The Montgomery T-tube tracheal stent

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In 1964, Dr. William W. Montgomery used for the first time a two-piece rigid acrylic stent during a reconstruction surgery of the cervical trachea to prevent postoperative tracheal stenosis [1]. This stent was designed as a combination tracheal stent and tracheotomy tube, but proved to be too rigid, with significant complexity in manufacturing and insertion. Nonetheless, it served as a prototype for the Montgomery T-tube tracheal stent introduced by Montgomery in 1965 [2]. The improved version was a one-piece flexible silicone stent that possessed greater flexibility and caused minimal tissue reaction (Fig. 1).

Once used exclusively by otolaryngologists, the T-tube tracheal stent is now also placed by thoracic surgeons and interventional pulmonologists to treat an ever expanding array of tracheal diseases, particularly benign tracheal stenosis following the use of artificial airways.

Description of device

The Montgomery T-tube is a silicone tube that serves as both a tracheal stent and a tracheotomy tube. The vertical limb of the T-tube is intraluminal, whereas the horizontal limb is extraluminal, protruding through a tracheotomy orifice (Fig. 2).

The junctions of the intraluminal and extraluminal limbs are angled obliquely to promote suctioning of respiratory secretions. The proximal and distal ends of the intraluminal limb are tapered and smooth to avoid mucosal abrasion and formation of granulation tissue as a result of frequent rubbing against the respiratory mucosa.

The extraluminal limb can be occluded with a plug held in place by friction, allowing the passage and humidification of air through the nasopharynx.

The proximal portion of the intraluminal limb is shorter than the distal portion, to accommodate the short distance between the vocal cords and tracheotomy stoma. The proximal end of the T-tube usually terminates under the vocal cords; however, it can extend above the vocal cords when stenting of the higher subglottic area is desired.

The T-tube is available in sequentially increasing sizes for children and adults, ranging from an outer diameter of 6 mm to one of 16 mm.

Since its introduction in 1965, numerous modified models of the T-tube have been produced (Fig. 3). The Safe T-tube has grooves on its external limb that can lodge a ring washer to prevent accidental sliding of the T-tube into the trachea. The Thoracic T-tube has an extra long distal portion of the intraluminal limb to stent the distal trachea.

The T-Y stent is a T-tube with a long distal intraluminal limb ending in a Y-bifurcation that rests on the main carina and stents the main stem bronchi.

The main advantages of the T-tube include the preservation of normal respiration and phonation, minimal cough and tissue reaction to the silicone material, and virtual elimination of the risk of migration owing to the anchored external limb. T-tubes are well tolerated by patients and have been reported to stay in place for as long as 20 years [3].

The main disadvantages of the T-tube consist of the need for a tracheotomy orifice and, to some
patients, the unpleasant cosmetic appearance of a protruding neck tube.

**Indications**

The T-tube is used in benign and malignant diseases, with palliative or curative intentions.

**Malignant disease**

The T-tube has been used as a palliative measure in malignant tracheal diseases including primary tracheal tumors, esophageal cancers with involvement of the trachea, metastatic cancer to the trachea, and compression of the trachea by mediastinal tumors such as lymphoma or mediastinal metastases [3–7].

**Benign disease**

The use of the T-tube in benign tracheal diseases continues to expand, primarily due to the increasing incidence of benign tracheal stenosis caused by the use of artificial airways in a growing and aging population. Other benign conditions where the T-tube has been employed include relapsing polychondritis, Ehlers-Danlos syndrome, sarcoidosis, tracheopathia osteoplastica, tracheobronchomegaly, tracheomalacia, caustic injury to the trachea due to ingestion or inhalation of chemical irritants, irradiation injury, and tuberculous infection of the trachea [2–4,6–16].

