Silicone T-tube for complex laryngotracheal problems

Hung-Chang Liu a,b,*, Kuo-Sheng Lee c, Charng-Jer Huang a, Ching-Ron Cheng d, Wen-Hu Hsu e,f, Ming-Hsiung Huang e,f

a Division of Thoracic Surgery, Mackay Memorial Hospital, #92, Sec 2, Chung-San N. Road, Taipei, Taiwan
b Taipei Medical University, Taipei, Taiwan
c Division of Otolaryngology, Mackay Memorial Hospital, Taipei, Taiwan
d Division of Anesthesiology, Mackay Memorial Hospital, Taipei, Taiwan
e Division of Thoracic Surgery, Veterans General Hospital, Taipei, Taiwan
f National Yang-Ming University, Taipei, Taiwan

Received 25 June 2001; received in revised form 22 October 2001; accepted 13 November 2001

Abstract

Objective: The use of a T-tube to manage complex laryngotracheal lesions, such as tracheal stenosis, tracheomalacia and tracheal injury, has previously been reported by other surgeons in the past. However, further validation of clinical details, including operative management and postoperative care, is needed. Methods: From January 1991 to May 2000, 53 patients, including 24 with post-tracheostomy stenosis, received 55 silicone T-tubes for transient or permanent stenting of the airway. There were 20 patients for subglottic stenosis; eight for long segment tracheostensis; seven with tracheal stenosis for severe cervicomediastinal fibrosis not amenable for reconstruction; six for complex tracheal injury; four for glottic injury; two each for tracheomalacia, failed tracheal surgery and tuberculotic tracheostenosis; and one each for tracheo-esophageal fistula and necrotizing tracheitis. We retrospectively analyzed these patients. Results: Thirty-eight out of 53 patients (71.8%) with T-tube stenting from 3 to 15 months was considered successful. Fifteen patients’ operations failed due to patients’ underlining diseases, previous intractable pulmonary infection, poor cognition and/or inadequate tube position. After removal of the tube, three patients (10.7%) developed partial airway obstruction with mild subglottic granulation tissue, which was resolved by carbon dioxide laser therapy. Two patients (7.1%) with prolonged tracheocutaneous fistula were conservatively treated by silver nitrate. Conclusion: Silicone T-tube can effectively resolve the complex laryngotracheal lesions with limited complications. Concurrent cardiopulmonary diseases and intractable infection were the two major causes for failure after the T-tube reconstruction. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Silicone T-tube; Tracheostomy; Tracheostenosis; Tracheomalacia

1. Introduction

The trachea is an important organ of the human body, providing inflow and outflow of air through its lumen. Tracheal abnormalities may thus be very troublesome and presents challenges to their doctors. Usually most tracheal problems result in obstruction, i.e. tracheostenosis, tracheomalacia, or tracheal injury. Treatment of such lesions includes direct or staged repair and reconstruction, or dilatation. However, sometimes all these methods are unavailing, e.g. in complex laryngotracheal injury, high level subglottic stenosis or long segment stenosis. That is when the silicone T-tube stenting is used as an alternative and safe management. It not only provides tracheal support but can also maintain humidification of the airway. Silicone has been found to be a relatively non-irritating substance. It can be used long-term in the human body and provides a good medium for re-epithelization of the tracheal wall [1].

