Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Assessment of Dyspnea in Patients Undergoing Tracheostomy: A Correlation Cohort Study Using the Modified Medical Research Council Scale

Anna Poghosyan

anna.yu.poghosyan@gmail.com

Yerevan State Medical University https://orcid.org/0000-0002-5116-5644

Rafik Shahparonyan

Yerevan State Medical University

Irina Malkhasyan

Yerevan State Medical University

Maya Harutyunyan

Yerevan State Medical University

Martin Misakyan

Yerevan State Medical University

Artur Grigoryan

Yerevan State Medical University

Hayk Petrosyan

Yerevan State Medical University

Khachatur Matosyan

Yerevan State Medical University

Artashes Tadevosyan

Yerevan State Medical University

Aren Bablumyan

Yerevan State Medical University

Armen Minasyan

Yerevan State Medical University

Armen Muradyan

Yerevan State Medical University

Research Article

Keywords: mMRC dyspnea scale, Spirometry, Dyspnea, Tracheal stenosis, Tracheostomy

Posted Date: March 26th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9214908/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: The authors declare no competing interests.

Abstract

Purpose: The aim of this study is to explore the association between patient-reported dyspnea and objective functional and structural airway findings in a post-tracheostomy population, and to compare these relationships between open surgical and percutaneous dilatational tracheostomy.

Methods: The prospective, single-center, observational cohort study included 156 patients evaluated in the late post-tracheostomy period. Dyspnea severity was assessed using modified Medical Research Council (mMRC) scale. All patients underwent spirometry (measuring vital capacity [VC] and FEV1/VC ratio) and neck and chest computed tomography (CT). Patients were divided into two groups based on tracheostomy type: open surgical tracheostomy (OST, n=76) and percutaneous dilatational tracheostomy (PDT, n=80). Associations between mMRC scores, spirometry patterns, and CT-defined tracheal stenosis were analyzed using Spearman correlation and ordinal logistic regression.

Results: Most patients in both groups reported minimal dyspnea (mMRC=0: OST 56.6%, PDT 43.7%). Spirometric abnormalities were observed in both groups without significant intergroup differences. Restrictive patterns were more common in the PDT group; obstructive patterns predominated in the OST group. CT-defined tracheal stenosis was present in 28.0% of OST and 31.3% of PDT patients, with higher-grade stenosis observed only in the PDT group. mMRC scores were significantly associated with spirometric category ($\rho = 0.343$, $p < 0.001$) and CT stenosis grade ($\rho = 0.461$, $p < 0.001$), but not with the FEV_1/VC ratio.

Conclusion: In post-tracheostomy patients, dyspnea severity assessed by the mMRC scale was associated with both functional and structural airway findings. These associations are biologically expected and consistent with observations in other airway diseases, but are demonstrated here in a specific and under-studied post-tracheostomy population. The results should be interpreted as descriptive and exploratory rather than indicative of diagnostic or screening utility.

Clinical trial registration: Trial “Quality of life in patients undergoing tracheostomy” was registered in ISRCTN24668317 (IRB no. YSMU №7/18–19) with date of registration April 23, 2019

Introduction

Dyspnea is a complex subjective symptom affecting quality of life across airway diseases. The modified Medical Research Council (mMRC) scale is widely used to describe activity-related breathlessness due to its simplicity and reproducibility, particularly in chronic airway diseases. [1–12] However, its role in post-tracheostomy patients has not been systematically explored, despite this population presenting unique anatomical and functional airway alterations.

The mMRC dyspnea scale is a five-level rating scale that is based on a patient’s perception of the severity of their breathlessness during daily activities [3–5, 7, 10]. Scores on the mMRC dyspnea scale has consistently been shown to be correlated with spirometry parameters in patients with respiratory

diseases caused by COPD [1, 2, 5]. Furthermore, scores on the mMRC dyspnea scale have been shown to be moderately positively correlated with other dyspnea indicators, including the Baseline Dyspnea Index (BDI) and the Oxygen Cost Diagram [1]. Despite the fact, that tracheostomy is a life-threatening procedure and as well the most frequently performed surgical procedure in intensive care units for patients under prolonged mechanical ventilation, it has the procedure related late complications like tracheal stenosis. In terms of its early diagnosis, the tracheal stenosis associated dyspnea has not been sufficiently investigated. The neck computed tomography scanning (CT scans) and bronchoscopy are the main methods for tracheal stenosis diagnostic. However they have some limitations for purpose of post-tracheostomy tracheal stenosis revealing standard examination, considering the cost related issues and CT scan related radiation. Although associations between dyspnea severity, spirometric abnormalities, and airway narrowing have been described in various obstructive and restrictive airway diseases, such relationships have not been systematically examined in patients following tracheostomy. This population represents a distinct clinical context, characterized by prior prolonged mechanical ventilation, airway instrumentation, and procedure-related structural changes that may influence symptom perception and respiratory function. The present study therefore focuses on characterizing the relationship between subjective breathlessness and objective airway findings specifically in post-tracheostomy patients. The aim was to compare outcomes between tracheostomy techniques and to explore associations between dyspnea severity, spirometry, and CT-defined airway changes in this context.

Materials and methods

This prospective, single-center, observational, cohort study was conducted from May 2019 to March 2020. Data were collected from patients in the ENT and Maxillofacial Surgery Department of Yerevan State Medical University, Yerevan, Armenia. The study protocol was approved by the Ethics Committee of Yerevan State Medical University, and the overarching trial “Quality of life in patients undergoing tracheostomy” was registered in ISRCTN24668317 (IRB no. YSMU №7/18–19) on April 23, 2019 [13, 14]. Dyspnea assessment was one of the primary outcomes in this trial. The feasibility of mMRC and the diagnostic value of the mMRC compared to spyrometry and neck CT scan were observed. Written informed consent was obtained from all participants after they received written and oral information about the study. One hundred fifty-six individuals in the late post-tracheostomy period (i.e., at least one month after cannulation) were assessed via the mMRC Dyspnea Scale. These patients also underwent spirometry and neck and chest CT scans. The post-tracheostomy follow-up duration ranged from 12 to 84 months, with an average time of 39.6 months. Patients who underwent tracheostomy in the intensive care unit (ICU) of Heratsi University Hospital from January 2013 to December 2018 were eligible for inclusion. The most common indication for tracheostomy was long-term mechanical ventilation. The exclusion criteria were as follows: (1) patients who underwent emergency tracheostomy, (2) patients with a previous history of neck trauma and scarring, (3) patients with a history of radiotherapy, (4) patients with keloid or hypertrophic scar history, and (5) patients with autoimmune diseases [13, 14].

