Received: 26 December 2018 | Revised: 3 September 2019 | Accepted: 11 October 2019

DOI: 10.1111/crj.13098

ORIGINAL ARTICLE

WILEY

Montgomery T-tube for management of tracheomalacia: Impact on voice-related quality of life

Alfonso Fiorelli | **Giovanni Natale** | **Chiara Freda** | **Roberto Cascone** | **Annalisa Carlucci** | **Saveria Costanzo** | **Vincenzo Ferrara** | **Mario Santini**

Thoracic Surgery Unit, Università della Campania Luigi Vanvitelli, Naples, Italy

Correspondence
Alfonso Fiorelli, Thoracic Surgery Unit, Università della Campania Luigi Vanvitelli, Piazza Miraglia, 2, Naples I-80138, Italy.
Email: alfonso.fiorelli@unicampania.it

Abstract

Introduction: Tracheostomy is a common procedure for management of tracheomalacia. However, the limitation to speak related to tracheostomy cannula could affect the quality of life.

Objectives: we reported a new minimally invasive procedure to replace tracheostomy cannula with Montgomery T-tube to improve the ability of speaking.

Methods: This is a single center study including all consecutive patients undergoing the replacement of standard tracheostomy cannula with T-tube for management of tracheomalacia. The end-points were to evaluate (a) the changes in Voice-related quality of Life (V-RQOL) before and after T-tube placement; and (b) the complications related to T-tube.

Results: Eleven patients were included in the study. T-tube was placed using flexible bronchoscopy and laryngeal mask airway. A suture was inserted through the proximal end of T-tube. Once the stent was introduced with a clamp into the trachea, a traction was applied on the suture to facilitate the alignment of the upper end of the stent. The comparison of V-RQOL values before and after T-tube insertion showed a significant improvement in social/emotional (39.2 ± 6.1 vs 66.8 ± 1.9; $P = .0001$); physical functioning (21 ± 5.7 vs 56.4 ± 5.3; $P = 0.0001$) and total V-RQOL scores (33.9 + 5.4 vs 61.3 + 6.1; $P = 0.0001$). No complications were seen during the insertion of the stent. In two patients, T-tube was obstructed by mucus that resolved with aspiration using flexible bronchoscopy (mean follow-up: 18 ± 10 months).

Conclusions: Our technique is simple and safe, not needing specific skills and/or cumbersome devices. The replacement of tracheostomy cannula with T-tube seems to improve the quality of voice without adding major complications.

KEYWORDS

bronchoscopy, Montgomery T-tube, tracheomalacia, tracheostomy, voice-related quality of life

1 | INTRODUCTION

Tracheomalacia is a pathological condition characterized by excessive expiratory collapse because of a reduction in the integrity of tracheal cartilage. When obstruction exceeds more than 50% of the airway lumen, it manifests clinically with dyspnea, cough, frequent infection and potential acute life-threatening respiratory distress.[1,2] The ideal treatment is still debate, and the choice depends on the nature and severity of the lesions. Medical options includes chest physiotherapy, bronchodilators, anti-muscarinic agents, mucolytics and antibiotics, but there is currently little evidence

for benefit.[3] When symptoms are severe, surgery including aortopexy or posterior tracheopexy, and tracheal resection or endoscopic procedures as insertion of airway stents of different materials and shapes have been proposed.[3] Traditional tracheostomy was the mainstay of surgical treatment in the past, but is now used as a last resort because of the severe limitations on patient's physical activities and quality of life (QOL). In the last years, the endoscopic insertion of Montgomery T-tube has been proposed as alternative to tracheostomy in patient with tracheomalacia. Montgomery T-tube is a stent designed in the shape of a "T" where the internal harm is used to support and shape the trachea, while the external harm is used to fasten the stent to the tracheostomy. Compared to traditional cylinder stent, the external limb reduces the risk of migrations and, when capped, restores nasal airflow and speech. However, the insertion of T-tube remains challenging, and it limits its widely use. The aim of this paper is to evaluate (a) the feasibility of a new minimally invasive procedure to insert Montgomery T-tube using flexible instead of rigid bronchoscopy in management of tracheomalacia and (b) whether the replacement of tracheostomy tube with T-tube could improve the ability of speaking.

