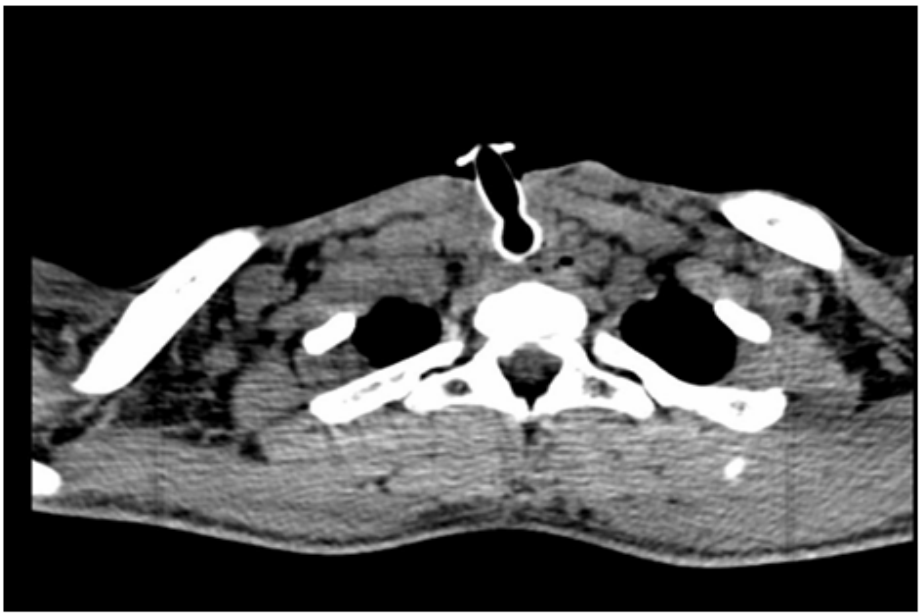

Figure 2. Postoperative neck and subcutaneous emphysema, which was self-absorbed after oxygen inhalation.

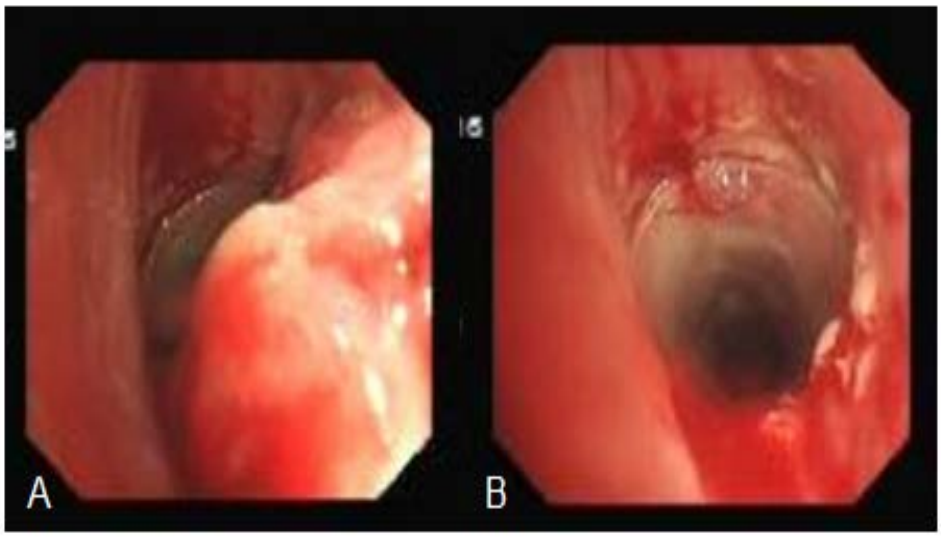

Figure 3. Granulation tissue formed on the upper limb of the tube and secondary airway stenosis (A); Airway stenosis was improved after endoscopic granulation tissue resection (B).

Ten patients were successfully removed T-tubes about 6 months after the operation, and no dyspnea or other uncomfortable symptoms was observed after T-tube removal. However, 2 patients replaced the T-tube. The remaining 8 patients have still been indwelling of T-tubes and following up.