Of the 156 recruited individuals, 76 underwent minimally invasive OST (Group 1), and 80 underwent PDT (Group 2). The mean age of the entire cohort was 54.7 years (range, 16–87 years), with a male-to-female ratio of 2:1 [13, 14]. The age and sex distribution of persons undergoing tracheostomy is presented in Fig. 1.

The mMRC dyspnea scale

To assess respiratory function impairment (i.e., dyspnea), the mMRC Dyspnea Scale was completed by patients in person. The mMRC Dyspnea Scale quantitatively assesses disability associated with dyspnea and is useful for characterizing baseline dyspnea in patients with respiratory diseases. However, the mMRC Dyspnea Scale does not provide an accurate quantitative assessment of the etiology of dyspnea (e.g., tracheal stenosis, COPD) and is not a reliable measurement of the patient's efforts to differentiate whether dyspnea is associated with pulmonary diseases or behavioral reactions to disability. Scores on these indicators reflect patients' perceptions of the duration of respiratory symptoms or disease severity and provide a foundational assessment of functional impairments related to dyspnea induced by respiratory diseases. The mMRC Dyspnea Scale consists of a five-point questionnaire ranging from 0 to 4: 0, no breathlessness except for strenuous exercise; 1, shortness of breath when hurrying on a flat surface or walking up a slight hill; 2, walks slower than people of the same age on a flat surface because of breathlessness or has to stop to catch breath when walking at their own pace on a flat surface; 3, stops due to breathlessness after walking ∼100 m or after a few minutes on a flat surface; and 4, too breathless to leave the house or breathless when dressing or undressing [14]. A score of 4 represents the most severe level of dyspnea. After learning about the questionnaire, patients circled the item that they felt best represented their condition.

The spirometry

Spirometry is a noninvasive method for measuring airflow and volume over a temporal scale via forced maneuvers. The most common indication for conducting spirometry is the diagnosis of airway obstruction. In obstructive disorders, there is a reduction in expiratory flow, the pathophysiological basis of which is an increase in airway resistance. In most cases, the severity of obstructive disorders is assessed by the degree of deviation of FEV1 (from the expected value. Spirometry was performed via a Flow Screen Pro spirometer (Jaeger, Germany). The device provides precise measurements of respiratory flow and lung capacity. Due to the use of advanced sensors and algorithms, the device offers invaluable insights into pulmonary function, thus enabling the assessment of conditions such as asthma, chronic obstructive pulmonary disease (COPD), and restrictive lung diseases with unprecedented accuracy. Spirometry parameters such as forced vital capacity (FVC) and forced expiratory volume in one second (FEV1) enable informed decisions regarding the diagnosis, treatment, and ongoing management of dyspnea. FVC is the maximum capacity of air that a patient can exhale after a maximum inspiration and FEV 1 is the volume of air exhaled in the first second of a forced exhalation. Furthermore, lung volume can be measured in two ways. In the first method, the volume of

inhaled or exhaled air (inspiratory and expiratory reserve volume, respectively) and time are measured directly, thereby generating a graph that depicts the relationship between lung volume and time—this "volume–time" curve is called a spirogram. In the second method, flow and time are measured, and lung volume is calculated by multiplying flow by time, resulting in a graph that depicts the relationship between the volumetric flow rate and lung volume, i.e., a "flow–volume" curve. Thus, both curves reflect the same parameters: the integral expression of airflow velocity yields volume, which can, in turn, be represented as a function of time. Conversely, the volume of exhaled air can be differentiated with respect to time to determine the flow velocity. The presentation of spirometry results as a flow–volume curve provides the simplest and most informative interpretation. Spirometry can be conducted during both quiet and forced breathing. Vital capacity (VC), i.e., the maximum volume of air that can be inhaled or exhaled is the primary parameter obtained during spirometry under resting conditions. The forced expiratory maneuver is used to measure forced vital capacity (FVC), volumetric airflow rate parameters (e.g., FEV1, the FEV1/FVC ratio, and flow rates at 25–75% of the FVC), and maximum volumetric flow rates at 25%, 50%, and 75% of the FVC. The interpretation of spirometry results was based on an analysis of key spirometry parameters (FEV1, VC, and the FEV1/VC ratio % SOLL). The volume of air exhaled in the first second represents a relatively constant fraction of the FVC, regardless of the lung size. In healthy individuals, this ratio is usually 75–85%, but it tends to decrease with age, as the expiratory flow rate decreases more significantly than the lung volume does. In obstructive disorders, the FEV1/FVC ratio decreases as FEV1 decreases as the severity of obstruction increases. FVC also decreases as the severity of obstruction increases, but the association is weaker. In cases of pulmonary restriction without obstructive changes, both the FEV1 and FVC decrease proportionately, resulting in the ratio remaining within normal limits or even slightly above normal limits. Thus, to differentiate between obstructive and restrictive disorders, the FEV1/FVC ratio (VC, FEV1, FEV%) is evaluated.

Computer tomography (CT) of the neck and chest

Considering that spirometry only reflects the state of respiratory function at the time of the examination, it is not possible to objectively determine whether patients had respiratory function abnormalities prior to tracheostomy or if they developed abnormalities after the procedure, e.g., due to fibrotic changes in the soft tissues surrounding the tracheostomy window following decannulation. Expiratory restrictive phenomena may be associated with tracheal stenosis or may be induced by interstitial inflammation of lung tissue, pulmonary atelectasis, and other factors. Consequently, patients diagnosed with restrictive disorders or tracheal stenosis based on spirometry findings subsequently underwent spiral computed tomography (CT) of the neck and chest. Imaging was performed via a multislice scanner, the Light Speed VCT 64 (General Electric, USA), with the following technical parameters: collimation – 8 × 1.5 mm, overlap – 0.6 mm, rotation time – 0.5 sec, 220 mA, and 120 kVp. Patients were placed in a supine position on the CT table, with images obtained in the cranio-caudal direction from the soft palate to the right dome of the diaphragm. The data acquisition time was approximately 6 s, allowing for the completion of the study within a single breath hold. The raw images were transferred to a computer workstation (Advantage Windows 4.0; GEMS, USA). Standard software for reconstruction was used for

virtual 3D imaging. Additionally, standard reformatted coronal and sagittal images of the trachea were obtained. CT images were evaluated by experienced radiologists who were blinded to patients' clinical symptoms, mMRC scores, and spirometry results at the time of assessment. Formal inter-observer reliability analysis was not performed; however, all cases of suspected stenosis were reviewed by consensus to minimize classification discrepancies.

