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Neck Circumference to Thyromental Distance Ratio and Neck Circumference to Thyromental Height Ratio as a Predictor of Difficult Intubation – A Hospital Based Cross Sectional Study

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Abstract

Background: Administration of general anesthesia involves anticipation of a difficult airway and the arising complications. There are several anatomical and anthropometric measurements in clinical practice for predicting difficult intubation.

Objectives: To evaluate and assess the effectiveness of neck circumference (NC), thyromental distance (TMD), thyromental height (TMH), and derived ratios (NC/TMD and NC/TMH) in predicting difficult intubation among patients undergoing elective surgery.

Methods: This cross-sectional analytical study was done on 150 adult patients scheduled for elective surgery under general anesthesia. Preoperative airway assessments included measurements of NC, TMD, TMH, and calculations of NC/TMD and NC/TMH ratios. Intubation difficulty was assessed using the Intubation Difficulty Scale (IDS), with IDS >5 considered difficult. Statistical analysis with SPSS included ROC curve evaluation to determine the diagnostic accuracy of each parameter.

Results: The mean age was 39 years. The mean IDS was 1.85, with 10% of participants classified as having difficult intubation (IDS ≥ 5).Statistical comparison showed weight was significantly higher in the difficult intubation group ($p = 0.009$), while other variables like age, BMI, NC, TMD, TMHT, and their ratios did not show significant differences ($p>0.05$). No predictor showed a statistically significant association with difficult intubation based on IDS when categorized by cut-off values ($p>0.05$), highlighting limited standalone predictive utility of these measurements.

Conclusion: Among all parameters tested, **NC/TMHT emerged as the most clinically useful**, followed closely by **TMHT**. NC/TMHT ratio can serve as a simple, non-invasive valuable adjunct to standard preoperative airway assessment and planning for difficult intubation.

Keywords: Difficult intubation; Thyromental height; Neck circumference; Thyromental distance; Airway assessment; Predictive ratios; ROC curve

Introduction

Securing the airway is one of the most crucial responsibilities in anesthetic practice, requiring careful anticipation and clinical judgment [1]. Even minor anatomical variations can transform a seemingly straightforward intubation into a complex and potentially life-threatening situation [2]. Among the various interventions performed, tracheal intubation stands out as a procedure

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demanding both anatomical insight and technical precision [3]. Though frequently performed, tracheal intubation can quickly become perilous, with unforeseen challenges can rapidly cascade into a life-threatening emergency [4]. Difficult intubation, though not common, carries grave implications and can have serious consequences if encountered unprepared [5]. Therefore, the ability to predict such challenges before induction of anesthesia stands as one of the most valuable skills in clinical anesthesiology.

Over the years, clinicians have sought to decode the human airway using various bedside predictors. The thyromental distance (TMD), once hailed as a simple and reliable test, became a routine part of pre-anesthetic evaluations. It offered numerical value to the space between the mentum and thyroid notch, a seemingly useful guide to the accessibility of the larynx [6]. However, clinical experience soon revealed its limitations. Patients with acceptable TMD measurements sometimes presented with unexpectedly difficult laryngoscopic views, while others with borderline readings underwent uneventful intubations [7]. As the field advanced, so did the realization that a single linear measurement cannot fully capture the complex, three-dimensional architecture of the airway.

Neck circumference (NC) emerged as another contender, especially in the context of the rising global burden of obesity. A thicker neck, laden with adipose tissue, often implies increased resistance to airway manipulation. Its association with difficult intubation has been noted particularly in patients with high body mass index (BMI). Yet, NC used alone, lacks adequate specificity. The challenge, therefore, shifted towards combining parameters, looking not just at size, but at proportion and anatomical relationships [8].

This led to the development of ratio-based indices, with one measurement contextualized alongside another. The ratio of neck circumference to thyromental distance (NC/TMD) gained attention as an insightful approach. Rather than viewing TMD and NC in isolation, this ratio offered a glimpse into the alignment of the bulk of the neck with the available space for laryngoscopic access [9].

Thyromental height (TMH), as a vertical measurement that adds depth to airway assessment. Unlike TMD, which traces a line along the mandible, TMH measures the vertical distance between the thyroid cartilage and the mentum in the neutral head position, thereby reflecting submandibular space in a more spatially accurate manner [10]. A novel ratio, NC/TMH, which combines NC and TMH, has been suggested as a possibly better indicator of challenging intubation [11].

