Tracheobronchoplasty outcomes: a narrative review

Jennifer L. Wilson[1,2]^, James S. Wallace[3]

[1]Department of Surgery, Harvard Medical School, Boston, MA, USA; [2]Department of Thoracic Surgery, Beth Israel Deaconess Medical Center, Boston, MA, USA; [3]Department of General Surgery, Beth Israel Deaconess Medical Center, Boston, MA, USA

Contributions: (I) Conception and design: Both authors; (II) Administrative support: None; (III) Provision of study materials or patients: None; (IV) Collection and assembly of data: None; (V) Data analysis and interpretation: None; (VI) Manuscript writing: Both authors; (VII) Final approval of manuscript: Both authors.

Correspondence to: Jennifer L. Wilson, MD, MPH, FACS. 185 Pilgrim Road, W/D 201, Boston, MA 02215, USA. Email: jwilso10@bidmc.harvard.edu.

Objective: Herein, we will summarize the most recent adult tracheobronchoplasty outcome data available. We hope this review will encourage others to report their outcome data and allow clinicians to design studies that capture previously reported outcome measures, so that novel and established therapies can be appropriately evaluated.

Background: Excessive central airway collapse (ECAC) consists of excessive dynamic airway collapse (EDAC) and severe tracheobronchomalacia (TBM), two aberrant pulmonary physiologies that refer to the inappropriate movement of the central airway. Typically, EDAC involves the abnormal movement of the posterior membrane, while TBM relates to changes in the cartilaginous portion of the trachea. All can cause debilitating respiratory symptoms. In general, these symptoms can mimic or overlap with common pulmonary diseases such as asthma and chronic obstructive pulmonary disease likely making diagnosis of ECAC underreported. Although screening protocols for ECAC are non-existent, once diagnosed, surgical intervention or tracheobronchoplasty can be offered to highly selected patients at centers with complex airway disease expertise. The preoperative evaluation of patients requires a multi-disciplinary approach. Comorbid conditions are then optimized, and patients with persistent symptoms that are surgical candidates often undergo a temporary stent trial over the course of 1–2 weeks to assess improvement of subjective and objective parameters. This process can help determine if a tracheobronchoplasty is likely to offer symptomatic relief. The scope of this review is to compile the recent data in severe adult TBM.

Methods: A narrative review through the PubMed (MEDLINE) database was performed using the keyword tracheobronchoplasty. Non-pediatric studies pertaining to perioperative, subjective, and objective outcomes after tracheobronchoplasty for severe symptomatic TBM in adults published between 2010–2020 were retained. Single patient case reports were excluded. Six publications from two institutions met inclusion criteria.

Conclusions: Almost half of the patients that undergo tracheobronchoplasty for severe symptomatic TBM will experience a perioperative complication (minor or major) regardless of operative approach. With appropriate patient selection, authors have demonstrated improvement of patient reported, objective, and functional outcomes. Current literature is limited to single center retrospective reviews from two institutions. More data can refine the current treatment paradigms and establish improved outcome metrics.

Keywords: Bronchomalacia; tracheobronchomalacia (TBM); tracheomalacia; patient reported outcome measures; postoperative complications

Received: 13 February 2021; Accepted: 26 July 2021; Published: 20 April 2022.

doi: 10.21037/jovs-21-10

View this article at: https://dx.doi.org/10.21037/jovs-21-10

^ ORCID: 0000-0001-8824-3952.

Introduction

Excessive central airway collapse (ECAC) can cause a plethora of symptoms including a barking cough, shortness of breath, inability to clear secretions, and recurrent respiratory tract infections. Except in rare cases of extreme pulmonary collapse where patients are left gasping for air, ECAC typically represents a non-life-threatening quality of life (QOL) problem. Associated symptoms can mimic or overlap with commonly recognized diseases such as asthma and chronic obstructive pulmonary disease (COPD). The true prevalence of symptomatic ECAC (TBM) remains unknown, but it is almost certainly under-diagnosed as screening data is non-existent (1). The cause remains elusive, although it is associated with gastroesophageal reflux disease (GERD) (2,3) and high dose inhaled corticosteroids (4). Over the past decade, interest in this disease has grown and is reflected in the increased number of publications available in recent literature. We aim to review the available literature regarding the outcomes of tracheobronchoplasty (TBP) for severe symptomatic TBM during the perioperative period and beyond.