2 | MATERIALS AND METHODS

2.1 | Study design

This is a single center study including all consecutive patients undergoing the replacement of standard tracheostomy cannula with T-tube for management of tracheomalacia from January 2016 to May 2018. Inclusion criteria to enter into the study were: (a) age more than 18 years old; (b) willingness to participate in the study; (c) ability to fill out questionnaire before and after T-tube insertion and (d) complete follow-up. Exclusion criteria were: (a) the presence of chronic disabling diseases that could interfere with the QOL; (b) incomplete questionnaire; and (c) incomplete follow-up.

The hypothesis of the study was that T-tube can provide an alternative treatment to standard tracheostomy in management of tracheomalacia, optimizing quality of phonation. To evaluate it, all patients completed a questionnaire on Voice-related quality of Life (V-RQOL) before and after T-tube placement, and the data were retrospectively compared. Yet, we also recorded complications related to T-tube during its insertion and the entire follow-up to show the feasibility and the safety of the procedure.

2.2 | Patients population

During the study period, 21 patients with pre-existing tracheostomy performed for management of tracheomalacia were referred to our attention. In all cases, surgery was contraindicated for technical reasons and poor clinical conditions. The indication for T-tube treatment were the presence of mature tracheostoma of at least 3-month duration and free of granulation, and not ventilator dependent. Exclusion criteria were poor manual dexterity and inability to care for the Montgomery T-tube, unfavourable anatomic condition for T-tube insertion, ongoing mechanical ventilation and active inflammation of the tracheal mucosa. Prior to inserting T-tube, all patients were evaluated with a High Resolution Computed Tomography (HRCT) of neck and chest with multiplanar reconstruction (MPR) and flexible bronchoscopy in order to choice the appropriate diameter and the length of T-tube.

2.3 | Procedure for T-tube insertion

The procedure, reported in Video S1, was performed in operating room. A 0/0 silk suture was inserted using a small needle into the lumen and through the wall of proximal end of T-tube. The needle was then cut-off and a long loop made by tying a knot at the end of the suture (Figure 1). After pre-oxygenation, anaesthesia was induced with propofol (2.5 mg/kg) and fentanyl (20 mg) and a size 5 Laryngeal Mask Airway (LMA) was inserted by the anaesthesiologist into its standard position over the supraglottis. Anaesthesia was maintained with a mixture of 50% air/oxygen and an infusion of propofol (0.16-0.11 mg/kg/min), and patient maintained a spontaneous ventilation during the entire procedure. A flexible bronchoscopy (XT-BF 160 Type, Video-bronchoscopy Olympus, Tokyo) was inserted into the LMA and placed just below them. The tracheostomy cannula was removed and the loop of the suture was inserted through the stoma into the trachea. Standard endoscopic forceps grasped the suture and withdrawn it through the LMA. Then, the operator placed a curved clamp through the horizontal limb and into the lumen of the vertical, distal end of the T-tube, introduced it into the trachea through the tracheostoma and directed inferiorly. Once the vertical, proximal end of T-tube was passed into the trachea; the assistant applied a gentle traction on the suture until proximal end was aligned. The hemostat was gently brought outside the T-tube and the suture was then extracted. At the end of the procedure endoscopy showed the normal movement of vocal folds and the prompt position of T-tube (Figure 2).

2.4 | Outcomes

2.4.1 | Voice-Related Quality of Life

V-RQOL is a subjective measure to quality phonation.[4,5] It has been validated as a 10 item survey that reliably evaluates the change in perceptual voice quality ratings before and after treatment for dysphonic patients. It has two domains: social/emotional and physical functioning. These two functional domains are reported as scores, with each reflecting

