Article

Comparison and Threshold Analysis of the ODET/GTD Ratio Between Patients With and Without Postoperative Sore Throat: A Retrospective Study

Ann. Ital. Chir., 2026 97, 4: 719–724
https://doi.org/10.62713/aic.4492

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AIM: This study aimed to retrospectively compare the outer diameter of the endotracheal tube to glottic transverse diameter (ODET/GTD) ratio between patients with and without postoperative sore throat (POST). An optimal ODET/GTD ratio cut-point was explored to provide a reference for endotracheal tube (ETT) selection and potentially help manage the risk of POST.
METHODS: We reviewed 150 patients in the Post Anesthesia Care Unit (PACU). Among these, 68 patients developed POST and 82 did not. The ODET/GTD ratio was calculated for each patient. This ratio was compared between the two patient groups. Receiver operating characteristic curve (ROC) analysis was performed, and the Youden index was used to identify the optimal ODET/GTD ratio cut-point for predicting POST.
RESULTS: The overall incidence of POST was 45.33%. The mean ODET/GTD ratio was significantly lower in patients without POST (1.02 ± 0.06) than in those with POST (1.18 ± 0.08), $p < 0.01$. ROC analysis identified an optimal ODET/GTD ratio cut-point of 1.10 (Youden index = 0.79) for predicting POST, with a sensitivity of 85% and a specificity of 79%.
CONCLUSIONS: Our findings suggest that a higher ODET/GTD ratio may contribute to the development of POST. Based on the ROC curve analysis, the ODET/GTD ratio of 1.10 was determined as a potential reference cutoff value for stratifying the risk of POST. These findings suggest that the ODET/GTD ratio may be useful for perioperative risk assessment; however, before applying it to guide the selection of tracheal intubation, further prospective studies and external validation are still needed.

Keywords: general anesthesia; Post Anesthesia Care Unit; endotracheal tube; glottis; postoperative sore throat

Introduction

Endotracheal intubation with an inappropriately sized tube can increase the incidence of postoperative sore throat (POST) [1]. A sore throat was defined as a discomfort, painful, or scratchy feeling in the throat, which was reported by Yu JH *et al*. [2]. POST may occur during swallowing or speaking [3], which will prolong the recovery time [4] and also delay the patient's return to normal activities [5]. Reported rates of POST following general anesthesia are as high as 62% [6]. Currently, no widely accepted guideline exists for selecting endotracheal tube (ETT) size in adults [1]. This choice is often influenced by multiple factors, including patient body size, sex, and anesthesiologist preference. Some studies [7,8] have shown that height can be used as one of the predictive factors for selecting ETT. The size of the ETT can be selected based on the patient's height. Moreover, most of the existing literature focuses on the relationship between the inner diameter of the tracheal tube and post-extubation complications [9,10]. However, the ETT wall occupies a measurable thickness between its inner and outer diameters; the outer surface of the ETT directly comes into physical contact with the airway anatomy, thereby causing airway stimulation. Selection based solely on inner diameter may lack scientific rigor. Correct selection of the outer diameter of the endotracheal tube (ODET) is crucial for minimizing POST after extubation in the Post Anesthesia Care Unit (PACU). In this study, we performed receiver operating characteristic (ROC) analysis. The Youden index was applied to identify the optimal ODET/glottic transverse diameter (GTD) ratio cut-point for predicting POST, to serve as a potential reference indicator for ODET selection. To validate this hypothesis, accurate measurement of the glottic transverse diameter is essential. Patients undergoing thyroid surgery represent an ideal cohort for this investigation, as preoperative neck computed tomography (CT) is routinely performed to assess nodule characteristics, providing reliable airway anatomical measurements without additional interventions. Specifically, this study focused on patients undergoing gas-

Submitted: 19 December 2025 Revised: 21 January 2026 Accepted: 4 February 2026 Published: 10 April 2026
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Editor: Chiara Dobrinja

less trans-subclavian approach endoscopic thyroidectomy for unilateral thyroid nodules (size $\leq$2 cm, no metastasis). By leveraging this specific surgical population, we aimed to retrospectively analyze the ODET/GTD ratio to identify an optimal cut-point for predicting POST and providing a reference for ETT selection.