The tracheal T-tube were initially introduced by Montgomery [1] in 1965 for tracheostenosis. We have been using the silicon T-tube method since 1980. During the first decade, we implanted the tube ten times and have reported those cases in a previous article [2]. Beginning in 1990, we used the tubes more because of increased experiences and development of a more mature technique. Although T-tube use is widely known, there have been few reports on clinical details. This retrospective analysis describes our experience with silicone tracheal T-tubes, including trivial problems that may occur during placement and after decannulation.
Necrotizing tracheitis would be done for the tracheotomy, and sometimes, dilatation of the airway. If the lesion was particularly difficult to manage, a partial upper sternotomy was performed to allow extension before emergent procedures. The decisions to implant T-tube were made after careful evaluation demonstrating that direct repair or resection was not suitable for managing the airway. A longitudinal tracheotomy, either by operative work-up, including blood cell routines, biochemistry, EKG, Chest X-ray film, bronchoscopy, traditional or computed tomography. Not all these studies were done before emergent procedures. The decisions to implant T-tube were made after careful evaluation demonstrating that direct repair or resection was not suitable for managing the airway. A longitudinal tracheotomy, either by operative intent or at the site of trauma, was performed, and intermittent ventilation was provided via the tracheotomy. If there were any associated esophageal injuries, they must be repaired and then laryngoplasty or tracheoplasty would be done. If the lesion was particularly difficult to manage, a partial upper sternotomy was performed to allow extension of the tracheotomy, and sometimes, dilatation of the airway would be done for firm fibrosis. In addition, we used bronchoscopy for assistance to evaluate the severity of the stenosis and measure the relevant airway parameters during T-tube implantations: total length of stenosis or injury, and diameter and positions of proximal and distal ends of the stenosis relative to the glottis and carina. In practice, even after careful measurements, slight adjustments in the lengths of the tube were sometimes needed to match the positions of upper and lower tip to the normal tracheal lumen. Using an endotracheal tube appropriate in size for the inner diameter of the T-tube, it was inserted via the horizontal limb into the lower limb and ventilation was thus temporarily provided via this limb [2]. After securely placing the T-tube, an anesthetic endotracheal tube would be inserted from the nasopharynx through the vertical limb (Fig. 1). The operated airway would then be reconstructed as naturally as possible. A tenting suture of the opened laryngotracheal wall with surrounding straight muscle or vascularized scarring tissue would be perform if it was difficult to approximate a thickened or disrupted anterior tracheal wall. A test for water-tightness was done before closure of the wound. The wound was closed loosely layer by layer. Drains were placed only if there was associated esophageal injury or a dirty wound.

The postoperative care included routine airway hygiene, humidified inhalation, regularly bronchoscopic examination, and airway toilet. Patients were followed every 1–2 weeks in the outpatient clinics. Bronchoscopy was also done at least once a month. If copious sputum or plaque obstruction of the T-tube was found on bronchoscopy, then the frequency of endoscopic clearance of the airway was increased to once every 2 weeks. Timing for decannulation of the tube was dependent on the doctors’ decisions, the severities of the lesions, conditions of the follow-up, and patients’ adaptive abilities. The tube was removed directly under heavily conscious sedation without surgical exploration.

### 2. Materials and methods

From January 1991 to May 2000, we had 3652 consecutive patients with respiratory problems requiring tracheal surgery. Of these, 53 patients had complex tracheal lesions necessitating 55 placements of a T-tube stent. The abnormalities are shown in Table 1. There were 46 females and seven males. Their ages ranged from 19 to 73 years old, with an average of 44.6 years old.

All patients undergoing elective surgery received preoperative work-up, including blood cell routines, biochemistry, EKG, Chest X-ray film, bronchoscopy, traditional or computed tomography. Not all these studies were done before emergent procedures. The decisions to implant T-tube were made after careful evaluation demonstrating that direct repair or resection was not suitable for managing the airway. A longitudinal tracheotomy, either by operative intent or at the site of trauma, was performed, and intermittent ventilation was provided via the tracheotomy. If there were any associated esophageal injuries, they must be repaired and then laryngoplasty or tracheoplasty would be done. If the lesion was particularly difficult to manage, a partial upper sternotomy was performed to allow extension of the tracheotomy, and sometimes, dilatation of the airway would be done for firm fibrosis. In addition, we used bronchoscopy for assistance to evaluate the severity of the stenosis and measure the relevant airway parameters during T-tube implantations: total length of stenosis or injury, and diameter and positions of proximal and distal ends of the stenosis relative to the glottis and carina. In practice, even after careful measurements, slight adjustments in the lengths of the tube were sometimes needed to match the positions of upper and lower tip to the normal tracheal lumen. Using an endotracheal tube appropriate in size for the inner diameter of the T-tube, it was inserted via the horizontal limb into the lower limb and ventilation was thus temporarily provided via this limb [2]. After securely placing the T-tube, an anesthetic endotracheal tube would be inserted from the nasopharynx through the vertical limb (Fig. 1). The operated airway would then be reconstructed as naturally as possible. A tenting suture of the opened laryngotracheal wall with surrounding straight muscle or vascularized scarring tissue would be perform if it was difficult to approximate a thickened or disrupted anterior tracheal wall. A test for water-tightness was done before closure of the wound. The wound was closed loosely layer by layer. Drains were placed only if there was associated esophageal injury or a dirty wound.