Table 3. Complications after T-tube implantation.

	Complications	Cases	Treatment measures and outcomes
Short-term < 24 h	Mediastinum / neck emphysema	1/20	Oxygen inhalation; self-absorbed after 3 d
	Dyspnea	2/20	Improved after oxygen inhalation
	Irritating cough	6/20	Not serious r; aerosol treatment
	Increased secretion of mucous	20/20	Aerosol treatment of saline
	Vocal cord edema	3/20	Untreated; improved after 24 h
	Obstruction due to mucous formation in T-tube	4/20	Suction under bronchoscope
	Combined with lower respiratory tract infection	1/20	Improved after antibiotics treatment
Long-term * > 24 h	Granulation tissue formed at proximal end of T-tube	13/20	Endoscopic granulation resection was performed in 5 cases
	Granulation tissue formed at distal end of T-tube	0/20	—
	T-tube re-implantation	3/20	Improved after T-tube re-implantation
	Subcutaneous soft tissue infection	1/20	local disinfection and antibiotics therapy

Note: among the 20 cases, 18 patients had been completed 1-month follow-up, but 2 patients had not yet reached the 1-month follow-up date.

4. Discussion

The incidence of secondary benign airway stenosis caused by long-term tracheal intubation and tracheotomy was rare previously. As reported, the incidence of benign airway stenosis in the critically ill patients with ICU mechanical ventilation was reported to be about 1% [3]. However, with the improvement of surgical operation and critical medicine at present, the incidence of benign tracheal stenosis is underestimated. Previous treatments of secondary benign airway stenosis were mainly based on curative surgical resection and reconstruction [4]. However, whether the operation can be performed is highly related to the degree and range of airway stenosis, the presence of infection and other factors. Besides, surgical treatment also requires patients in good condition and can tolerate surgery. However, these patients tend to have more complications, for examples, most of the 20 patients in this study have traumatic brain injury, cerebrovascular accident and other severe central nervous system injury, which do not allow the patients to tolerate surgical treatment after assessments. Moreover, there are many problems such as large surgical trauma, many perioperative complications and difficult operation, and even occurrence of long-term anastomotic restenosis in a considerable ratio [5]. Although the surgical treatment, when not contraindicated by associated diseases or by the excessive length of the tracheal lesions, still remains the treatment of choice, with the development of interventional therapy, endoscopic interventional therapy has become an effective and feasible method for treatment of benign

tracheobronchial stenosis because of its limited trauma, easy operation and rapid relief of symptoms.

In 1965, William Montgomery pioneered the use of T-tube for the prevention of tracheal stenosis after tracheal surgery [6]. The original T-tube was made of acrylic material and was later changed to silicone material due to the hard texture. The internal branch of the T-tube is used to support and shape trachea, and the external branch is used for external fixation, preventing T-tube slippage and displacement. There are different diameter models in internal branch of T-tube, which can be chosen according to the tracheal thickness of patients. The operating doctor can determine the length of upper and lower branches according to the length of tracheal stenosis and the location of incision. This should be carefully measured and evaluated before T-tube placement. The advantages of the T-tube in treatment of benign airway stenosis are as follows:

a. Patients can restore natural cavity breathing and phonate after T-tube placement.

b. T-tube is made by silicone material which is soft and has considerably less irritation to airway, and not easy to produce granulation tissue compared with metal material [7,8]; patients are well tolerated with T-tube which is good for supporting and conducive to airway remodeling.

c. The external branch of T-tube plays a fixed role and overcomes the disadvantage that the straight cylinder type silicone stent is easy to shift. It has been reported that stent displacement occurs in approximately 6–18% of patients with the most frequently used straight cylinder type silicone DUMON stent [9,10].

d. If stenosis of the upper end of T-tube or blockage due to secretions in T-tube appears again, the doctor can open the external branch of T-tube to conduct ventilation and mucous suction through the external branch which can connect to a ventilator. DUMON stent is more likely to result in accumulation and blockage of mucous, and there is no effective way to avoid. If necessary, DUMON stent must be removed. T-tube has obviously better safety compared with DUMON stent and metal stent.

e. T-tube is easy to place and remove, and the support time of T-tube usually takes at least 6 months. Compared with silicone stent, metal stent is not easy to remove [7,11]. Therefore, for subglottic benign airway stenosis, the Montgomery T-tube is a better choice compared with traditional self-expanding metal stent and straight cylinder silicone DUMON stent.