Potential causes of tracheal stenosis in tracheostomies include ulceration of the tracheal mucosa or inflammation of the tracheal wall, which lead to the formation of granulation tissue, in turn resulting in stenosis. Such stenosis most frequently occurs at the level of the tracheostomy tube cuff, followed by the stoma formation area and, to a lesser extent, at the distal end of the tracheostomy tube. The main etiological factors include chronic trauma from prolonged tracheostomy and perichondritis. To diagnose and assess the degree of tracheal stenosis, coronal and sagittal CT sections were evaluated. The normal tracheal wall thickness is 1–2 mm. Concentric or eccentric tracheal narrowing in cases of tracheal stenosis typically ranges from 1.5 to 2.5 cm in length. In cases of tracheal stenosis, granulation soft tissue is often observed medial to the tracheal cartilage structures. The degree of tracheal stenosis was evaluated via the Cotton–Myer classification grading system, which is widely used to describe subglottic stenosis according to the percent area of obstruction (grade I: 0% to 50%, grade II: 51% to 70%, grade III: 71% to 99%, grade IV: full obstruction).Although originally developed for subglottic stenosis, this classification is commonly applied in adult tracheal stenosis and post-interventional airway narrowing due to its simplicity, reproducibility, and clinical familiarity. Its use in this study was intended to provide a standardized descriptive framework rather than to imply prognostic or therapeutic thresholds. The correlation between mMRC, Dyspnea Scalle scores and CT findings were performed.

Statistical analysis

Statistical analysis was performed via SPSS software version 16.0 (SPSS Inc., Chicago, IL, USA). Continuous variables were checked for normality using the Shapiro-Wilk test. Variables that showed non-normal distribution were summarized using medians and interquartile ranges (IQRs), while categorical variables were summarized as frequencies and percentages. Differences in dyspnea severity measured by the mMRC were evaluated using the Mann-Whitney U test. The FEV_1/VC ratio, which demonstrated non-normal distribution, was also compared between groups using the Mann–Whitney U test. Differences in categorical variables, including spirometry categories and CT-based tracheal stenosis grades, were assessed using the Pearson's chi-square test.The Spearman rank correlation analysis was used to obtain bivariate correlation coefficients. Correlation analyses were performed between mMRC dyspnea scores and spirometry category, CT-based tracheal stenosis grade, and the FEV_1/VC ratio. Ordinal logistic regression was performed to identify independent predictors of dyspnea severity with the mMRC score used as the dependent variable. The independent variables were tracheostomy technique, spirometry category, CT-based stenosis, and the FEV1/VC ratio. The logit link function was used, and the proportional odds assumption was evaluated using the test of parallel lines. Model fit was assessed using likelihood ratio tests and goodness-of-fit statistics. Regression results were reported as regression

coefficients (β), odds ratios (ORs), and corresponding p-values. All statistical tests were two-tailed and a p value of < 0.05 was considered to indicate statistical significance.

Results

Demographic information of the participants of the study is similar to the previously published by Shahparonyan et al. [13]. The results of the analysis of the mMRC Dyspnea Scale showed no statistically significant difference between the groups (p-0.210) and indicated that the majority of patients in the ST (43; n = 76) and the PDT groups (35; n = 80) had a score of zero on the scale, corresponding to the statement "I experience dyspnea only with strenuous exercise" (Table 1).

Table 1
Comparative analysis of mMRC Dyspnea Scale ratings based on tracheostomy method

Variable		OST Group (n, %)	PDT Group (n, %)	p-value
mMRC score	0	43 (56.6%)	35 (43.7%)	0.210
	1	20 (26.3%)	30 (36.3%)	
	2	5 (6.6%)	9 (12.5%)	
	3	4 (5.3%)	3 (3.8%)	
	4	4 (5.3%)	3 (3.8%)	
Spirometry category	No abnormality	37 (48.7%)	44 (55.0%)	0.463
	Restrictive type 1	13 (17.1%)	11 (13.8%)	
	Restrictive type 2	6 (7.9%)	4 (5.0%)	
	Obstructive type 1	18 (23.7%)	20 (25%)	
	Obstructive type 2	2 (2.6%)	1 (1.3%)	
FEV_1/VC ratio median (IQR)		105.35 (10.0)	93.95 (25.1%)	< 0.001
CT stenosis grade	No stenosis	55 (72.4%)	60 (75.0%)	-
	Grade I	21 (27.6%)	12 (15.0%)	
	Grade II	0 (0.0%)	4 (5.0%)	
	Grade III	0 (0.0%)	4 (5.0%)	
		76 (100%)	80 (100%)	

Values are presented as n (%) unless otherwise indicated.

p-values are shown only for main outcome comparisons between procedures.

Demographic characteristics were similar between groups and have been previously reported (Shahparonyan et al. [13]).

Non-parametric tests were used where appropriate due to non-normal distributions.

Among patients undergoing open surgical tracheostomy, 37 patients (48.7%) demonstrated no spirometric abnormalities. Restrictive patterns were identified in 19 patients (25.0%), while obstructive patterns were observed in 20 patients (26.3%), including 2 patients (2.6%) with obstructive type 2 disorder. In the percutaneous dilatational tracheostomy group, 44 patients (57.9%) had no spirometric abnormalities. Restrictive type 1 disorder was present in 11 patients (14.5%), while obstructive patterns were identified in 21 patients (27.6%), including 1 patient (1.3%) with obstructive type 2 disorder (Table 1). Moreover, the distribution of spirometry categories did not differ significantly between patients undergoing open surgical tracheostomy and those undergoing percutaneous dilatational tracheostomy.