Reviewing the available data is a challenge due to highly variable follow-up intervals and a broad array of metrics. In addition, patients that are lost to follow up, undoubtedly impedes long-term outcome reporting. Furthermore, there are no validated QOL measurement scales specific to TBM. Authors have reported QOL data using existing measurement scales that were designed and validated in common respiratory diseases such as asthma and COPD and served as a QOL surrogate in this population. Despite the similarities in clinical presentation, it is unclear if this is an accurate way to report QOL data for patients with TBM. We present the following article in accordance with the Narrative Review reporting checklist (available at https://jovs.amegroups.com/article/view/10.21037/jovs-21-10/rc).

Methods

A narrative review through the PubMed (MEDLINE) database was performed using the keyword tracheobronchoplasty. Non-pediatric studies pertaining to perioperative, subjective, and/or objective outcomes after tracheobronchoplasty for severe symptomatic TBM in adults published from 2010–2020 were retained. Single patient case reports were excluded. Six publications from 2 institutions met inclusion criteria. These publications are limited to single center retrospective reviews from Lenox Hill Hospital in New York, New York (1 publication) and Beth Israel Deaconess Medical Center in Boston, Massachusetts (5 publications).

Results

Perioperative outcomes

Tracheobronchoplasty is a complex and laborious procedure that requires appropriate patient selection, in-hospital resources, and a multidisciplinary care team approach. Generally speaking, post-operative outcomes are impacted by patient comorbidities and operative modalities. We will discuss the 2 most recent TBP perioperative outcome manuscripts in detail (5,6) (*Table 1*). Both institutions stratified perioperative complications based on the Clavien-Dindo classification system (5). This classification grades the severity of complications in an objective and reproducible manner and delineates outcomes from I to V based on divergence from a normal postoperative course. Clavien-Dindo grade I describes any deviation from a normal post-operative course without the need of pharmacological treatment or surgical/endoscopic/radiologic interventions. A class IIIa complication is any problem that requires surgical/endoscopic/radiologic interventions that do not require anesthesia (7). Thirty- and 90-day outcomes have been reported by only 2 institutions over the past decade (3,5,6). Both institutions report a significant incidence of perioperative complications (45–47%) (*Table 1*). However, Lazzaro *et al.* reported outcomes on 42 patients that underwent a robotic TBP (rTBP) from 2016–2017 while Buitrago *et al.* reported outcomes of 161 patients that underwent an open TBP from 2002–2016 (5). Both authors further classified their complications as major (Clavien-Dindo ≥ IIIa) or minor (Clavien-Dindo < IIIa). The most common complications reported by these institutions were pulmonary in nature and included respiratory failure, respiratory infections, pneumothorax, and subcutaneous emphysema. To follow, we will discuss perioperative complications after TBP in more detail.

The largest series published resulted in a single center retrospective analysis of 161 patients that underwent TBP from October 2002 to September 2016 at BIDMC (5). The authors found that several preoperative factors were associated with an increased risk of post-operative complications in particular, age (P<0.001), coronary artery disease (P=0.003), COPD (P<0001), congestive heart failure (P=0.0003), diabetes mellitus

Table 1 Perioperative outcomes after tracheobronchoplasty

First author	Institution	Operative approach	Inclusion years	# patients	Overall perioperative complications	Minor complications†	Major complications†
Buitrago (5)	BIDMC	Thoracotomy	2002–2016	161	75/161 (47%)	37/161 (23%)	38/161 (24%)
Lazzarro (6)	LHH	Robotic	2016–2017	42	19/42 (45%)	11/42 (26%)	8/42 (19%)

†, minor complications classified as Clavien-Dindo < IIIa and major complications classified as Clavien-Dindo ≥ IIIa. BIDMC, Beth Israel Deaconess Medical Center (Boston, Massachusetts); LHH, Lenox Hill Hospital (New York, New York).