Methods

We retrospectively reviewed data from 150 patients who underwent gasless trans-subclavian approach endoscopic thyroidectomy and subsequent extubation in the PACU between December 2022 and October 2025. Among these, 68 patients developed POST and 82 did not. All participants were classified as American Society of Anesthesiologists (ASA) physical status grade I or II. To ensure methodological rigor and isolate the impact of the ODET/GTD ratio on POST, the perioperative management was strictly standardized. To minimize procedural variability and the potential for mucosal injury caused by the intubation itself, several control measures were implemented. First, all tracheal intubations were performed by a single team of senior anesthesiologists, each possessing at least 5 years of clinical experience, ensuring high technical proficiency. Second, intubations were conducted under video laryngoscopy to achieve clear visualization of the glottis and ensure gentle ETT insertion, thereby avoiding forceful manipulation. Third, a water-soluble lubricant was uniformly applied to the distal end of the ETT to reduce friction against the airway mucosa. All ETTs were sourced from the same manufacturer (0611251203, Tianjin Medis Medical Device Co., Ltd.) to maintain consistency in material properties. Critically, to further eliminate confounding factors related to mechanical trauma, patients requiring more than two intubation attempts or those exhibiting visible airway trauma during the procedure were excluded from the study. Complete muscle relaxation was achieved prior to intubation in all cases to facilitate a smooth procedure. For patients who have already undergone a preoperative neck CT scan as part of routine clinical care, the study utilised these images for GTD measurements. The study protocol was approved by the Ethics Committee of Sir Run Run Shaw Hospital (Approval No. 2025-1316), and informed consent was obtained from all participants.

Data Collection

Inclusion criterion: Patients with a clearly visible glottis on CT images and a normal preoperative examination of the throat and vocal cords, without any pathology.

Exclusion criteria: Patients with a history of active upper respiratory disease, preoperative sore throat, airway trauma, any condition potentially altering normal airway anatomy, or more than two intubation attempts. Patients with motion artifacts or poor image quality on CT scans were also excluded.

Postoperative sore throat (POST) was systematically assessed and quantified using the Visual Analogue Scale (VAS), a validated and sensitive gold-standard tool for evaluating clinical pain intensity. Data collection was performed by registered nurses in the Post Anesthesia Care Unit (PACU) within an early postoperative window of 2 hours following extubation. This focused timeframe was chosen to assess immediate extubation-related mucosal trauma, rather than delayed inflammatory responses. The VAS consists of a 10-cm horizontal line ranging from '0' (no pain) to '10' (most severe pain imaginable). For this study, an occurrence of POST was defined as a VAS score $\geq$1. To ensure evaluative consistency and minimize subjective bias, all assessing nurses underwent standardized training in VAS administration before the study. Collected variables also included patient age, height, weight, ODET, duration of intubation, and duration of surgery. GTD was measured by radiologists using cross-sectional neck CT images (Fig. 1). The ODET/GTD ratio was calculated by dividing ODET by GTD.

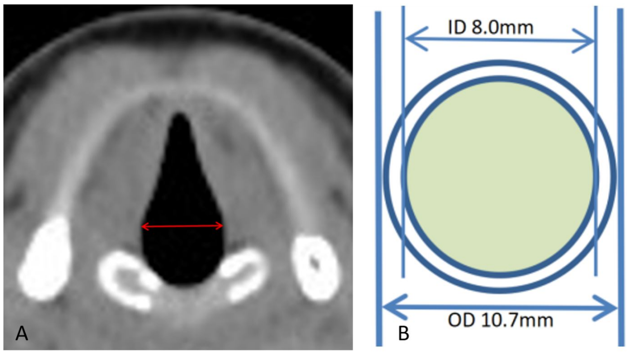

Fig. 1. The glottic transverse diameter and the diameter of endotracheal tube. (A) Measurement of the GTD (red arrow) using a CT image. (B) The inner diameter (ID) and outer diameter (OD) of the endotracheal tube (ETT). Abbreviations: GTD, glottic transverse diameter; CT, computed tomography.