Pearson's chi-square test demonstrated no statistically significant association between tracheostomy technique and spirometric pattern ($\chi^2 = 7.21$, $p = 0.125$). Similarly, no significant linear trend across spirometry categories was observed ($p = 0.463$).

The FEV_1/VC ratio demonstrated wide variability in both groups. Normality testing using the Shapiro–Wilk test showed that the FEV_1/VC ratio was not normally distributed in either the OST or PDT group ($p < 0.001$ for both), and non-parametric methods were therefore applied. Median FEV_1/VC values were 105.35 (IQR 10.0) in the OST group and 93.95 (IQR 25.1) in the PDT group.

Among patients undergoing open surgical tracheostomy, the majority demonstrated no radiological stenosis (55 patients, 72.4%) or grade I stenosis (21 patients, 27.6%), with no cases of grade II or grade III stenosis observed. In contrast, patients undergoing percutaneous dilatational tracheostomy exhibited a broader distribution of stenosis severity, including grade II stenosis in 4 patients (5.0%) and grade III stenosis in 4 patients (5.0%), in addition to no stenosis (60 patients, 75.0%) and grade I stenosis (12 patients, 15.0%). The distribution of CT-based tracheal stenosis grades differed significantly between tracheostomy techniques (Table 1). Pearson's chi-square analysis demonstrated a statistically significant association between type of tracheostomy and stenosis grade ($\chi^2 = 10.576$, $p = 0.014$).

Correlation analyses demonstrated significant associations between dyspnea severity and both functional and structural measures. A statistically significant positive correlation was observed between spirometry category and mMRC dyspnea score (Spearman's $\rho = 0.343$, $p < 0.001$), indicating higher dyspnea severity with worsening spirometric abnormalities. Dyspnea severity also demonstrated a moderate positive correlation with CT-based tracheal stenosis grade (Spearman's $\rho = 0.461$, $p < 0.001$). In contrast, no statistically significant correlation was observed between the FEV_1/VC ratio and mMRC dyspnea score (Spearman's $\rho = 0.048$, $p = 0.554$) (Table 2). In unadjusted analyses, mMRC dyspnea severity correlated significantly with spirometry category and CT-based tracheal stenosis, but not with the FEV_1/VC ratio. In adjusted ordinal regression models, spirometry category and CT stenosis grade remained independently associated with dyspnea severity, whereas the FEV_1/VC ratio and tracheostomy technique were not (Table 3).

Table 2
Unadjusted associations between mMRC dyspnea score and functional/structural measures

Variable	Spearman's ρ	p-value
Spirometry category	0.343	< 0.001
CT stenosis grade	0.461	< 0.001
FEV_1/VC ratio	0.048	0.554
Unadjusted associations were assessed using Spearman's rank correlation coefficient.		

Table 3
Unadjusted and adjusted associations between dyspnea severity (mMRC) and functional/structural measures

Predictor	Unadjusted association (Spearman's ρ)	p-value	Adjusted association (Ordinal regression OR, 95% CI)	p-value
Spirometry category	0.343	< 0.001	1.49 (1.17–1.89)	0.001
CT stenosis grade	0.461	< 0.001	4.26 (2.53–7.18)	< 0.001
FEV_1/VC ratio	0.048	0.554	1.01 (0.99–1.03)	0.518
Tracheostomy type	—	—	0.68 (0.34–1.37)	0.282

Unadjusted associations were assessed using Spearman's rank correlation. Adjusted associations were estimated using ordinal logistic regression with mMRC dyspnea score as the dependent variable, accounting for the ordinal nature of the outcome. Odds ratios represent the change in odds of higher dyspnea severity. The proportional odds assumption was satisfied.

Discussion

Dyspnea is a well-recognized determinant of quality of life and functional limitation across a wide range of airway diseases, and its association with spirometric impairment and structural airway changes is biologically plausible and well documented [1–3, 15]. The contribution of this study lies in demonstrating that these expected relationships are preserved in patients following tracheostomy, a population in whom dyspnea assessment is often challenging due to heterogeneous comorbidities, prior critical illness, and procedure-related airway alterations.

Previous studies in obstructive and restrictive airway diseases have demonstrated associations between dyspnea severity, spirometric impairment, and structural airway changes. [1–12] The present findings align with this existing body of evidence but extend it to the post-tracheostomy setting, where symptom interpretation is complicated by prior critical illness, airway instrumentation, and heterogeneous comorbidities.

Although tracheostomy is a lifesaving procedure that is widely used in intensive care units worldwide for patients undergoing prolonged mechanical ventilation, there is a lack of literature specifically addressing the quality of life of patients who have undergone tracheostomy. The presented study has its aim to open one of the undisclosed states of persons who undergo tracheostomy in some stage of their life- the dyspnea emersion, his early diagnostic for further treatment. From a clinical perspective, the relevance of these findings lies in the potential role of patient-reported dyspnea as an initial descriptive marker rather than a diagnostic tool. In post-tracheostomy patients, routine spirometry or CT imaging is not always feasible or justified. Within this context, the mMRC scale may assist clinicians in identifying individuals who warrant further structural or endoscopic evaluation, while acknowledging that such use remains exploratory. Therefore, patient-reported dyspnea assessment using instruments such as the

mMRC scale may serve as a descriptive measure of symptom burden. In the present study, mMRC scores were examined in relation to spirometric findings and CT-based tracheal stenosis to explore potential associations rather than to establish diagnostic or clinical utility.