(P=0.011), continuous home oxygen requirement (P<0.001), and recent treatment (<90) of pneumonia (P=0.014). Baseline functional factors that contributed to postoperative complications were impaired pulmonary function tests (FEV1, FVC; P<0.0001), and diffusion capacity (DLCO; P<0.001). The study results showed that 47% of patients (75 of 161) experienced a post-operative complication while approximately 50% of patients with complications were classified as severe (Clavien-Dindo > IIIa). The non-severe (< IIIa) complications (23%) included postoperative respiratory infections, acute kidney injury, recurrent pleural effusion, pneumothorax, atrial arrhythmias, urinary tract infections, and wound infections. The severe complications identified were postoperative bleeding, mesh erosion, acute chest wall hernia, rhabdomyolysis, acute kidney injury requiring HD, and sepsis. The 30-day mortality in this series was 1.2%, with most patients (69%) abled to be discharged home or home with VNA by day 8. Although limited to 30 days, this study provides a safety assessment that can help improve perioperative management in future studies.

In addition, Lazzaro *et al.* at Lenox Hill were able to provide compelling data on the benefits of robotic tracheobronchoplasty as well create a risk profile using the Clavien-Dindo classification (6). They presented data from a cohort of 42 patients that underwent robotic tracheobronchoplasty with comorbidities similar to the BIDMC group. Many patients had asthma (88%), COPD (52%), GERD (85%), hypertension (52%), diabetes mellitus (26%), and cardiovascular disease (14%). Using the Clavien-Dindo classification, Lazzaro *et al.* had a total of 19 postoperative complications, with 8 patients having severe complications (19%). The minor complications were an asymptomatic pneumothorax, self-resolving subcutaneous emphysema, pneumonia, and bronchitis. Their Clavien-Dindo classification IIIa and above complications included hemothorax evacuation, pneumothorax and subcutaneous emphysema requiring decompression, a return to ICU for bronchoscopy and arrhythmia, and a takeback for revision at postoperative day 125. This group evaluated these complications at a 90-day benchmark and had no reintubations, tracheostomies or mortalities.

In summary, almost half of patients undergoing TBP experience a complication in the perioperative period. The top 3 complications observed in the open cohort from BIDMC were respiratory failure (17%), respiratory infection requiring antibiotics (18%), and acute renal failure (11%) (5). The top 3 complications in the rTBP cohort from Lenox Hill were respiratory infection requiring antibiotics (16.7%), pneumothorax or subcutaneous emphysema requiring no intervention (9.5%), and pneumothorax or subcutaneous emphysema requiring intervention (9.5%) (6). Future technological advancements and improvement in operative performance may bridge the gap between a complex surgery and good outcomes.

Patient-reported outcomes

How do we define 'success' when we are treating a QOL problem with no validated QOL measurement tool?

While TBM remains a non-life-threatening airway disease that impacts QOL, existing QOL measurement scales have never been validated in patients with TBM. This remains an area of interest and ongoing research at BIDMC. As evident in *Table 2*, different QOL scales have been employed in this population including the Modified Medical Research Council Dyspnea Scale (mMRC), Cough Specific Quality of Life Scale (CSQOL), St. George's Respiratory Questionnaire (SGRQ), American Thoracic Society (ATS) dyspnea scale (3,6,8-10). In addition, the Karnofsky Performance Scale has been used as a self-reported functional impairment metric.