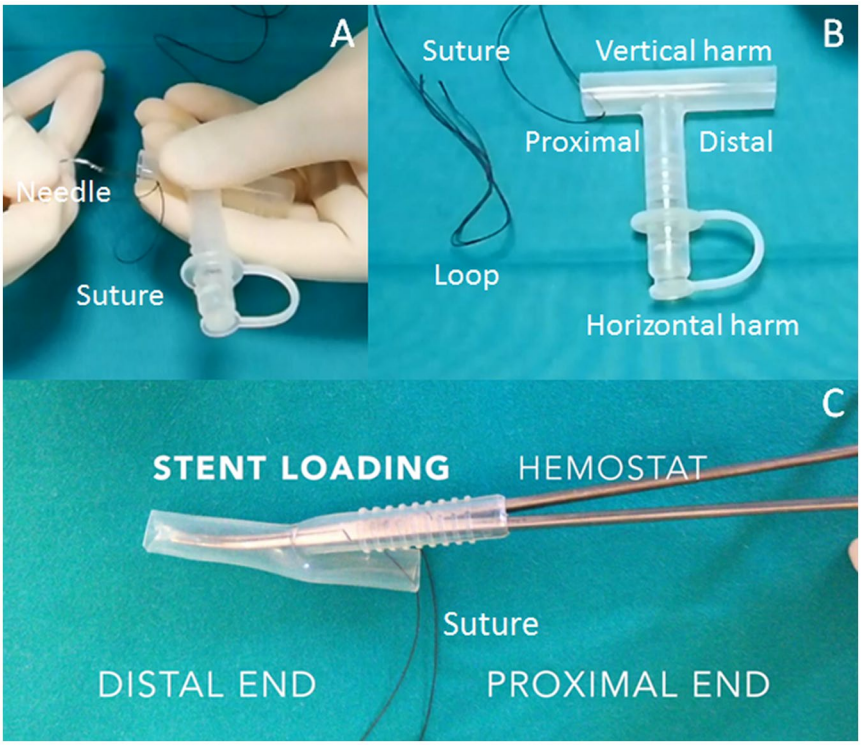

FIGURE 1 Introduction of the suture through the proximal end of the stent (A); stent with the suture (B); stent loaded in the hemostat (C)

one component of how a patient's deficit can influence his/her daily life as specific to vocal communication. The scores from those two domains are supplemented by a final total V-RQOL score with a better voice outcome reflected by higher V-RQOL scores. The questionnaire was completed before and 1-3 months after T-tube insertion.

2.4.2 | Complications

All potential complications related to T-tube as granulations, difficulty ventilating, dyspnea, need to resize T-tube, tracheitis and dislocation were collected. The length of time each patient maintained a T-tube was also recorded.

2.5 | Statistical analysis

Data were expressed as mean ± Standard Deviation (SD) for continuous variables, and absolute number and percentage for categorical variables. Significant differences between V-RQOL values before and after T-tube insertion were compared using student *t* test. A value of $P < 0.05$ was considered statistically significant. MedCalc statistical software (Version 12.3, Broekstraat 52; Mariakerke, Belgium) was used for this analysis.

3 | RESULTS

Among 21 patients observed in the study period, 8 patients were considered non-candidate for T-tube insertion because of the anatomical conditions (n = 4); active stoma (n = 3); and inability to care T-tube (n = 1). Thirteen patients underwent T-tube insertion, but of which one did not complete V-RQOL questionnaire and another was lost in the follow-up. Thus, our study population included 11 patients (Figure 3), reported in Table 1. The mean age was 61.5 ± 4.2 year olds (8 male and 3 female). The most of patients (10/11; 91%) presented Chronic obstructive pulmonary disease (COPD) (stage I-II GOLD) associated with cardiac (n = 2) and cerebral disease (n = 1). The mean BMI was 22.8 ± 2.7. The interval time between tracheostomy and T-tube insertion was 6.5 ± 1.6 months. In all cases, T-tube was successfully inserted using LMA and flexible bronchoscopic, and no complications during the procedure were observed.

4 | OUTCOMES

4.1 | Voice-Related Quality of Life

The data are summarized in Table 2 and in Figure 4. Patients used different strategies to improve the ability of speaking as closing the tube with finger in a tracheostomy (n = 3), a fenestrated cannula (n = 4) and a speaking valve (n = 4), but the results were poor. In three cases, the fenestrated cannula was replaced 1 month after its introduction with a standard tracheostomy cannula because of the granulations formation. In three cases, the speaking cannula was not routinely used since it impaired the cleaning of secretion. The comparison of V-RQOL values before and after T-tube insertion showed a significant improvement in social/emotional (39.2 ± 6.1 vs