Statistical Analysis

Statistical analysis was performed using SPSS version 26.0 (SPSS Inc., Chicago, IL, USA). Continuous variables were expressed as mean $\pm$ standard deviation (SD) after confirming a normal distribution via the Shapiro-Wilk test. To assess the homogeneity of variance, Levene's test was conducted. For variables meeting both normality and variance homogeneity assumptions, an independent samples t-test was employed for between-group comparisons. For categorical variables, data were presented as counts (percentages) and analyzed using the Pearson Chi-Square test (no expected cell counts were less than 5). The ODET/GTD ratio met the normality assumption ($p > 0.05$ in Shapiro-Wilk testing), but did not show the homogeneity of variance after Levene's test ($p < 0.05$); therefore, we used Welch's t-test

Table 1. Participant baseline characteristics.

Variable	With POST (n = 68)	Without POST (n = 82)	t-value/χ^2	p-value
Age (years)	45.03 ± 10.97	43.00 ± 10.50	1.16	0.25
Height (m)	1.62 ± 0.06	1.63 ± 0.07	0.74	0.46
Weight (kg)	64.30 ± 6.16	64.12 ± 7.57	0.16	0.87
BMI (kg/m^2)	24.36 ± 1.95	24.06 ± 2.48	0.82	0.42
Duration of surgery (min)	129.54 ± 42.27	131.13 ± 33.59	0.26	0.80
Duration of intubation (min)	189.50 ± 46.16	185.76 ± 45.63	0.50	0.62
ASA I	35 (51.47%)	43 (52.44%)	0.01	0.91
ASA II	33 (48.53%)	39 (47.56%)		

Abbreviations: POST, postoperative sore throat; BMI, body mass index; ASA, American Society of Anesthesiologists.

to analyze the ODET/GTD ratio. The ODET/GTD ratio is presented as mean ± SD. ROC curve analysis was utilized to determine the optimal ODET/GTD ratio cut-point for predicting POST by maximizing the Youden index. The area under the ROC curve (AUC) with its 95% confidence interval (CI), sensitivity, and specificity were calculated. A two-tailed p-value < 0.05 was considered statistically significant.

Results

Baseline Characteristics and Procedural Data

Patient demographic and perioperative data are summarized in Table 1. The overall incidence of POST in our cohort was 45.33% (68/150). To evaluate potential confounding factors related to procedural duration, we compared surgical and intubation times between groups. There were no statistically significant differences in the duration of surgery (129.54 ± 42.27 vs. 131.13 ± 33.59 min, $t = 0.26$, $p = 0.80$) or the duration of intubation (189.50 ± 46.16 vs. 185.76 ± 45.63 min, $t = 0.50$, $p = 0.62$) between patients with and without POST. This statistical equivalence indicates that the duration of mechanical pressure on the tracheal mucosa was comparable across both groups.

Comparison of ODET/GTD Ratio

The ODET/GTD ratio differed significantly between the two groups. As shown in Fig. 2, patients without POST had a significantly lower ODET/GTD ratio (1.02 ± 0.06) compared to those who developed POST (1.18 ± 0.08) ($t = 13.53$, $p < 0.01$). This significant disparity highlights the potential role of the tube-to-glottis size ratio in the development of postoperative throat discomfort.

ROC Analysis and Cut-Point Determination

To evaluate the predictive performance of the ODET/GTD ratio, ROC curve analysis was performed (Fig. 3). The area under the ROC curve (AUC) was 0.95 (95% confidence interval (CI): 0.91~0.98), indicating excellent discriminative ability. The analysis identified an optimal ODET/GTD ratio cut-point of 1.10 (Youden index = 0.79). At this threshold, the sensitivity was 85%, and the specificity was 79%.