Some previous studies have examined potential aesthetic and functional impairments among patients who have undergone tracheostomy; however, no studies have comprehensively examined functional impairments such as dyspnea, dysphagia, and voice changes after tracheostomy and their impact on quality of life [13, 16]. Our previous clinical trial < < Quality of life in patients undergoing tracheostomy>> (ISRCTN24668317) examined the influence of post-tracheostomy scars on quality of life [13, 14]. The present study focused on the manifestations of dyspnea and the methods of assessing dyspnea among patients who have undergone tracheostomy. Dyspnea is a complex subjective sensation that is common and usually debilitating in patients with COPD; furthermore dyspnea is an important predictor of exercise tolerance [17]. The mMRC Dyspnea Scale classifies the impairments associated with breathlessness by asking respondents to assess activities that induce or are restricted by breathlessness [2–4, 8, 18, 19]. In the present study, 156 persons who underwent OST or PDT at least 4 months before enrollment completed dyspnea assessments via the mMRC Dyspnea Scale, spirometry, and neck and chest CT scans. The results of the analysis of the mMRC Dyspnea Scale revealed that more than half of the patients in each groups reported some level of breathlessness during their everyday activities. However, it should be noted that in the present study, the assessment of breathlessness was not performed in a group of patients with the identical health conditions, such as COPD, obesity, tuberculosis, and pulmonary fibrosis. Instead, this assessment was performed among a group of patients who underwent an identical intervention – i.e., tracheostomy due to prolonged mechanical ventilation in the ICU. In this context, it is essential to examine the correlations of the mMRC Dyspnea Scale with spirometry and CT findings in order to understand the real cause of dyspnea. Several studies have explored the correlation between scores on the mMRC Dyspnea Scale and spirometry results. These studies have indicated that the mMRC Dyspnea Scale is often found to correlate with spirometry measures such as FEV1 [5, 20–22]. Patients reporting higher levels of dyspnea (higher mMRC scores) usually have lower FEV1 values, indicating worse lung function [5, 10, 20, 21]. Some studies have reported variations in the correlation based on the population studied (e.g., age, sex, comorbidities), with the mMRC Dyspnea Scale sometimes being more reflective of a patient's perceived health status than spirometry parameters [22–24]. COPD is the main pathology that was investigated in the abovementioned studies. In the present study, a positive correlation between spirometry measures and mMRC Dyspnea Scale scores was observed in 45 patients (59.2%; n = 76) in the OST group and in 54 patients (67.5%; n = 80) in the PDT group. The majority of the individuals in both groups exhibited no discernible impairments in terms of external respiratory function according to the spirometry parameters. The changes indicative of obstructive syndrome were slightly more prevalent in the OST group, whereas restrictive insufficiency due to tracheal stenosis predominated in the PDT group. However, spirometry findings do not adequately reflect all of the manifestations of the disease, and other factors need to be accounted for in its diagnosis and management. Current guidelines emphasize the importance of multiple assessments in addition to the severity of airflow limitation [7]. The correlation between airflow limitation, which is

evaluated via spirometry, and the corresponding airway diameter, which is measured via computed tomography, is still under investigation [23]. Karayama et al. [24] reported that FEV1 was correlated with both the airway inner luminal area and the wall thickness. Yasui et al. [7] investigated the correlation between the mMRC Dyspnea Scale score and airway structure via quantitative CT measurements in patients with COPD. The authors concluded that the mMRC Dyspnea Scale was correlated with the airway wall of sixth-generation bronchi in patients with COPD. Usuba et al. [25] investigated correlations between the cross-sectional area (CSA) of the trachea and spirometry values in patients with relapsing polychondritis. They reported that the tracheal CSA measured via chest CT is strongly correlated with spirometry parameters and can thus be used as a clinical predictor of lung function in patients with RP. Alrabiah et al. [26] evaluated the relationship between tracheal stenosis severity and pre- and post-balloon dilatation spirometry parameters to assess for significant changes in spirometry values and to evaluate the effects of stenosis-associated factors on post-dilation spirometry values, including the vertical length and grade of the stenosis, as well as the role of wound-modifying agents. Mahros et al. [23] evaluated the possible correlations of forced expiratory volume in the first second (FEV1%), forced vital capacity (FVC%), FEV1/FVC, and peak expiratory flow 25–75% (PEF 25–75%) with the diameter of the airway at 3 different levels via CT. The authors found a significant and positive correlation between the CT-detected airway luminal area at the expiratory stage of respiration and the FEV1%, whereas at the inspiratory phase, there was no positive correlation. The present study revealed that mMRC Dyspnea Scale scores of 0 were weakly and positively correlated with spirometry findings in both groups and strongly and positively correlated with the CT scan results. Additionally, a strong positive correlation was observed between mMRC Dyspnea Scale scores of 4 and the spirometry and CT scan results. This study reported that 28% (n = 76) of the patients in the OST group and 31.25% (n = 80) of those in the PDT group experienced post-trracheostomy stenosis. Cases of advanced stenosis (grade III), which require some invasive interventions, were observed in two patients (2.5%) in the PDT group. This finding largely consistent with those reported by Bibas et al. [27], who found that up to 20% to 30% of patients with tracheostomy had tracheal stenosis, with severe stenosis being observed in 1% to 7% of cases, thus indicating the need for invasive procedures.

Study limitations:

This study has several limitations that should be considered when interpreting the findings. It’s a single-center design, which may limit the generalizability of the findings to broader populations. The relatively modest sample size, particularly within subgroups, may limit the power to detect smaller associations or differences. Future multicenter studies with larger, more diverse cohorts and longitudinal follow-up are needed to validate and expand upon these findings.

A major limitation of this study is the presence of baseline pulmonary comorbidities, including chronic obstructive pulmonary disease, obesity-related respiratory impairment, pulmonary fibrosis, and post-tuberculosis sequelae, all of which may independently influence dyspnea severity. Although tracheostomy was the shared intervention among participants, heterogeneity in underlying pulmonary

conditions limits the ability to attribute dyspnea exclusively to post-tracheostomy airway changes. Due to sample size constraints and incomplete comorbidity stratification, additional adjustment or subgroup analyses were not feasible. Consequently, the observed associations should be interpreted as descriptive and non-causal.

Conclusion

In this cohort of post-tracheostomy patients, dyspnea severity assessed by the mMRC scale was significantly associated with both spirometric findings and CT-defined tracheal stenosis. These results demonstrate alignment between subjective symptom reporting and objective functional and structural airway measures. Restrictive spirometric patterns and higher grades of tracheal stenosis on CT were more frequently observed in PDT group, while obstructive patterns were more prevalent in the OST group. While such relationships are biologically expected in airway disease, this study demonstrates their relevance specifically in the post-tracheostomy setting, an under-studied population with complex and heterogeneous respiratory complaints. Given the observational design, these results should not be interpreted as evidence of clinical usefulness. Further longitudinal and interventional studies are necessary to determine whether these associations translate into clinically meaningful applications.

Declarations

Funding

“This study was not supported by any funding.”