Surgical resection remains the optimal treatment for short segmental benign tracheal stenoses; however, the T-tube plays a role in the following situations:

1. A bridge to definitive reconstructive surgery in patients with active coexisting medical conditions or severe deconditioning following their extended ICU stay, or in freshly injured or infected trachea
2. An adjunct to primary surgical interventions on the trachea, permitting the newly repaired delicate mucosa to heal. Such indications include reconstruction of trachea, and segmental resection with end-to-end anastomosis
3. A therapeutic intervention in the postoperative period to address complications such as partial dehiscence, and failed surgical repair leading to recurrence of the stenosis
4. A definitive treatment when the poor general condition of the patient prohibits a surgical operation or when the tracheal lesion is not amenable to surgical repair due to its length or relation to surrounding organs

When choosing a stent for benign subglottic or higher tracheal disease, T-tubes are superior to silicone stents because they seldom migrate, provide an easy access to suction respiratory secretions, and are easily removable in case of acute obstruction.

Migration is a troublesome complication of silicone stents, and has been reported to occur in up to 17.5% of patients [17]. Internal [18] or external fixation [19] of silicone stents in the subglottic space with sutures has been performed successfully, but has not been widely used.

**Contraindications**

T-tube tracheal stents are unsuitable conduits for positive pressure ventilation and should not be placed

Fig. 1. The Montgomery T-Tube tracheal stent.

Fig. 2. The T-tube in place.
in patients with anticipated need for prolonged mechanical ventilation in the near future.

T-Tubes that extend above the vocal cords can prevent complete glottis closure and increase the risk of aspiration and are, therefore, contraindicated in patients with documented aspiration. Caution is advised when T-tubes of small inner diameters are used, namely in children. Special attention to precise placement and meticulous cleaning of the T-tube is mandatory to prevent obstruction with dry secretions. In a retrospective review of the complications of 26 T-tubes placed in children aged 2.4 to 17.9 years, Stern et al found a 23% rate of aspiration, 16% rate of formation of proximal granulation tissue, and 11.5% rate of intolerance to plugging of the T-tube necessitating its removal [20]. The proximal end of the intraluminal limb extended above the vocal cords in all patients in this series.

In another series by Gaissert et al, the T-tube had to be removed in 5 out of 10 children under the age of 10 due to airway obstruction [3].

Insertion and removal

Since the original method of insertion was described by Montgomery, many authors devised minor modifications to render the insertion process an easier and less time-consuming one.

Herein, we describe our technique of insertion (Fig. 4), adopted from the technique by Cooper et al [8], followed by a summary of other reported methods.

A tracheotomy opening is a prerequisite for the insertion of the T-tube and can be either pre-existing or created immediately before the procedure. A rigid tracheoscope is introduced under general anesthesia and its beveled distal tip is placed in the subglottic space above the tracheotomy stoma. In many cases, endoscopic interventions such as balloon dilatation or laser application may be required before the placement of the T-tube. The diameter of the T-tube is chosen based on radiographic data such as computed tomography (CT) of the airways with external (3-D reconstruction) or internal (virtual bronchoscopy) rendering. Alternatively, the diameter can be estimated under
direct bronchoscopic visualization. The ideal diameter would lead to a snug fit of the T-tube inside the airways with minimal anterior-posterior displacement. Likewise, the ideal length of the T-tube is attained with careful bronchoscopic measurements of the distance between the vocal cords and the tracheotomy stoma, as well as the length of the tracheal lesion distal to the tracheotomy stoma. The edges of the intraluminal limb are cut with a scalpel to the desirable length and smoothed with sandpaper.

An umbilical tape is inserted through the horizontal limb into the proximal portion of the vertical limb. The proximal end of the tape is then inserted through the tracheotomy stoma, grasped by rigid forceps, and brought outside the mouth. After the tape is placed through the T-tube and the trachea, it is important to grasp both of its ends with hemostat forceps to prevent accidental retraction from the T-tube or the trachea during the rest of the insertion process.

Next, a hemostat is used to clamp and advance the distal portion of the vertical limb through the tracheotomy stoma toward the distal trachea. The grasped portion of the T-tube can be made smaller by folding it in half on itself before grasping, therefore allowing an easier insertion.

Once the distal portion of the vertical limb is inside the trachea, one operator advances the proximal portion of the vertical limb into the proximal trachea, while a second operator pulls the tape upward through the tracheoscope. This simultaneous pushing and pulling causes the proximal limb of the vertical limb to unfold in the proper location.