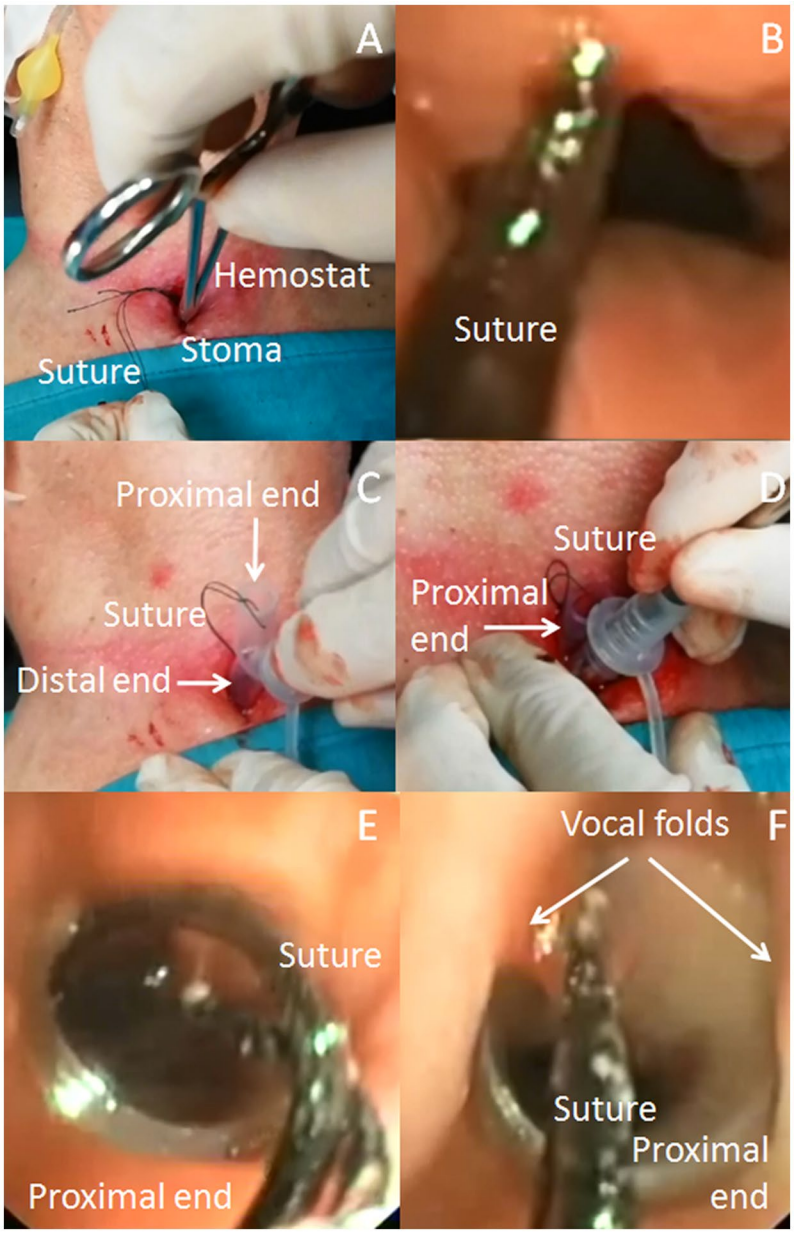

FIGURE 2 Introduction of the suture through tracheostomy (A) into the trachea (B); introduction of distal end (C) and proximal end (D) of the stent; kinking of proximal end of the stent (E) and alignment by traction on the suture (F)

66.8 ± 1.9; $P = 0.0001$); physical functioning (21 ± 5.7 vs 56.4 ± 5.3; $P = 0.0001$) and total V-RQOL scores (33.9 + 5.4 vs 61.3 + 6.1; $P = 0.0001$) after T-tube insertion.

4.2 | Complications

The mean follow was 18 ± 10 months. In two patients, T-tube was obstructed by mucus that resolved with aspiration using flexible bronchoscopy. In one patient, T-tube was replaced with another similar dimension since the patient spontaneously shortened the external limb of the stent to reduce its profile. In all cases CT scan and endoscopy showed a normal movement of focal folds and no damage and/or migration of T-tube.

5 | DISCUSSION

Tracheostomy is a common procedure for management of tracheomalacia in patients not candidate for surgery.[1-3] However, tracheostomy cannula could complicated with granulation, infection, maleodor and difficult to speak that will additionally affect the QOL.[6-8] Mc Neil et al[9] reported that 20% of interviewed cohort volunteers would have preferred radiotherapy to surgery for management of laryngeal cancer, willing to trade a better-quality voice to an improved-probability of survival. Several techniques (ie, to close the tracheostomy with finger) and devices (ie, fenestrated cannula, speaking valve) have been proposed to favour the phonation in patient with tracheostomy, but the results are generally poor,[10] as observed in