Short term self-reported outcomes

Lazzaro *et al.* reported improvement in SGRQ over a median of 2 months (IQR 1-4 months) of follow up in 15 patients (6). Majid *et al.* showed an improvement in

Table 2 Patient reported outcomes after tracheobronchoplasty

First author	Institution	Inclusion years	# patients	Average or median follow up (range)	Improvement of symptoms	Patient-reported scale demonstrating improvement
Bezuidenhout (8)	BIDMC	2003–2016	18	1.5 years	Overall: 14/17 (82%)	–
				6 years	Overall: 11/17 (65%)	–
Ernst (9)	BIDMC	2002–2009	21	–	–	SGRQ, ATS dyspnea scale, KPS
Gangadharan (3)	BIDMC	2002–2009	33	–	–	SGRQ, ATS dyspnea scale, KPS
Lazzaro (6)	LHH	2016–2017	33	13 months (8 to 15.5)	Improved: cough 24/33 (72%), SOB 19/33 (57%), respiratory infections 17/25 (68%), ability to 'move air' 25/35 (71%); satisfaction with the overall results of the procedure: 29/35 (82%)	–
			15	2 months (1 to 4)	–	SGRQ
Majid (10)	BIDMC	2013–2015	13	3 months	Improved: dyspnea 10/13 (77%), cough 11/13 (85%), secretions 5/6 (83%)	mMRC and CQLQ

BIDMC, Beth Israel Deaconess Medical Center (Boston, Massachusetts); LHH, Lenox Hill Hospital (New York, New York). HRQOL, health related quality of life; SOB, shortness of breath; SGRQ, St. George Respiratory Questionnaire; mMRC, modified Medical Research Council; CQLQ, Cough Quality of Life Questionnaire; ATS, American Thoracic Society; KPS, Karnofsky Performance Scale.

the mMRC and CSQOL scales at a mean 3 months of follow up in 13 patients (10). In addition, 11/13 (77%) reported improved dyspnea and 11/13 reported improved cough, 5/6 (83.3%) reported improved ability to clear secretions (10). Gangadharan *et al.* showed an improvement in the Karnofsky performance scale, ATS dyspnea score, and SGRQ quality of life questionnaire (all P>0.001) (3).

Intermediate and longer-term self-reported outcomes

Lazzaro *et al.* noted improvement in self-reported symptoms over a median follow up of 13 months (IQR 8–15.5 months) including cough (24/33, 72%), shortness of breath (19/33, 57%), ability to manage respiratory infections (17/25, 68%), ability to "move air" while breathing (25/35, 71%), and overall satisfaction with the results (29/35, 82%) (6). Bezuidenhout *et al.* reported the intermediate outcomes of 17 patients followed for a mean of 1.5 years and showed that 14/17 (82.3%) had self-reported improvement of symptoms (8). This improvement decreased to 11/17 (64.7%) at a longer term follow up of 6 years (8).

Objective outcomes

While ECAC (TBM) mainly affects the quality of life, finding objective measures to collect that can track the success, failure, durability, and other desired outcome metrics have proven challenging. Several authors have noted that TBM and TBP do not correlate with changes in pulmonary function testing and therefore we will not review these outcomes in this review. We have summarized the most recent literature available in *Table 3*. Interestingly, Lazzaro *et al.* demonstrated statistically significant improvement in median predicted FEV1 (62.5% to 76%; P=0.01), median predicted FVC (69.5% to 84%; P<0.0001), and median predicted peak expiratory flow (60% to 81%; P<0.001) after rTBP. It is unclear if the primary driver is the robotic approach or patient selection, however, finding objective improvement is applauded (6).

The 6-minute walk test (6MWT)

Pulmonary function tests are obvious test measures for respiratory diseases, however the forced expiratory volume

Table 3 Objective outcomes after tracheobronchoplasty

First author	Institution	Operative approach	Inclusion years	# patients	Mean follow up	6MWT improvement	Mean anatomic improvement in percentage collapse on surveillance dynamic airway CT
Bezuidenhout (8)	BIDMC	Thoracotomy	2003–2016	18	1.5 years	50 meters (±98)[†]	Upper trachea: 35% (±21)
							Lower trachea: 33% (±19)
					6 years	20 meters (±131)[†]	Upper trachea: 21% (±20)
							Lower trachea: 21% (±17)
Lazzaro (6)	LHH	Robotic	2016–2017	17	5 months	1.8 meters	–

[†], this outcome was reported for 11 patients. BIDMC, Beth Israel Deaconess Medical Center (Boston, Massachusetts); LHH, Lenox Hill Hospital (New York, New York); CT, computed tomography; 6MWT, 6-minute walk test.