Montgomery’s original method consisted of grasping the distal portion of the intraluminal limb with a hemostat and advancing it into place inferiorly, applying the same technique on the proximal portion in a superior direction, and finishing the procedure by pulling the extraluminal limb anteriorly to help direct insertion.
the proximal portion of the intraluminal portion in place [21]. This method proved to be technically challenging to some physicians, as the pliable T-tube bent during insertion into the airways.

In 1977, Duvall et al presented their modified insertion technique under direct bronchoscopic vision [9]. A heavy silk string is placed through the tracheotomy stoma and pulled outside the mouth with rigid forceps. The rigid bronchoscope is then removed and the T-tube is loaded over its distal end. The proximal end of the string is tightly tied to the extraluminal portion of the loaded T-tube while the distal end of the string extends through the trachea and out of the tracheotomy stoma. The T-tube and the rigid bronchoscope are inserted into the trachea and the string is pulled through the tracheotomy stoma, drawing with it the extraluminal portion of the T-tube.

Cooper et al further modified the Duvall technique to stabilize the loaded T-tube on the distal end of the rigid bronchoscope [4]. This is accomplished by loading an endotracheal tube over the proximal portion of the rigid bronchoscope to provide support to the distally loaded T-tube. Another technique uses a special rigid bronchoscope possessing an inflatable balloon at its distal end. When inflated, the balloon fixes the T-tube loaded proximal to it.

Two other methods described in the literature focus on adequate airway control during the insertion process by maintaining an endotracheal tube above the tracheotomy stoma while a nasogastric tube [22] or gum elastic bougie [23] is used to facilitate the insertion of the T-tube into the trachea.

Removal of the T-tube can be accomplished with a hard sturdy anterior pull of the extraluminal limb. T-tube removal is rarely necessary except in the case of malpositioning in the immediate postoperative period, inability to clean retained secretions with resultant chronic partial obstruction, or acute complete obstruction [24]. When plugged, T-tubes have been reported to stay in place for prolonged periods of time with rare need to exchange them.

Periodic removal of the T-tube and assessment of the stenotic tracheal segment beneath it is recommended in benign tracheal diseases to judge the continued need for the T-tube as a stenting device. The ideal interval for such assessment is not known. A 6- to 12-month period is consistent with observations reported in T-tube series.

**Short- and long-term results**

There are no randomized controlled clinical trials addressing outcomes associated with the use of the T-tube tracheal stent. The majority of data comes from small retrospective series that demonstrate a favorable symptomatic improvement and low complication rate [3–6,8–11,15,16].

In a retrospective review by Gaissert et al of 140 patients who have undergone T-tube placement over a 23-year period, T-tubes achieved long-term airway patency in 80% of patients and were the only needed intervention in 11% of patients [3]. In the remaining 20% of patients, T-tubes were removed within the first 2 months following insertion, predominantly due to airway obstruction or aspiration.

Puma et al treated 45 patients with benign tracheal stenosis with silicone stents (27 T-tubes, 16 Dumon stents, and 2 Dynamic stents), either as a bridge to surgery or as a definitive treatment [15]. All patients were not initially considered optimal surgical candidates due to the characteristics of their lesions or poor general condition. Immediate symptomatic improvement was achieved in all patients. In the bridge to surgery group, 88% of patients had a successful surgery with a median interval of 9 months between stenting and surgery. In the definitive treatment group, 30% of patients died of unrelated causes, 32% still had the stents at the study time, 27% had successful removal of stents (median interval of 32 months), and 11% had symptomatic recurrence within 6 weeks of stent removal.

Complications of T-tubes are rare, with no reported mortality directly related to the T-tube. Complications include subcutaneous emphysema following insertion, migration requiring removal and reinsertion, posterior displacement into the trachea causing acute airway obstruction, buildup of dried luminal respiratory secretions needing bronchoscopic suctioning or removal of T-tube, airway infection, tracheal hemorrhage, formation of granulation tissue, and prolonged healing of tracheocutaneous fistula [3,11,15,25].