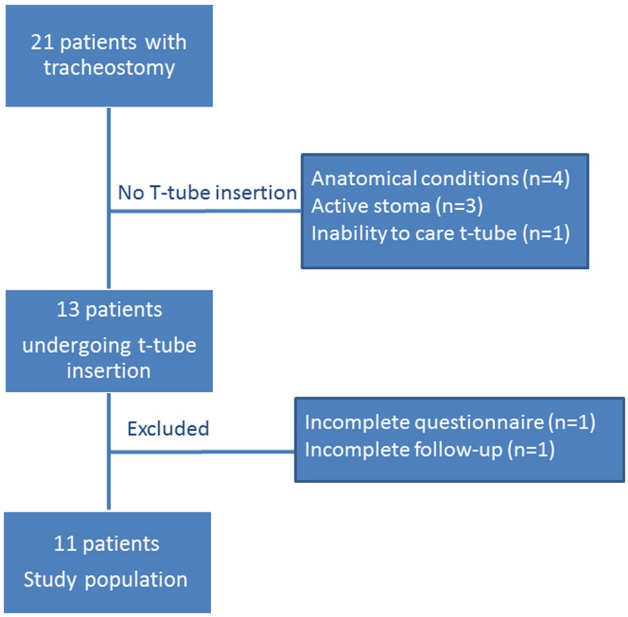

FIGURE 3 Flow chart of the study

our series. Montgomery T-tube was first described by William Montgomery in 1965 for the management of subglottic of upper airway stenosis and in the following years it has been proposed in the management of several pathological conditions including tracheomalacia.[5,11,12] Despite T-tube presents potential advantages over standard tracheostomy tube as the possibility of phonation, the lower profile and the easier of care, it remained under-used probably because its insertion remains challenging. Montgomery's original method of T-tube 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 directly.[12] However, the proximal, vertical limb of T-tube often cannot be "pushed in" upward from the stomal site and it must be grasped with forceps through rigid bronchoscopy and pulled upward below the vocal fold. In the years, other procedures have been proposed in order to facilitate the insertion of proximal vertical end of T-tube but they require the use of rigid bronchoscopy and/or of cumbersome devices are not widely available.[13-15] Thus, we proposed a new minimally invasive technique, not been reported before, to facilitate the T-tube insertion compared to the traditional procedure. The main differences compared to traditional and other techniques[13-16] are as follow: (a) the use of flexible instead of rigid bronchoscopy, as in patients with tracheomalacia the dilation of airway stenosis was not required before insertion of T-tube; (b) the ventilation was assured by LMA that allowed an easy access to subglottic region and did not interfere with the placement of proximal end of horizontal limb compared to standard orotracheal tube and (c) the hemostat was inserted through the horizontal arm into the distal end of vertical arm. In this way, all segments

TABLE 1 Characteristics of study population

Patient	Age	Sex	Comorbidities	BMI	Tracheostomy duration (months)	T-tube dimension (mm)			Permanence of t-tube (months)	Complications
						Size	Proximal end length	Distal end length		
1	67	M	COPD	22	6	14	2	4	34	None
2	59	M	COPD, cerebral	23	5	14	2.5	4	30	None
3	63	M	COPD	26	6	14	2	4	28	None
4	67	M	COPD, cardiac	24	7	14	2.5	4	25	Plugging
5	66	M	COPD	21	4	12	2	4	20	None
6	65	F	COPD	20	9	12	2.5	4	19	None
7	57	M	COPD, cardiac	19	8	14	2.7	3	17	None
8	57	F	COPD	20	9	14	2.5	4	10	Plugging
9	56	F	Cardiac	27	7	14	2	4	8	None
10	59	M	COPD	26	6	14	2	4	5	None
11	61	M	COPD	23	5	12	2.5	4	3	None
Mean ± SD	61.5 ± 4.2			22.8 ± 2.7	6.5 ± 1.6	13.4 ± 0.2	2.3 ± 0.2	3.9 ± 0.3	18 ± 10	

TABLE 2 VRQL value before and after T-tube insertion

Variables	Trachestomy	T-tube	*P* value
Social/emotional	39.2 ± 6.1	66.8 ± 1.9	0.0001
Physical/functional	21 ± 5.7	56.4 ± 5.3	0.0001
Total	33.9 + 5.4	61.3 + 6.1	0.0001