in 1 second (FEV1) does not correlate with the extent of TBM or TBP outcomes (3,11). However, using the 6MWT as a functional surrogate to document improvement in the distance walked after surgery has been described. Bezuidenhout *et al.* showed an increase in the distance walked by an average of 50 meters in the intermediate term (1.5 years) in 11 patients (8). This improvement decreased to 20 meters over a 6-year follow up in the same patient cohort (8). Gangadharan *et al.* reported an increase of 60 meters on average in a series of 63 patients (3). Lazzaro reported an increase in the distance walked by 1.83 meters over a median follow up of 5 months in 11 patients after rTBP (6). The reason for significant difference in the change in 6MWT between operative approaches remains unclear.

Dynamic airway CT and bronchoscopy findings

TBM can be defined with dynamic expiratory CT imaging or dynamic bronchoscopy when there is a >70% reduction in the tracheal luminal cross-sectional area. However, an intervention is typically only considered if the reduction reaches ≥80–90% (3,6,8). A helical CT performed in the craniocaudal dimension can be used to analyze and document this change in the central airway infrastructure. To calculate the percentage of luminal collapse, the cross-sectional area of the airway lumen is measured on end-inspiratory and dynamic expiratory scans by tracing the inner wall of the airway with an electronic tracing tool at standard levels (8,12,13). Although dynamic airway CT is highly sensitive in evaluating severe airway collapse at centers that perform frequent dynamic airway CT scans, deficient coaching or suboptimal respiratory effort during the exam can produce inaccurate results (14).

Monitoring the durability of TBP postoperatively with serial dynamic airway CT scans and/or dynamic bronchoscopy has also been described (8). Bezuidenhout *et al.* were the first to report intermediate (1.5 years) and long term (6 years) clinical and radiographic outcomes in patients that underwent TBP at BIDMC (8). The authors showed that post-operative clinical outcomes correlated with CT findings and degree of recurrent collapsibility after TBP. Over time, patients symptoms remained improved over baseline, but decreased in the long term with reported improvement going from 82% to 65%. In addition, 11 of the patients had serial 6MWTs performed and this showed an increase in the distance walked at 1.5 years of an average of 50 meters (±99 m). This decreased to 20 meters (±131 m) in the long term. These findings suggest that radiographic dynamic airway collapse does correlate with symptom recurrence.

Limitations

This review is limited by the paucity of existing and retrospective data that reflect the experience of 2 single centers. Therefore, outcomes are subject to selection bias and outcomes may not be generalizable.

Conclusions

TBP remains an arduous procedure that is associated with a significant rate of perioperative complications. It is clear that subjective and objective outcome measures improve after TBP in highly selected patients at centers with expertise in TBM. However, outcome reporting after

TBP remains a challenge for several reasons. First, very few centers routinely treat patients with ECAC and are able to follow patients longitudinally. Second, physiological and anatomic assessments provide significant, but limited information of the impact of the disease process on a patient's life and sequalae of central airway stabilization. Specifically, there are no current QOL measurement tools that have been specifically validated in patients with TBM and therefore it is unclear if the scales that have been employed are the best way to capture meaningful patient reported outcome data.

Furthermore, until recently, TBP related outcomes have been published by only 1 center (BIDMC). We are very excited that the team at Lenox Hill Hospital has contributed to the literature and we would invite those performing TBP nationally to also collect and report their data so that we no longer reside in an academic echo chamber. It is unclear how many surgeons or centers in the United States are treating patients with TBM. The paucity of literature from only 2 centers greatly limits our ability to collectively learn and improve patient care.

All of this taken together demonstrates a tremendous opportunity for improvement. Now is a perfect time to review current outcome metrics for TBP so that centers relatively new to treating TBM can track and report their results with the common aim of improving patient care. In order to improve upon the treatment of TBM, it is important that centers collect and track subjective and objective outcome measures so that patient care can be optimized in the future and newer developing treatment modalities can be compared to surgical TBP as the Gold standard. In the future, standardizing follow up protocols and outcome data reporting across institutions could facilitate meaningful advancements in the field.