In this context, the Intubation Difficulty Scale (IDS) offers a validated, objective measure of intubation complexity by incorporating intraoperative factors such as the number of attempts, use of adjuncts, lifting force, and glottic view. In contrast to preoperative assessments, the IDS captures real-time procedural difficulty and serves as a reference standard for evaluating the predictive performance of selected parameters -NC, TMD, TMH, and their ratio-based derivatives (NC/TMD, NC/TMH). Correlating these indices with IDS scores enhances their clinical relevance in anticipating difficult intubation [12].

In a clinical setting, time is precious and precision paramount, the simplicity of these TMD, TMH, and NC measurements, makes them ideal for routine practice. Both NC/TMD and NC/TMH ratios are non-invasive, quick to perform, and do not require specialized equipment [9]. Their comparative assessment, however, remains underexplored, especially in diverse patient populations with varying anatomical features. A tertiary care centre, managing a wide array of elective and emergency surgical cases, presents the ideal environment to undertake such an evaluation.

Despite numerous studies on individual parameters, the comparative effectiveness of NC/TMD and NC/TMH in predicting difficult intubation remains to be clearly established [9,13,14,15]. In particular, their performance across a spectrum of patients receiving various surgical procedures under general anesthesia offers valuable data for anesthesia providers.

Methodology

The study was done as a cross-sectional analysis at Karpaga Vinayaga Institute of Medical Sciences and Research Centre, Madurantakam, Chengalpattu, Tamil Nadu, over a six-month period from February to July 2024. It aimed to evaluate the predictive value of the neck circumference to thyromental distance (NC/TMD) ratio and neck circumference to thyromental height (NC/TMHT) ratio in identifying difficult intubation in patients scheduled for elective surgeries under general anesthesia. The study population consisted of patients scheduled for elective surgery requiring orotracheal intubation in a tertiary care hospital.

Participants included in the study were adults aged 18 to 65 years, classified as ASA physical status I or II, and scheduled for elective procedures under general anesthesia involving oro-tracheal intubation. The study excluded individuals who were pregnant, airway pathology, craniofacial abnormalities, obesity (BMI >40 kg/m^2), restricted neck or temporomandibular joint mobility, edentulous patients, or those requiring rapid sequence intubation. Additionally, Patients who declined to provide consent for participation were also excluded from the study. The sample size for this study was calculated based on the sensitivity of the NC/TMD ratio, which was reported as 82.9% by Sukhdev Rao et al. [13]. Assuming a 95% confidence interval and absolute precision of 5 %, the minimum required size of sample was estimated as 60 patients for an analytical cross-sectional

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design. To account for potential dropouts and ensure robust data, a total enrollment of 150 patients were made, and these patients were randomly selected after obtaining informed consent.

Data collection involved the measurement of several airway parameters. Neck circumference (NC) was recorded at the level of the cricoid cartilage by making the patient seated with the head in a neutral position. Thyromental distance (TMD) was measured as the straight distance from the lower border of the thyroid notch to the mentum, with the patient's head extended and mouth closed. The NC/TMD ratio >5.0 considered an indicator of difficult intubation. A TMD <12.5 cm was also documented as being associated with increased intubation difficulty. Similarly, the thyromental height test (TMHT) was employed to measure the vertical distance between the anterior border of the mentum and the thyroid cartilage, serving as an indicator of mandibular protrusion and the anterior positioning of the larynx. The NC/TMHT ratio was calculated to further evaluate its predictive capacity for difficult intubation [16-18].

Modified Mallampati classification was performed without phonation, and patients were categorized based on the visibility of the soft palate, fauces, uvula, and pillars into Class I to Class IV. Temporomandibular joint mobility was evaluated to detect impairments, such as retrognathia or an inability to protrude the lower teeth beyond the upper teeth. Neck mobility was also evaluated to determine any restrictions in flexion or extension. The incisor gap was noted, particularly for the presence of any abnormally protruding upper teeth [16-18].

Intubation complexity in all patients was objectively evaluated using the Intubation Difficulty Scale (IDS). The score combines seven parameters (N1–N7): the number of extra attempts (N1), the need for additional operators (N2), use of alternative techniques (N3), Cormack-Lehane grade minus one (N4), increased lifting force during intubation (N5), requirement of external laryngeal pressure (N6), and the position of the vocal cords (N7). The overall IDS score is calculated by summing these individual components, where a score of 0 represents optimal intubation conditions. Scores of 5 or higher were classified as indicative of difficult intubation [19].