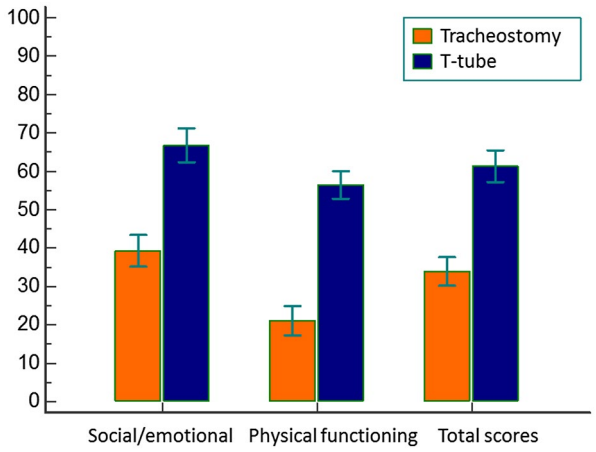

FIGURE 4 The comparison of V-RQOL values before and after T-tube insertion showed a significant improvement in social/emotional ($P = 0.0001$); physical functioning ($P = 0.0001$) and total V-RQOL scores ($P = 0.0001$) after T-tube insertion

of T-tube advanced into trachea as a single unit without additional maneuvers as in standard Montgomery's technique; (d) a suture was inserted in the proximal end of T-tube. Once it was inserted into trachea, the physician pulled up by suture and easily aligned the stent without needing of other cumbersome instruments.

T-tube provided significant improvement in phonation as demonstrated by the higher scores of V-RQOL questionnaires observed after its insertion compared to standard tracheostomy. In line with our results, Dhillon et al[5] evaluated 13 patients undergoing T-tube insertion for management of different pathologies as subglottic stenosis (n = 12) and tracheomalacia (n = 1), and found significant improvement in V-RQOL scores, yet, 5 patients (38%) went from aphonia to voicing. Bayan et al[17] reported that 15 of 20 patients, undergoing the replacement of tracheostomy with T-tube, desired to continue to maintaining the use of the T-tube rather than reverting back to the standard tracheostomy cannula due to the easy clearance and the increased comfort. Additionally, T-tube resulted to be a safe procedure. We observed only two cases of obstruction by mucus that resolved with aspiration. In another patient, T-tube was replaced with another since the patient spontaneously shortened the external harm in order to reduce its profile but it reduced the possibility to readily grasp the cannula and pull it forwards in case of migration. In contrast to other authors, we did not observed granulation, dislocation or tracheitis related to T-tube. However, our study does not include patients with pathological conditions as subglottic stenosis and/or obstruction sleep apnoea that were more likely to be unable to tolerate use of T-tube, as reported in other series.[5,17]

The high success rate of our procedure likely reflects correct technique for T-tube insertion, careful patient selection and prompt patient education. For the technical success of the insertion, we recommended: (a) to use a small needle in order to prevent the damage of proximal end of T-tube during the insertion of the thread; (b) the hemostat should be remained in the external harm to prevent the migration of the stent during the pulling out of the proximal end of T-tube; (c) all aperture bars of the LMA should be removed, if present, to facilitate the handling of the endoscopy and (d) the upper end of the stent should be at least 0.5 mm from vocal folds to avoid impairment of movement and granulations.[18] Our procedure is not indicated in obese patients, and in presence of airway stenosis needing a dilation with rigid bronchoscopy before T-tube insertion. Yet, Physicians should educate patients so they can actively participate in care of T-tube. Bayan et al[17] reported a posterior displacement of the T-tube in the airway resulting in respiratory distress. In both cases, patients were able to retrieve the cannula by pulling it forward. They should also be encouraged to drink water frequently to promote expectoration, and to close the valve in order to prevent luminal dryness and dry sputum.

Our results should be evaluated with cautions, before drawing definitive conclusions. (a) The small number of patients, the retrospective nature of the study, and the brief follow-up are the main limitations. Since in all our cases T-tube was a definitive treatment of tracheomalacia without any possibility of decannulation, in theory T-tube could be not tolerated for longer time than that of our follow-up. However, in Bayan's series[17] 15 patients had the T-tube in place for a mean of 51.3 months and the longest period was 11.3 years without any particular problems; (b) The V-QRL scores were not correlated with the age, sex, professional and social activity of patients; (c) V-QRL scores were measured 1-3 months after T-tube insertion but not later, making impossible to evaluate any changes during the entire follow-up.