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### 3. Results

Among the 53 patients with a T-tube stent, the mean follow-up was 64.3 months (range: 3–108 months). Fifteen of the 53 patients’ operations were considered to be unsuccessful: including five patients who died postoperatively (three with underlying heart failure and two with severe pneumonia, which were caused by prolonged tracheostenosis (35 and 42 days)); four patients who had previously intractable and trivial pneumonia, whose T-tubes were replaced by traditional tracheostomy tubes and who required persistent ventilatory support throughout the follow-up period; four patients with unstable pulmonary function from underlying destroyed lung secondary to tuberculosis; one schizophrenic patient with tracheo-esophageal fistula and two T-tube placements, who repeatedly removed the tube and still had tracheostomy at death; and one post-thyroidectomy patient with necrotizing tracheitis with re-obstruction of the subglottic area by severe granulation.

![Fig. 1](https://example.com/fig1.png)

**Fig. 1.** (a) The T-tube is inserted with a stenting endotracheal tube from the horizontal limb. (b) After appropriate placement of the T-tube, an anesthetic tube is inserted to ventilate the patient.
tissue, and who also had a second T-tube placed with good result during the follow-up period. In 38 (71.8%) out of the 53 patients, T-tube placements were considered successful. Of those 38 patients, 28 patients had their T-tubes successfully removed subsequently after 3–15 months; ten out of these 38 patients were waiting for T-tube removal at the end of this study period. Among the 38 successful patients, there were a total of seven out of the above 28 patients and three out of the above ten patients whom had the T-tube placed with the upper tip over the vocal cord; seven of them later had successful removal of the tube, three of them are still waiting for removal.

The durations of the tube placements among the 28 patients in whom it was subsequently removed are shown in Table 2. Most patients’ tubes were removed after 9–12 months. The two patients with stents in place for more than 12 months required them for psychological reasons. After removal of the tube, the stoma sealed well in most patients. The two patients with stents in place for more than 12 months required them for psychological reasons. After removal of the tube, the stoma sealed well in most patients. In addition, the T-tube provides immediate airway access in an emergency, and the patients themselves can easily maintain its condition afterward. Microscopically, the T-tube is both a medium and a support during re-epithelialization of the tracheal wall. After several weeks of reciprocal stimulation, the airway may become simply obstructed or collapse. However, in most cases, obstruction is not clinically apparent until removal of the stenting tube.

Conventional managements for tracheostenosis have included: repeated dilatation causing relatively high risks of dangers, segmental resection of the stenotic trachea and reanastomosis, and staged reconstruction with cartilaginous graft and myocutaneous flap. However, such approach requires a well-prepared airway and that the patients are in good physiological conditions. The presence of complicating factors, such as subglottic stenosis, a long segment of tracheostenosis just over the cervicothoracic junction, severely firm fibrosis due to previous surgery or radiation leading to difficult dissection, and poor physiological status, increases the risks of failure during conventional procedures. Under such circumstances, placement of a T-tube seems to be the best alternative, since it is easily manipulated and physically safe.