In this study, 20 cases of T-tube placement were under general anesthesia, which is more conducive to implementation of the operation [12,13]. A tracheostomy cannula was placed before T-tube placement to ensure safe ventilation and operation. Among them, 8 patients had complete airway obstruction and required retrograde exploration of the distal end of atresia airway by surgical teamwork; besides, electrocoagulation was performed for airway recanalization. These patients need more sufficient assessments and teamwork before operation, and should be carefully operated to avoid tracheal perforation, fracture, tracheo-esophageal fistula and other complications. All patients were operated under rigid bronchoscopy, which is easier and safer for balloon dilatation, granulation excision or other operation of airway before T-tube implantation. After placing T-tube in incision stoma, it needs to be adjusted under rigid bronchoscopy [14].

The most important point for T-tube implantation is preoperative evaluation. The achievement rate of T-tube placement is closely related to the location and length of stenosis. Therefore, the range and severity of airway stenosis, as well as the distance from stenosis area to glottis and carina should be evaluated by imaging examination before operation. The major points are as follows:

a. The upper branch of T-tube cannot be longer than the glottis, or else it will result in glottis discomfort and dysfunction; the distance from the upper end of T-tube to glottis is at least 1 cm, so that patient with the distance from narrow segment to glottis shorter than 2 cm is not suitable for

T-tube placement.

b. The diameter of T-tube should be appropriate, otherwise, it will cause the risk of granulation tissue on the edge of T-tube. Besides, the compressed and ischemic airway mucosa is also easy to combine with infection and restenosis. The diameter of T-tube should not be too small, or it will cause mucous obstruction and is not easy for airway support.

c. There is a function of the structure of tracheal cartilage. If the cartilage collapse and lose support function completely, the patient is not suitable for T-tube implantation.

The success rate and safety of T-tube placement were higher, similar as those in previously reports [15–17]. All of the 20 patients were successfully placed T-tubes. Although 2 patients failed in T-tubes plugging in 24h after operation, they were successfully completely plugged several days. We attributed the delay of T-tube plugging to the adaptation and condition of the patients. We found that the short-term complications mainly included mucous secretion, irritating cough, and transient dyspnea, which were generally alleviated after symptomatic treatments alone; while long-term complication was mainly granulation tissue hyperplasia on the edge of T-tube, and only 5 patients needed for endoscopic resection of granulation tissue due to secondary airway stenosis. Since many patients suffer from sputum retention and require long-time T-tube implantation, attention and assessments of expectoration in patients should be considered after operation, and regular cleaning of the wall is necessary to prevent T-tubes from occlusion. For benign airway stenosis, support time of T-tube has not been determined yet [12,18]. The removal time should be determined based on the characteristics of each patient's condition, and performed at 6 months after the operation is generally appropriate. After T-tube removal, a temporary tracheostomy cannula should be placed, which can be removed if there is no airway collapse at 2 months after the operation. Otherwise, T-tube replacement or surgical treatment should be selected. There are 3 cases re-implanted the T-tube. One patient re-implanted due to the moving down of T-tube, another two patients re-implanted due to re-stenosis after T-tube removal (3 months and another 2 months later). For those two patients, treatment should in fact be based on a combination of surgical and endoscopic treatments, and also remind us that T-tubes may be effective and safe, however, surgical treatment still is an important choice. The target group of T-tube implantation should be careful and precise, exclude those patients who eligible for surgery.

5. Conclusions

In summary, for patients with secondary benign airway stenosis after tracheal intubation or tracheostomy who are not suitable for surgery, Montgomery T-tube replacement under rigid bronchoscopy is an effective, safe and well-tolerated method for tracheal stenosis, and is helpful for improvement of quality of life.

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Conflict of interest

The authors declare no conflict of interest.

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