The anesthesia protocol for all patients was standardized. Each patient received premedication with 0.01mg/kg Glycopyrrolate intravenously and Emeset Injection (0.15mg/kg) before induction after Intravenous access was secured with an 18/20 G cannula, and Ringer's lactate was infused. Following three minutes of preoxygenation, induction of general anesthesia was done with Propofol Inj. (2.0mg/kg) and Inj. Fentanyl (2mcg/kg). Vecuronium Inj. (0.1mg/kg) was given for Neuromuscular blockade, and mask ventilation was performed for three minutes before intubation. Laryngoscopy was performed by an experienced anesthesiologist (minimum of two years' experience), blinded to the assessments of preoperative airway. A size 3 of Macintosh blade was used for female patients and size 4 for males. Endotracheal tubes of sizes 6.5 to 8.5 mm ID were selected based on patient characteristics. A difficult intubation cart was kept standby, and intubations were performed in accordance with the ASA Difficult Airway Algorithm**.**

Hemodynamic parameters, including heart rate, mean arterial pressure, SpO2, electrocardiogram (ECG), and ETCO2, were continuously monitored throughout the procedure. The level of intubation difficulty was evaluated by recording the number of attempts, the use of alternative techniques, changes in equipment, and the Cormack-Lehane grading. These data were used to classify the cases into difficult and non-difficult intubation groups.

The primary outcome of the study was to assess the NC/TMD and NC/TMHT ratios as predictors of difficult intubation. Secondary outcomes included comparing these ratios with other individual predictors of difficult intubation, such as RHTMD, NC, TMD, TMHT, and the inter-incisor gap.

Statistical analyses

Statistical analysis was performed using SPSS software, Version 22. The normality of quantitative variables was assessed through visual inspection of histograms and Q-Q plots. Furthermore, the Shapiro-Wilk test was performed, where a p-value exceeding 0.05 was interpreted as evidence of a normal distribution. Descriptive statistics were applied to summarize quantitative data using means and standard deviations, whereas categorical data were presented as frequencies and percentages. For quantitative variables following a normal distribution, group comparisons were made using the independent samples t-test. The Chi-square test was employed to analyze differences in categorical variables. The Intubation Difficulty Scale (IDS) classification served as the reference standard to assess the diagnostic utility of the screening parameters (NC, TMD, and NC/TMD ratio). Sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic accuracy were calculated for each test, along with 95% confidence intervals. A p-value below 0.05 was regarded as significant statistically, ensuring the reliability of the findings.

Results

A total of 150 participants were enrolled in the study. As presented in **Table 1**, the mean age of the study population was 39 years. The average height and weight were 155.38 cm and 62.62 kg, respectively, resulting in a mean BMI of 26.03 kg/m², which reflects a predominantly overweight group. Neck circumference averaged 36.16 cm, with a mean Thyromental Distance (TMD) of 8.45 cm and Thyromental

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Height (TMHT) of 7.89 cm. The NC/TMD and NC/TMHT ratios were 4.35 and 4.66, respectively, reflecting a moderate relationship between neck size and airway dimensions. The RHTMD ratio averaged 0.94, suggesting a relatively consistent anatomical proportion of the ramus to TMD across participants. The mean Intubation Difficulty Score (IDS) was 1.85, indicating that the population experienced mild to moderate intubation difficulty.

Table 1: Descriptive characteristics of the study participants (N=150).

Parameters	Mean ± SD	95% CI(Lower)	95% CI(Upper)
Age (years)	39 ± 10.86	37.25	40.75
Height (cm)	155.38 ± 9.35	153.87	156.89
Weight (kg)	62.62 ± 10.94	60.86	64.38
BMI (kg/m²)	26.03 ± 4.65	25.28	26.78
Neck Circumference (cm)	36.16 ± 3.32	35.63	36.7
TMD (cm)	8.45 ± 1.01	8.29	8.61
TMHT (cm)	7.89 ± 1.01	7.73	8.06
NC/TMD Ratio	4.35 ± 0.70	4.23	4.46
NC/TMHT Ratio	4.66 ± 0.79	4.54	4.79
RHTMD	0.94 ± 0.15	0.92	0.97
IDS Score	1.85 ± 1.78	1.56	2.13

SD- standard deviation; **CI** -confidence interval; **BMI** - Body Mass Index; **TMD** - Thyromental Distance, **TMHT** - Thyromental Height Test; **NC/TMD** - Neck Circumference/Thyromental Distance Ratio; **NC/TMHT** - Neck Circumference/Thyromental Height Ratio; **RHTMD** - Relative Height Thyromental Distance; **IDS** - Intubation Difficulty Scale

Table 2: Frequency distribution of categorical variables.