Since 1965, a number of reports have documented the advantages of using the T-tube [3,15–17]. In summary, it is an inert and stable prosthesis causing little harm in the human body even after long-term usage. The patients’ voice is preserved and lower airway humidification is maintained. In addition, the T-tube provides immediate airway access in an emergency, and the patients themselves can easily maintain its condition afterward. Microscopically, the T-tube is both a medium and a support during re-epithelialization of the tracheal wall [15]. Squamous metaplasia occurs along the prothesis, creating a smooth mucosal surface over the stenotic area. Thus, the T-tube decreases the formation of granulation during the recovery stage.

Despite these advantages, the T-tube did not always yield successful results. For example, we had a 28.2% failure rate in our series, slightly higher than that report by Grillo [17]. The reasons for these unsuccessful instances varies among the following: most of the failure were due to patients’ underlying/unstable conditions, such as, primarily advanced cardiopulmonary disease, followed by long-term infection, including pneumonia and tuberculosis, resulting in a chroni-

### Table 2
The duration of the T-tube in patients

<table>
<thead>
<tr>
<th>Duration</th>
<th>Patient No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 3 months</td>
<td>4</td>
</tr>
<tr>
<td>4–6 months</td>
<td>2</td>
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<tr>
<td>7–9 months</td>
<td>6</td>
</tr>
<tr>
<td>9–12 months</td>
<td>14</td>
</tr>
<tr>
<td>12–15 months</td>
<td>1</td>
</tr>
<tr>
<td>More than 15 months</td>
<td>1</td>
</tr>
</tbody>
</table>

### Table 3
Duration for healing of the stoma

<table>
<thead>
<tr>
<th>Duration</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 5 days</td>
<td>3</td>
</tr>
<tr>
<td>6–10 days</td>
<td>15</td>
</tr>
<tr>
<td>11–15 days</td>
<td>4</td>
</tr>
<tr>
<td>16–20 days</td>
<td>2</td>
</tr>
<tr>
<td>More than 20 days</td>
<td>4</td>
</tr>
</tbody>
</table>

Among the 3398 operations performed for tracheostomy, 64 (1.8%) operations were found to have postoperatively symptomatic tracheostenosis, which required further management. This data is probably an underestimation of the true incidence of stenosis, since some partial obstruction are not detected clinically. Symptoms usually occur only when the lumen is narrowed by over 25% [6]. Depending on methods of evaluation, reports of the incidence of stenosis in previous literatures varied from 0 to 31% [6–14].

After injury by inadequate translaryngeal intubation and/or inappropriate cuff pressure, ischemic pressure necrosis can occur due to primary inflammation and secondary edematous change in the damaged mucosa [3,4,15]. Reactively increased secretion with secondary infection may happen later. This occurrence would then stimulate the formation of granulation tissue and deterioration of the trachea wall. After several weeks of reciprocal stimulation, the airway may become simply obstructed or collapse.

### 4. Discussion

Tracheostomy is a reasonable procedure for prolonged intubation. However, tracheal stenosis from tracheostomy may occur in the subglottic area, stoma, and cuff [3–5].
cally irritated airway. In these trivial cases with a stenotic airway admitting a small caliber endotracheal tube, surgical enlargement of the airway lumen can provide for adequate pulmonary hygiene. We suggest that tracheoplasty with a traditional tube for mechanical ventilation is enough for easy care. Another reason for our unsuccessful incidence is that the psychiatric patient in our series demonstrated the dangers of self-removal of the tube, since fixation is difficult. Therefore, we conclude that patients with incurable cardiopulmonary disease, poor ability to cooperate, intractable infection and poor pulmonary function requiring long-term mechanical ventilation, are not suitable for T-tube stenting.