Conflict of interest

“The authors declare that they have no conflicts of interest.”

Ethical approval

“All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.”

The study protocol was approved by the **Institutional Review Board (IRB)** of Yerevan State Medical University (IRB no. YSMU №7/18–19).

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Consent for publication

Consent for publication was obtained for every individual person’s data included in the study.

Availability of data and materials

Data available from the corresponding author upon reasonable request

Code availability

Not applicable.

Author contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by R.S, M.H., Kh.M, A.S., A.G., A.T., M.M. and I.M. The first draft of the manuscript was written by A. P. and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

References

1. Chhabra SK, Gupta AK, Khuma MZ (2009) Evaluation of three scales of dyspnea in chronic obstructive pulmonary disease. Ann Thorac Med 4:128–132. https://doi.org/10.4103/1817-1737.53351
2. Launois C, Barbe C, Bertin E, Nardi J, Perotin JM, Dury S, Lebargy F, Deslee G (2012) The modified Medical Research Council scale for the assessment of dyspnea in daily living in obesity: a pilot study. BMC Pulm Med 12:61. https://doi.org/10.1186/1471-2466-12-61
3. Hsu KY, Lin JR, Lin MS, Chen W, Chen YJ, Yan YH (2013) The modified Medical Research Council dyspnoea scale is a good indicator of health-related quality of life in patients with chronic obstructive pulmonary disease. Singapore Med J 54:321–327. https://doi.org/10.11622/smedj.2013125
4. Mahler DA, Wells CK (1988) Evaluation of clinical methods for rating dyspnea. Chest 93:580–586. https://doi.org/10.1378/chest.93.3.580
5. Perez T, Burgel PR, Paillasseur JL, Caillaud D, Deslée G, Chanez P, Roche N (2015) Modified Medical Research Council scale vs Baseline Dyspnea Index to evaluate dyspnea in chronic obstructive pulmonary disease. Int J Chron Obstruct Pulmon Dis 10:1663–1672. https://doi.org/10.2147/copd.s82408
6. Celli BR, Cote CG, Marin JM, Casanova C, De Oca MM, Mendez RA, Plata VP, Cabral HJ (2004) The body-mass index, airflow obstruction, dyspnea, and exercise capacity index in chronic obstructive pulmonary disease. N Engl J Med 350:1005–1012. https://doi.org/10.1056/NEJMoa021322
7. Yasui H, Inui N, Karayama M, Mori K, Hozumi H, Suzuki Y, Furuhashi K, Enomoto N, Fujisawa T, Nakamura Y, Watanabe H, Suda T (2019) Correlation of the modified Medical Research Council dyspnea scale with airway structure assessed by three-dimensional CT in patients with chronic obstructive pulmonary disease. Respir Med 146:76–80. https://doi.org/10.1016/j.rmed.2018.11.020

8. Bestall JC, Paul EA, Garrod R, Garnham R, Jones PW, Wedzicha JA (1999) Usefulness of the Medical Research Council (MRC) dyspnoea scale as a measure of disability in patients with chronic obstructive pulmonary disease. Thorax 54:581–586. https://doi.org/10.1136/thx.54.7.581.
9. Nishiyama O, Taniguchi H, Kondoh Y, Kimura T, Kato K, Kataoka K, Ogawa T, Watanabe F, Arizono S (2010) A simple assessment of dyspnoea as a prognostic indicator in idiopathic pulmonary fibrosis. Eur Respir J 36:1067–1072. https://doi.org/10.1183/09031936.00152609
10. Sunjaya A, Poulos L, Reddel H, Jenkins C (2022) Qualitative validation of the modified Medical Research Council (mMRC) dyspnoea scale as a patient-reported measure of breathlessness severity. Respir Med 203:106984. https://doi.org/10.1016/j.rmed.2022.106984
11. Lerum TV, Aaløkken TM, Brønstad E et al. (2021) Dyspnoea, lung function and CT findings 3 months after hospital admission for COVID-19. Eur Respir J 57:2003448. https://doi.org/10.1183/13993003.03448-2020
12. Gupta MB, Bagri S, Garg A, Singh DK, Choudhary P, Sahni S (2022) Pulmonary function in cured pulmonary tuberculosis cases. Indian J Tuberc 69:535–538. https://doi.org/10.1016/j.ijtb.2021.08.024
13. Shahparonyan RG, Poghosyan AY, Minasyan AM, Bablumyan AY, Malkhasyan IE, Gnuni AS, Matosyan KH, Sargsyan AM, Tadevosyan AE, Muradyan AA (2023) Evaluation of post-tracheostomy scars and their impact on persons' quality of life: a case-control study. Int Wound J 20:372–380. https://doi.org/10.1111/iwj.13885
14. ISRCTN (2023) Quality of life in patients undergoing tracheostomy. ISRCTN24668317. https://doi.org/10.1186/ISRCTN24668317
15. Yorke J, Khan N, Garrow A, Tyson S, Singh D, Vestbo J, Jones PW (2022) Evaluation of the individual activity descriptors of the mMRC breathlessness scale: a mixed method study. Int J Chron Obstruct Pulmon Dis 17:2289–2299. https://doi.org/10.2147/copd.s372318
16. Bausewein C, Farquhar M, Booth S, Gysels M, Higginson IJ (2007) Measurement of breathlessness in advanced disease: a systematic review. Respir Med 101:399–410. https://doi.org/10.1016/j.rmed.2006.07.003
17. Rajala K, Lehto JT, Sutinen E, Kautiainen H, Myllärniemi M, Saarto T (2017) mMRC dyspnoea scale indicates impaired quality of life and increased pain in patients with idiopathic pulmonary fibrosis. ERJ Open Res 3:00084–2017. https://doi.org/10.1183/23120541.00084-2017
18. Adetiloye AO, Akor AA, Awopeju OF, Adewole OO, Adewuya OA, Erhabor GE (2023) Effect of chronic obstructive pulmonary disease severity on inspiratory flow rates via inhaler devices. West Afr J Med 40:989–996.
19. Ouaalaya EH, Falque L, Dupis JM, Sabatini M, Bernady A, Nguyen L, Ozier A, Nocent-Ejnaini C, Le Guillou F, Molimard M, Raherison-Semjen C (2021) The determinants of dyspnoea evaluated by the mMRC scale: the French Palomb cohort. Respir Med Res 79:100803. https://doi.org/10.1016/j.resmer.2020.100803