In conclusion, our technique for inserting T-tube is a simple and safe strategy that does not require specific skills and/or cumbersome devices. The replacement of tracheostomy cannula with T-tube seems to obtain an improvement on quality of voice without adding further complications. Our impressions should be corroborated by future prospective studies.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest with the contents of the article.

ETHICS

The study design was approved by Local Ethics Committees of University "Luigi Vanvitelli", Naples, Italy; all patients gave a written informed consent for the insertion of T-tube and were aware that all information could be used anonymously for scientific purpose only.

ORCID

Alfonso Fiorelli https://orcid.org/0000-0002-0628-613X

REFERENCES

1. de Trey LA, Dudley J, Ismail-Koch H, et al. Treatment of severe tracheobronchomalacia: Ten-year experience. *Int J Pediatr Otorhinolaryngol*. 2016;83:57-62.
2. Hysinger EB. Laryngomalacia, tracheomalacia and bronchomalacia. *Curr Probl Pediatr Adolesc Health Care*. 2018;48(4):113-118.
3. Wallis C, Alexopoulou E, Antón-Pacheco JL, et al. ERS statement on tracheomalacia and bronchomalacia in children. *Eur Respir J*. 2019;54(3):1900382.
4. Hogikyan ND, Wodchis WP, Terrell JE, Bradford CR, Esclamado RM. Voice-related quality of life (V-RQOL) following type I thyroplasty for unilateral vocal fold paralysis. *J Voice*. 2000;14(3):378-386.
5. Dhillon VK, Akst LM, Best SR, Hillel AT. Voice outcomes in laryngotracheal stenosis: impact of the montgomery T-tube. *Clin Surg*. 2018;3:1855.
6. Gilony D, Gilboa D, Blumstein T, et al. Effects of tracheostomy on well-being and body-image perceptions. *Otolaryngol Head Neck Surg*. 2005;133:366-371.
7. Bibas BJ, Cardoso PF, Salati M, et al. Health-related quality of life evaluation in patients with non-surgical benign tracheal stenosis. *J Thorac Dis*. 2018;10(8):4782-4788.
8. Fiorelli A, Ferraro F, Nagar F, et al. A new modified evans blue dye test as screening test for aspiration in tracheostomized patients. *J Cardiothorac Vasc Anesth*. 2017;31(2):441-445.
9. McNeil BJ, Weichselbaum R, Pauker SG. Speech and survival: tradeoffs between quality and quantity of life in laryngeal cancer. *N Engl J Med*. 1981;305:982-987.
10. Hess DR, Altobelli NP. Tracheostomy tubes. *Respir Care*. 2014;59(6):956-971.
11. Wu F, Chen E. Application of the Montgomery T-tube in subglottic tracheal benign stenosis. *J Thorac Dis*. 2018;10(5):3070-3077.
12. Wahidi MM, Ernst A. The Montgomery T-tube tracheal stent. *Clin Chest Med*. 2003;24(3):437-443.
13. Cooper JD, Todd TR, Ilves R, Pearson FG. Use of the silicone tracheal T-tube for the management of complex tracheal injuries. *J Thorac Cardiovasc Surg*. 1981;82(4):559-568.
14. Kato R, Kobayashi T, Watanabe M, et al. Improved technique for inserting a T tube in patients with subglottic stenosis. *Ann Thorac Surg*. 1991;51(2):327-329.
15. Bibas BJ, Bibas RA. A new technique for T-tube insertion in tracheal stenosis located above the tracheal stoma. *Ann Thorac Surg*. 2005;80(6):2387-2389.
16. Fiorelli A, Carlucci A, Pota V, Santini M. A simplified insertion technique for tracheal T-tube. *J Thorac Cardiovasc Surg*. 2018;155(4):1912-1914.
17. Bayan S, Hoffman HT. Indications and outcomes for use of Montgomery cannulas. *JAMA Otolaryngol Head Neck Surg*. 2015;141(2):142-147.
18. Fiorelli A, Mazzone S, Mazzone A, Santini M. The digital AcuBlade laser system to remove huge vocal fold granulations following subglottic airway stent. *Interact Cardiovasc Thorac Surg*. 2013;17(3):591-593.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

How to cite this article: Fiorelli A, Natale G, Freda C, et al. Montgomery T-tube for management of tracheomalacia: Impact on voice-related quality of life. *Clin Respir J*. 2020;14:40–46. https://doi.org/10.1111/crj.13098