When the proximal end of the T-tube is positioned just above the vocal cords to stent the subglottic area, additional complications are encountered, including aspiration and voice weakening [4,8]; however, vocal cord injury has not been observed, even with periods of over one year of T-tube use.

**Care of the T-tube**

The T-tube should be plugged at all times to preserve phonation and allow normal humidification of air entering the respiratory tree. Open T-tubes promote dryness of respiratory secretions and luminal obstruction. Respiratory distress experienced when the T-tube is occluded is indicative of laryngeal edema.
during the immediate postoperative period or formation of subglottic granulation tissue in later stages.

If the T-tube must remain open for a short time, respiratory secretions can be kept moist with the administration of humidified air, mucolytic agents (acetylcysteine), or expectorants (Guaifenesin).

Two-to-three daily instillation of 1 cc to 2 cc of normal saline into the T-tube’s lumen and cleaning of the extraluminal limb with a Q-tip soaked in 1/2 hydrogen peroxide is recommended by the manufacturer (Hood Laboratories, Pembroke, MA) in the first 1 or 2 postoperative weeks.

Similarly, frequent suctioning of the T-tube is advised during the early postoperative period, but rarely needed afterward if the tube is kept plugged. The extraluminal limb of the T-tube can be tilted superiorly and inferiorly to help direct the suction catheter upward and downward. The suction catheter should not be advanced beyond the length of the intraluminal portions of the T-tube to avoid mucosal irritation.

A spare tracheostomy tube in a size selected to fit the tracheotomy orifice should always be within the patient’s reach to replace an acutely obstructed T-tube.

Special considerations

Modifications of the T-tube

T-tube modifications into a thoracic T-tube and T-Y tube to accommodate distal tracheal and bronchial disease were mentioned above.

Burial of the extraluminal limb of the T-tube subcutaneously and closure of the skin has been performed [26,27]; however, concerns of inability to easily access the T-tube in case of emergency have made this practice unpopular.

To decrease the risk of intraluminal blockage with secretions and continue to take advantage of the T-tube as a stenting device, some physicians have put together combinations of T-tubes and tracheostomy tubes [28,29]. This entails modification of the T-tube to accommodate a fenestrated tracheostomy tube positioned through the extraluminal limb into the lower portion of the intraluminal limb.

Anesthesia and the T-tube

General anesthesia and short-term positive pressure ventilation may be required in patients with T-tubes for periodic assessment of the tracheal lesions or other unrelated surgical procedures. The T-tube presents a challenge to the anesthesiologist due to the escape of air through its open proximal end and the difficulty in finding an adaptor to fit its extraluminal limb. The preferred method in our institution is the use of jet ventilation with a manual injector through a rigid bronchoscope, whose tip is positioned just above the proximal intraluminal end of the T-tube.

Montgomery recommended the insertion of an arterial embolectomy catheter (Fogarty) through the extraluminal limb and inflating its balloon inside the upper portion of the intraluminal limb [30]. An endotracheal tube, inserted into the extraluminal limb, directed the flow of gas into the distal airways.

The Hebeler T-tube (Boston Medical Products, Westborough, MA) is a modified Montgomery T-tube that contains an internal balloon located in the proximal portion of the intraluminal limb. The balloon can be transiently inflated to achieve ventilation of the distal airways.

The laryngeal mask airway (LMA) can also provide controlled anesthesia and ventilation while a T-tube is in place [14,31].

If all else has failed or in a case of emergency such as cardiopulmonary resuscitation, an endotracheal tube size 6.0 mm can be passed through the intraluminal limb of most T-tubes used in adults. A second operator should grasp the extraluminal limb while the endotracheal tube is being inserted to prevent accidental dislodging of the T-Tube.

Summary

The Montgomery T-tube is a valuable tracheal stent that provides a functional airway while supporting the tracheal mucosa. It is used in benign and malignant tracheal diseases and provides symptomatic relief to the majority of the patients. T-tubes are simple to insert and rarely cause serious complications.

The use of T-tubes continues to gain popularity with the increasing incidence of benign tracheal stenosis following the use of artificial airways. Physicians dealing with diseases of the airways should be familiar with the indications, contraindication, complications, and care of the Montgomery T-tubes.

References