20. Rhee CK, Kim JW, Hwang YI, Lee JH, Jung KS, Lee MG, Yoo KH, Lee SH, Shin KC, Yoon HK (2015) Discrepancies between modified Medical Research Council dyspnea score and COPD assessment test score in patients with COPD. Int J Chron Obstruct Pulmon Dis 10:1623–1631. https://doi.org/10.2147/copd.s87147
21. Burgel PR, Escamilla R, Perez T, Carré P, Caillaud D, Chanez P, Pinet C, Jebrak G, Brinchault G, Court-Fortune I, Paillasseur JL, Roche N (2013) Impact of comorbidities on COPD-specific health-related quality of life. Respir Med 107:233–241. https://doi.org/10.1016/j.rmed.2012.10.002
22. Jin X, Yang Y, Chen G, Shao Y, Liu C, Li R, Liu Y, Zhang L (2024) Correlation between body composition and disease severity in patients with chronic obstructive pulmonary disease. Front Med (Lausanne) 11:1304384. https://doi.org/10.3389/fmed.2024.1304384
23. Mahros M, Hosny H, Ismail A, Moussa H (2020) Airflow limitation: is there a correlation between spirometry and quantitative computed tomography measurements in patients with chronic obstructive pulmonary disease? Egypt J Bronchol 14:8. https://doi.org/10.1186/s43168-020-00011-4
24. Karayama M, Inui N, Mori K et al. (2017) Respiratory impedance is correlated with morphological changes in the lungs on three-dimensional CT in patients with COPD. Sci Rep 7:41709. https://doi.org/10.1038/srep41709
25. Usuba A, Yamashiro T, Handa H, Matsuoka S, Yamano Y, Mineshita M, Miyazawa T (2015) Quantitative computed tomography measurement of tracheal cross-sectional areas in relapsing polychondritis: correlations with spirometric values. Respiration 90:468–473. https://doi.org/10.1159/000441303
26. Alrabiah A, Almohanna S, Aljasser A, Zakzouk A, Habib SS, Almohizea M, Bukhari M, Alammar A (2022) Utility of spirometry values for evaluating tracheal stenosis patients before and after balloon dilation. Ear Nose Throat J 101:NP62–NP67. https://doi.org/10.1177/0145561320936968
27. Bibas BJ, Cardoso PFG, Hoetzenecker K (2020) The burden of tracheal stenosis and tracheal diseases health-care costs in the 21st century. Transl Cancer Res 9:2095–2096. https://doi.org/10.21037/tcr.2020.02.59