One of our current patients had ischemic tracheitis due to malpractice of thyroid surgery and developed subglottic inflammatory stenosis just above the upper tip of the tube 12 days after the first T-tube was placed. This type of obstruction, upper and lower ends of the vertical limb, was the most common complication in our previous report [2], a problem also mentioned by other investigators [15–17]. After placement, the tube adapted somewhat to the trachea. Acute postoperatively edema of the tracheal wall contributed to chronic irritation by the tip and was unavoidable. The presence of the microbes in the airway incited infection and aggravated the granulation tissue formation [18]. Therefore, such irritation related to the tip would have serious consequences. In real practice, we had tried to correct this problem by blunting the tip before insertion; however, technically, it was difficult to manipulate the tip to the same blunt as the originally manufactured tube. Irritation was always unavoidable, and in this case, it was likely that the sharp upper edge of the tip was too near the glottis. Thus, we would like to recommend keeping the tip 0.5 cm below the hyperactive glottis. If this is impossible because of subglottic stenosis, which is within 0.5 cm of vocal cord, then the tube should be placed so it extends through the glottis.

In the past, the presence of granulation tissue after T-tube placement always required the removal of the tube. However, laser treatment now provides an alternative resolution. The energy of laser is absorbed by water and therefore vaporizes intracellular water at a relatively low temperature [19,20]. This treatment is a combination of photo-coagulation and photo-resection. Sharpe et al. had reported the successful management (98%) with neodymium:yttrium aluminium garnet (Nd:YAG) laser, which was guided by optic fiber through Moghissi-Jessop operating rigid bronchoscope, for tracheal obstruction [21]. Trenter et al. [22] also noted that the wound by the CO₂ laser developed little inflammatory response or collagen formation from myofibroblasts. Laser treatment could create minimal scarring and tissue deformation from irritation of T-tube placement. It can be selectively and safely used in the laryngotracheal surgery with minimal damage to underlying and surrounding tissue.

Dry mucus plaques are another problem caused by the T-tube. Cooper [16] reported, and our experience confirms, that frequent bronchoscopic clearance and use of a Fogarty balloon every 4–6 weeks may be able to solve this problem. Unfortunately, in some cases, such procedures still fail to clear the extremely thick and sticky sputum plaques. On the other hand, the optimal frequency of bronchoscopy has not been clear before. As a result of comparing our earlier experience with that from the most recent decade, we suggest that bronchoscopy should be done within 2 weeks after insertion, especially for patients who are hyper-secretive. If 3–4 four biweekly bronchoscopic exams document good hygiene, the frequency of bronchoscopy can be reduced to once every 4 weeks. When some small to moderate sizes of dry and tenacious plaques are difficult to be removed, hydrogen peroxide toilet and the use of a metallic curved suction tube with large caliber lumen are usually adequate to clear the plaque.

No standard time for tube removal has ever been established, since it must be decided on a cases-by-case basis. The minimal time suggested, however, is seven months, except for patients with traumatic condition. Usually, after several months of stenting, infection is unlikely and airway secretions will decrease as the laryngotracheal lesion heals. The T-tube can then be removed by direct traction of horizontal limb, using curved forceps under conscious sedation. Thin gauze is adequate to cover the stoma for temporary hygiene. Over 7–14 days, the stoma will close spontaneously. Occasionally, there is a persistent tracheocutaneous fistula, usually due to chronic infection and persistent discharge through the stoma. This can be conservatively managed with silver nitrate. Silver is a heavy metal toxic for varieties of microbes, by blocking respiratory enzyme and components of the microbial electron transport system as well as impairing some DNA system [23]. Such treatment breaks the cycle of repeated irritation of the infected stoma and promote wound epithelization and healing.

In conclusion, although certain failure from a T-tube usage are inevitable, we believe that, overall, the silicone T-tube is an excellent artificial prosthesis which can be safely and easily placed for management of laryngotracheal stenosis. Using the T-tube provides reliable patency of the stenotic airway and can be long-term used. In carefully selected patients, the T-tube is highly successful in the management of complex laryngotracheal lesions not amenable to surgical reconstruction.

References