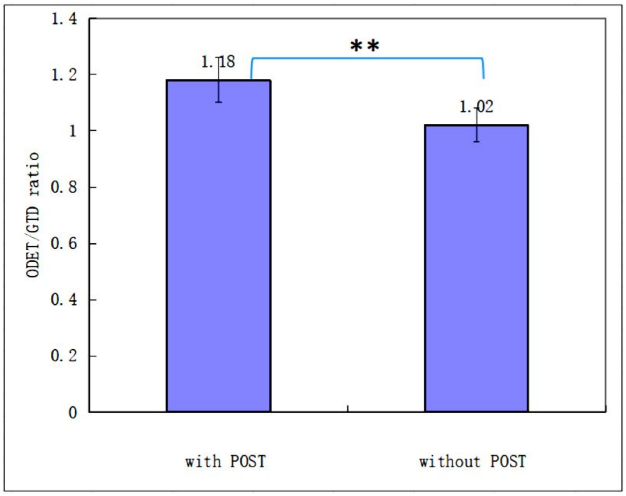

Fig. 2. Comparison of the ODET/GTD ratio between patients with POST and without POST. Abbreviations: ODET/GTD, outer diameter of the endotracheal tube to glottic transverse diameter; POST, postoperative sore throat; **, $p < 0.01$.

These results suggest that an ODET/GTD ratio exceeding 1.10 may be an effective indicator for POST risk in this patient population.

Discussion

For patients undergoing surgery with general anesthesia and tracheal intubation, the selection of ETT size varies across clinical specialties. Typically, the anesthesiologist selects the ETT size based on personal experience. In general, intensive care and anesthesiology departments often emphasize the benefits of larger ETTs, such as improved ventilation, and commonly recommend their use. In contrast, otolaryngology tends to prioritize avoiding tracheal stenosis and generally recommends using the smallest feasible ETT that does not increase the risk of stenosis [11]. Karmakar A *et al.* [7] reported no correlation between age, weight, or body mass index (BMI) and the tracheal cross-sectional area, although patient height showed a significant positive correlation with tracheal cross-sectional area. Most existing literature focuses on the inner diameter of the ETT [9,10].

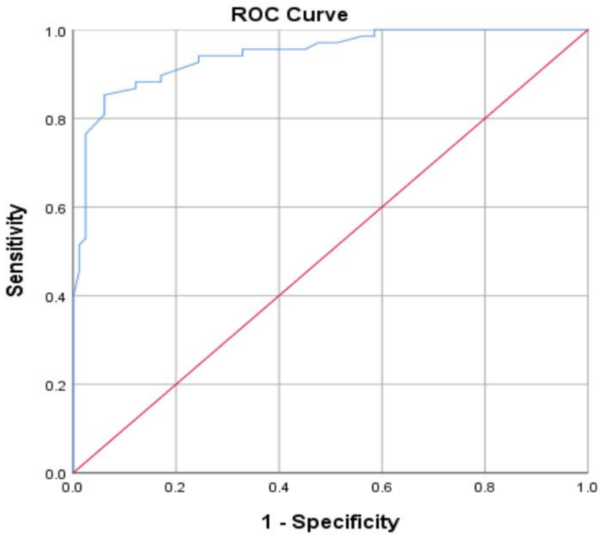

Fig. 3. Receiver operating characteristic (ROC) curve for the ODET/GTD ratio.

However, given variations in body habitus and tracheal size among individuals, and considering that the ETT wall occupies a measurable thickness between its inner and outer diameters, selection based solely on inner diameter may lack scientific rigor. Because the glottis contacts the outer surface of the tube, using the ODET may be more appropriate for our investigation (Fig. 1). The transverse diameter at the level of the vocal cords represents the narrowest segment of the larynx [8,12,13]; therefore, we used the ODET/GTD ratio as the primary parameter in this study. ROC analysis was performed. The Youden index was applied to determine the optimal ODET/GTD ratio cut-point for predicting POST, from which an optimal ODET calculation can be derived.