Figures

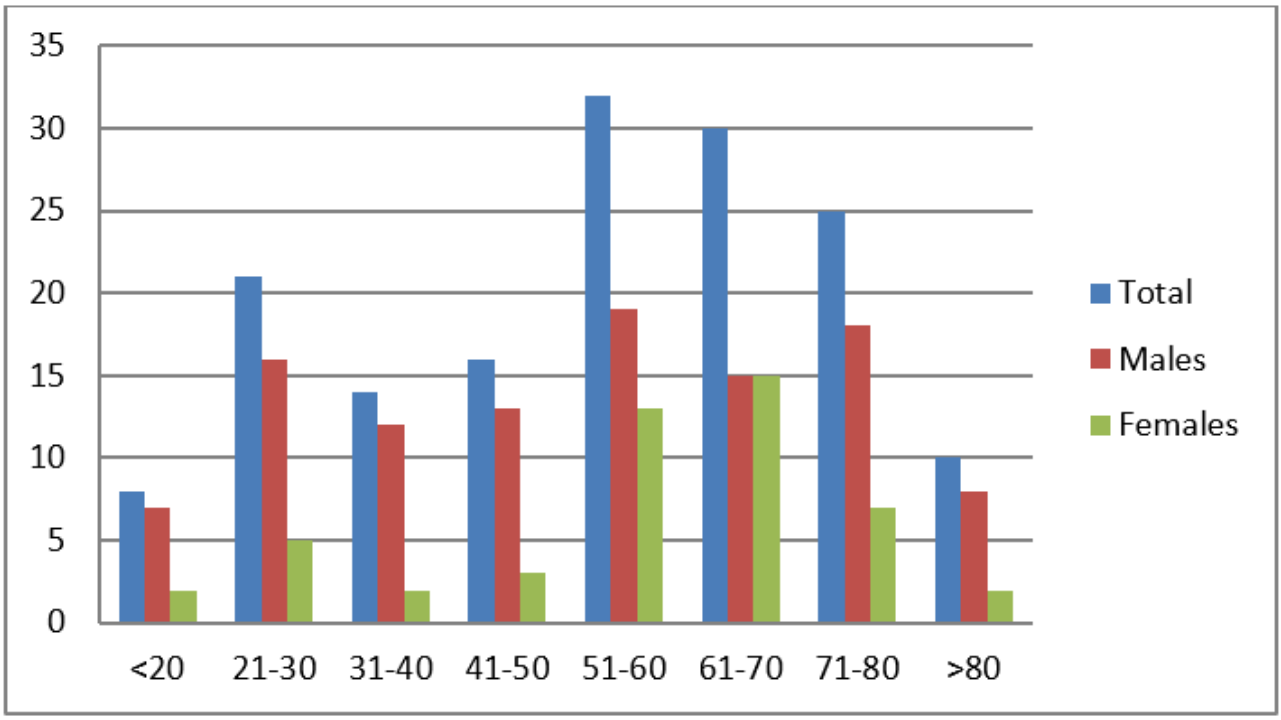


Fig.1

Figure 1

Age and sex distribution of recruited persons undergoing tracheostomy

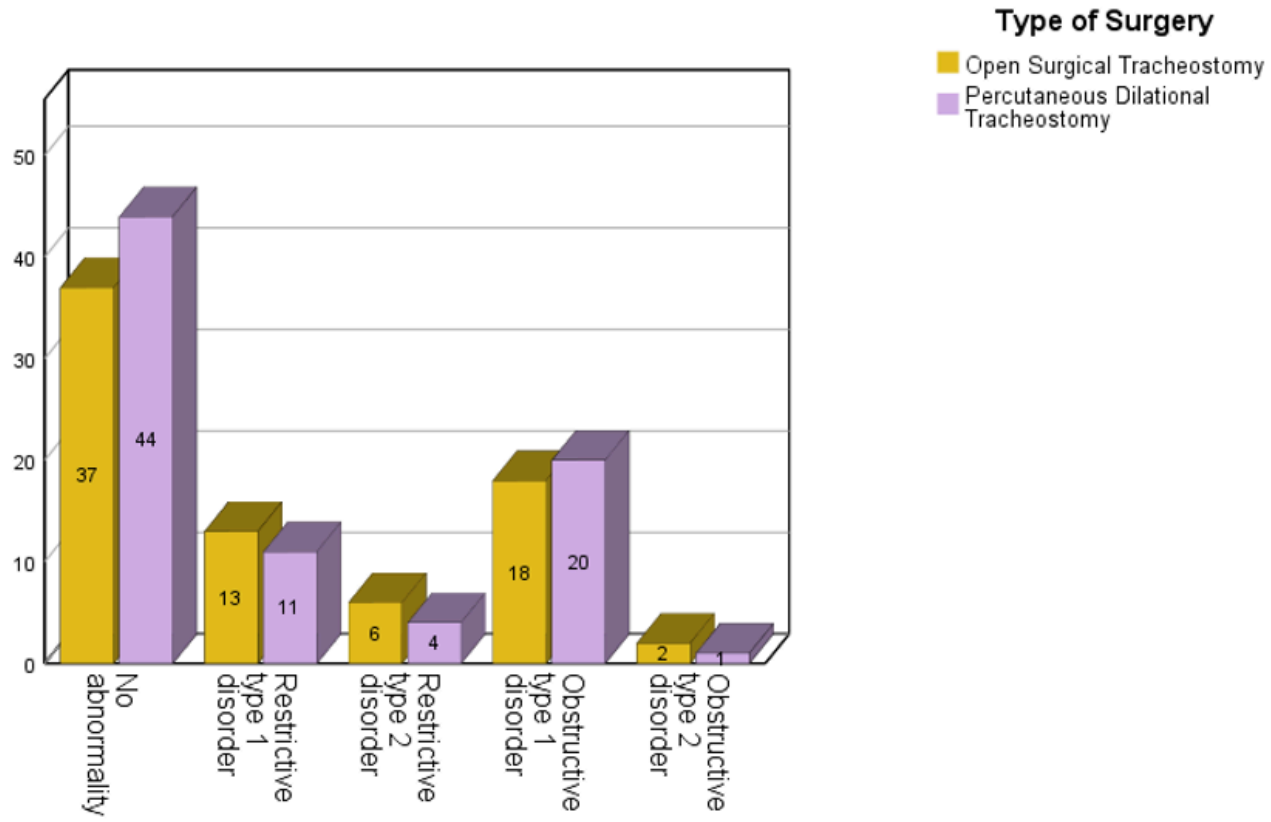


Fig. 2

Figure 2

The diagnostic results of spirometry among patients in the OST and PDT groups

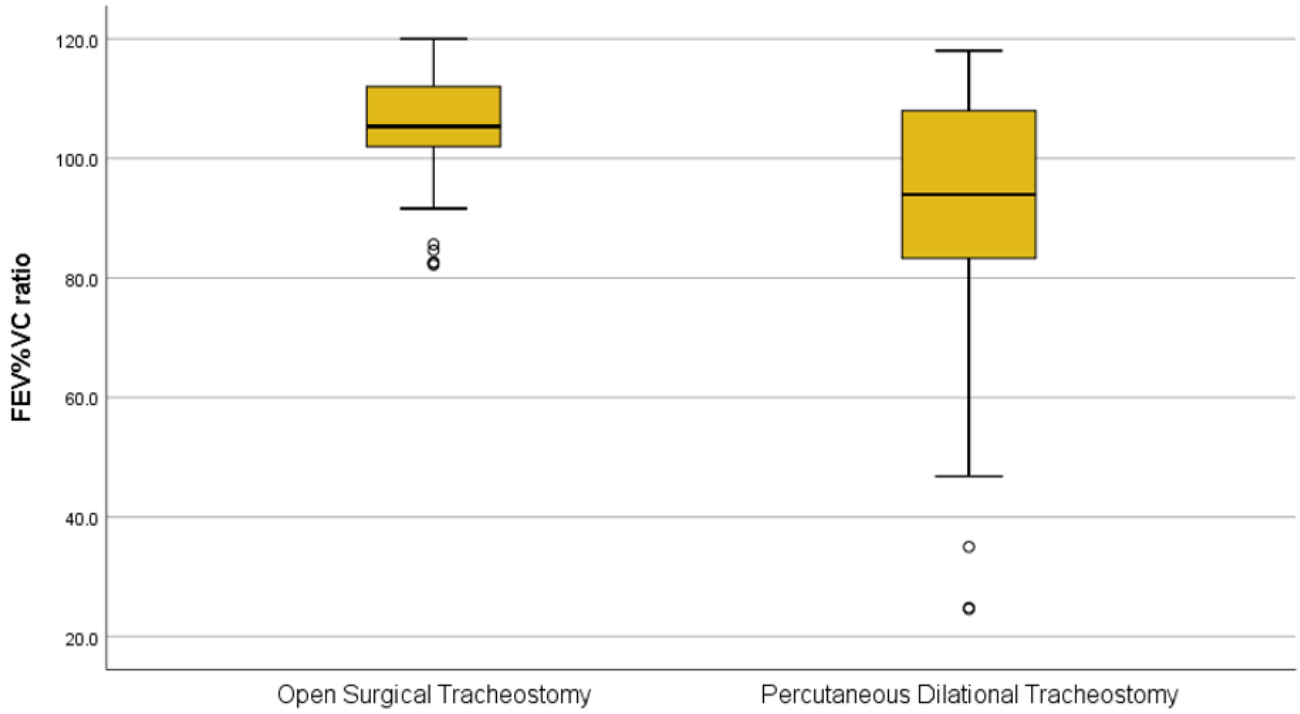


Fig. 3

Figure 3

FEV1\VC ratio distribution based on type of tracheostomy