Acknowledgments

The authors would like to thank Sidhu Gangadharan MD MHCM, Adnan Majid MD, and Mihir Parikh MD for their contribution to this work.
Funding: None.

Footnote

Provenance and Peer Review: This article was commissioned by the Guest Editors (Charles T. Bakhos and Abbas E. Abbas) for the series "Tracheobronchoplasty" published in *Journal of Visualized Surgery*. The article has undergone external peer review.

Reporting Checklist: The authors have completed the Narrative Review reporting checklist. Available at https://jovs.amegroups.com/article/view/10.21037/jovs-21-10/rc

Conflicts of Interest: Both authors have completed the ICMJE uniform disclosure form (available at https://jovs.amegroups.com/article/view/10.21037/jovs-21-10/coif). The series "Tracheobronchoplasty" was commissioned by the editorial office without any funding or sponsorship. The authors have no other conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

1. Abia-Trujillo D, Majid A, Johnson MM, et al. Central Airway Collapse, an Underappreciated Cause of Respiratory Morbidity. Mayo Clin Proc 2020;95:2747-54.
2. Majid A, Kheir F, Alape D, et al. The Prevalence of Gastroesophageal Reflux in Patients With Excessive Central Airway Collapse. Chest 2019;155:540-5.
3. Gangadharan SP, Bakhos CT, Majid A, et al. Technical aspects and outcomes of tracheobronchoplasty for severe tracheobronchomalacia. Ann Thorac Surg 2011;91:1574-80; discussion 1580-1.
4. Shah V, Husta B, Mehta A, et al. Association Between Inhaled Corticosteroids and Tracheobronchomalacia. Chest 2020;157:1426-34.
5. Buitrago DH, Majid A, Alape DE, et al. Single-Center Experience of Tracheobronchoplasty for Tracheobronchomalacia: Perioperative Outcomes. Ann Thorac Surg 2018;106:909-15.
6. Lazzaro R, Patton B, Lee P, et al. First series of minimally

invasive, robot-assisted tracheobronchoplasty with mesh for severe tracheobronchomalacia. J Thorac Cardiovasc Surg 2019;157:791-800.
7. Clavien PA, Barkun J, de Oliveira ML, et al. The Clavien-Dindo classification of surgical complications: five-year experience. Ann Surg 2009;250:187-96.
8. Bezuidenhout AF, Boiselle PM, Heidinger BH, et al. Longitudinal Follow-up of Patients With Tracheobronchomalacia After Undergoing Tracheobronchoplasty: Computed Tomography Findings and Clinical Correlation. J Thorac Imaging 2019;34:278-83.
9. Ernst A, Odell DD, Michaud G, et al. Central airway stabilization for tracheobronchomalacia improves quality of life in patients with COPD. Chest 2011;140:1162-8.
10. Majid A, Alape D, Kheir F, et al. Short-Term Use of Uncovered Self-Expanding Metallic Airway Stents for Severe Expiratory Central Airway Collapse. Respiration Int Rev Thorac Dis 2016;92:389-96.
11. McGinn J, Herbert B, Maloney A, et al. Quality of life outcomes in tracheobronchomalacia surgery. J Thorac Dis 2020;12:6925-30.
12. Boiselle PM, Feller-Kopman D, Ashiku S, et al. Tracheobronchomalacia: evolving role of dynamic multislice helical CT. Radiol Clin North Am 2003;41:627-36.
13. Boiselle PM, O'Donnell CR, Loring SH, et al. Reproducibility of forced expiratory tracheal collapse: assessment with MDCT in healthy volunteers. Acad Radiol 2010;17:1186-9.
14. Buitrago DH, Wilson JL, Parikh M, et al. Current concepts in severe adult tracheobronchomalacia: evaluation and treatment. J Thorac Dis 2017;9:E57-66.

doi: 10.21037/jovs-21-10
Cite this article as: Wilson JL, Wallace JS. Tracheobronchoplasty outcomes: a narrative review. J Vis Surg 2022;8:16.