The Possible Pathogenesis of POST

Direct physical contact between the endotracheal tube and the tracheal mucosa is the most probable mechanism leading to airway edema following extubation [14]. The glottic transverse diameter is typically smaller than the anteroposterior diameter, which may result in excessive pressure being exerted on the lateral walls of the glottis [15]. During intubation and extubation under general anesthesia, the tube must pass through the glottis, the narrowest segment of the upper airway. This passage can cause mucosal injury to the vocal cords, contributing to POST. When an ETT traverses the glottis, a tube with a larger outer diameter applies increased pressure at the tube-mucosal interface. This may lead to scratching or friction against adjacent tissues, disrupting mucosal microcirculation and resulting in edema, erosion, ulceration, or necrosis. These mechanisms collectively represent potential etiological factors for POST (Fig. 4).

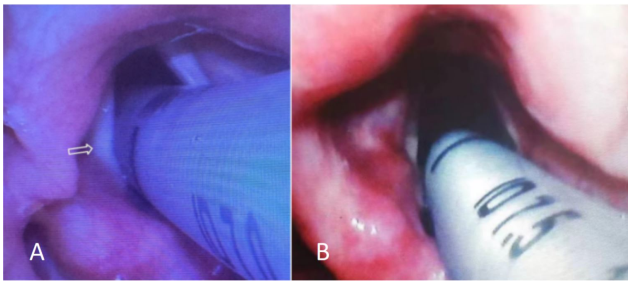

Fig. 4. The effect of endotracheal tube size on vocal cord compression. (A) When the ODET exceeds the GTD, it compresses the right vocal cord, forming an arc-shaped protrusion and exerting higher pressure at the tube-mucosa interface (arrow). (B) With an appropriately sized ODET, no obvious compression or displacement of the vocal cord is observed.

Disadvantages of the Large ETT

Generally, a larger ETT facilitates ventilation and airway access [11]. However, if the ETT is too large, it may cause damage to the larynx or trachea. The ETT passes through the vocal cords before entering the lower airway. An overly large tube can lead to damage to the mucous membrane. Some studies report that a large-diameter ETT reduces mucosal perfusion and leads to mucosal ischemia [7,11,13]. The use of a large-diameter ETT is also associated with increased patient discomfort after recovery from anesthesia. A potential drawback of a larger ETT is related to its cuff. A larger cuff may not inflate fully, which leaves folds. These folds may pose a potential risk of damage to the vocal cords during tracheal extubation. Aljathlany Y *et al.* [8] reported that BMI is negatively correlated with tracheal transverse diameter. Their study found that an increase of 1 kg/m^2 predicts a decrease of 0.05 mm in the tracheal transverse diameter, and they recommend against using a larger ETT for obese patients. Although BMI did not differ significantly between groups in our cohort (Table 1), a previous study suggests an inverse correlation between BMI and tracheal dimensions [8]. Thus, while our data do not directly confirm this link, it remains prudent to consider measuring the GTD using CT images in obese populations to select the correct ETT size. Ali S *et al.* [5] reported that ETT size has a significant impact on the frequency of POST in patients undergoing breast surgery. Their research shows that the group with an ETT size of 7.0 mm (51%) had a higher incidence of POST in the Post Anesthesia Care Unit than the group with an ETT size of 6.0 mm (27.1%). Our study finds that the ODET/GTD ratio in patients with POST (1.18 $\pm$ 0.08) is higher than in patients without POST (1.02 $\pm$ 0.06), with $p < 0.01$ (Fig. 2). When the ODET is greater than the GTD, it compresses the vocal cords to form an arc-shaped protrusion and exerts higher pressure at the tube-mucosa interface (Fig. 4). Our study has shown that the optimal ODET/GTD ratio cut-point for predicting the occurrence of POST, determined by ROC curve analysis, is

1.10 (Youden index 0.79) (Fig. 3). When the ODET/GTD ratio is greater than 1.10, it is possible to scratch the vocal cords or the tracheal wall during tracheal intubation or extubation. Therefore, a high ODET/GTD ratio may be one of the causes of POST.

Advantages of the Small ETT

Christiansen P *et al*. [4] indicated that a smaller ETT results in greater patient comfort following elective surgery. The research of Cao AC *et al*. [1] demonstrates that a 1 mm reduction in ETT size has little impact on ventilator pressures, while it increases the ease of insertion and reduces tracheal injury. A smaller ETT, with its proportionally smaller cuff, lower laryngeal interface pressure, and reduced mucosal contact surface area, decreases the incidence of laryngeal injury and POST. Studies by El-Boghdadly K *et al*. [6] have shown that a smaller ETT subjectively provides a better view of the tube through the larynx, which may reduce trauma associated with laryngoscopy and intubation. Hu B *et al*. [10] indicated that the incidence of POST in the PACU was reduced by the use of smaller tubes compared with larger ones. Our study indicates that when the ODET/GTD ratio exceeds 1.10, the incidence of POST after extubation in the PACU significantly increases. Conversely, a lower ODET/GTD ratio appears to be a favorable predictor associated with reduced airway trauma. Based on these findings, current evidence suggests that an ODET less than 1.10 $\times$ GTD may be considered as a potential reference limit for ETT selection, which could help mitigate the risk of POST following extubation. Therefore, based on our preliminary data, an ODET/GTD ratio below 1.10 may serve as a potential reference parameter for ETT selection to assist in predicting and potentially managing POST risk, subject to validation in larger cohorts.

Limitations

Several limitations of this study warrant consideration. First, this investigation was designed as a single-center retrospective analysis with a relatively limited sample size, which may inherently subject the findings to selection bias. Second, our cohort consisted exclusively of patients of Asian descent; thus, the generalizability of the ODET/GTD ratio to other ethnic populations remains to be established through more diverse, large-scale studies. From a procedural perspective, while a single senior anesthesiology team performed all intubations to maintain consistency, subtle interpersonal variations in technical proficiency may still exist. Furthermore, although ETT dimensions are directly related to cuff size, cuff pressure—which is difficult to correlate directly with the actual pressure at the tube-mucosa interface—was not measured in a way that fully reflects local ischemic impact. Most importantly, the ROC-derived cut-point of 1.10 identified in this cohort has not yet been externally validated. Consequently, this criterion should be interpreted as a preliminary clinical reference rather than a universal gold standard. Further multi-center prospective trials across various surgical populations are necessary to strengthen the methodological rigor and to confirm the broad clinical applicability of our findings. Finally, POST was assessed only within the first 2 hours after extubation in the PACU. While this captures immediate mechanical trauma, it may fail to account for delayed-onset throat pain occurring at 24 hours. Therefore, our findings primarily reflect early-stage postoperative discomfort, and extrapolation to long-term POST outcomes should be approached with caution.

Conclusions

Our research suggests that a high ODET/GTD ratio may be a contributing factor to POST. An ODET/GTD ratio of 1.10 was identified as the optimal cut-point for ODET selection. We suggest that preoperative CT measurement of GTD could be a valuable adjunctive step. An ODET/GTD ratio below 1.10 may serve as a potential risk stratification tool and clinical reference for reducing POST incidence, though further external validation is required.

Availability of Data and Materials

The data that support the findings of this study are available from the corresponding authors upon reasonable request.

Author Contributions

WPZ, JZ and WL designed the research and analyzed the data. NZ contributed to the data collection and manuscript drafting. YNW contributed to the data collection and references collection. All authors contributed to the critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The study protocol was approved by the Ethics Committee of Sir Run Run Shaw Hospital (Approval No. 2025-1316) and informed consent was obtained from all participants. The study conformed to the provisions of the Declaration of Helsinki.

Acknowledgment

Not applicable.

Funding

This study was supported by the Zhejiang Provincial Department of Eduation, China (No. Y202557473).

Conflict of Interest

The authors declare no conflict of interest.

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