Parameter	Difficult Intubation (Mean ± SD)	Easy Intubation (Mean ± SD)	P Value
Age	38.07 ± 12.38	39.1 ± 10.72	0.727
Height (cm)	159 ± 9.9	154.98 ± 9.23	0.114
Weight (kg)	69.6 ± 11.1	61.84 ± 10.68	0.009
BMI	27.81 ± 5.75	25.83 ± 4.5	0.119
NC (cm)	37.23 ± 4.13	36.05 ± 3.22	0.192
TMD (cm)	8.53 ± 1.51	8.44 ± 0.94	0.738
TMHT (cm)	7.61 ± 0.84	7.92 ± 1.02	0.258
NC/TMD	4.47 ± 0.85	4.33 ± 0.68	0.47
NC/TMHT	4.95 ± 0.85	4.63 ± 0.78	0.134
RHTMD	0.93 ± 0.24	0.95 ± 0.14	0.656

- **SD**- standard deviation ; **p-value less than 0.005** is considered **statistically significant; BMI** - Body Mass Index; **NC**- neck circumference; **TMD** - Thyromental Distance; **TMHT** - Thyromental Height Test; **NC/TMD** - Neck Circumference/Thyromental Distance Ratio; **NC/TMHT** - Neck Circumference/Thyromental Height Ratio; **RHTMD** - Relative Height Thyromental Distance; **IDS** - Intubation Difficulty Scale

Table 2 represents the frequency distribution of categorical variables in the study population (N=150), it shows that the majority of participants were **female (62.67%)**, with **males (31.33%)** and **transgender individuals (6.00%)** making up smaller proportions. In terms of **ASA status**, most participants were classified as **ASA II (51.33%)**, indicating mild systemic disease, while **48.67%** were **ASA I** (healthy individuals). Regarding the **Mallampati Classification (MPC)**, the largest group was in **MPC II (64.00%)**, indicating moderate difficulty in airway visualization, followed by **MPC I (20.67%)** and **MPC III (15.33%)**. According to **Cormack-Lehane (CL) grading**, **38.67%** were in **CL I**, suggesting easy visualization of the airway, while **CL III** and **CL IV** groups, representing more difficult visualization, made up **23.33%** and **4.67%**, respectively. Only **10.00%** of the participants had **Difficult Intubation (IDS ≥5)**, while **90.00%** had **IDS <5**, indicating mostly uncomplicated intubations. The **IDS scores** ranged from **0 to 7**, with **30.00%** scoring **0**, indicating no difficulty, and higher scores becoming increasingly rare.

Table 3 presents a comparison of mean values between the easy and difficult intubation groups, showing that individuals in the difficult intubation group had a significantly higher average weight (69.6 kg) than those in the easy intubation group (61.84 kg). This difference was significant statistically, with a p-value of 0.009. However, insignificant differences were found for **age**, **height**, **BMI**, **neck circumference**, **TMD**, **TMHT**, **NC/TMD ratio**, **NC/TMHT ratio**, or **RHTMD**, as all had **p values** exceeding **0.05**, suggesting that these factors independently do not significantly contribute to the difficulty of intubation prediction.

Table 3: Comparison of mean values between difficult and easy intubation groups.

Parameter	Difficult Intubation (Mean ± SD)	Easy Intubation (Mean ± SD)	P Value
Age	38.07 ± 12.38	39.1 ± 10.72	0.727
Height (cm)	159 ± 9.9	154.98 ± 9.23	0.114
Weight (kg)	69.6 ± 11.1	61.84 ± 10.68	0.009
BMI	27.81 ± 5.75	25.83 ± 4.5	0.119
NC (cm)	37.23 ± 4.13	36.05 ± 3.22	0.192
TMD (cm)	8.53 ± 1.51	8.44 ± 0.94	0.738
TMHT (cm)	7.61 ± 0.84	7.92 ± 1.02	0.258
NC/TMD	4.47 ± 0.85	4.33 ± 0.68	0.47
NC/TMHT	4.95 ± 0.85	4.63 ± 0.78	0.134
RHTMD	0.93 ± 0.24	0.95 ± 0.14	0.656

- **SD**- standard deviation ; **p-value less than 0.005** is considered **statistically significant; BMI** - Body Mass Index; **NC** - neck circumference; **TMD** - Thyromental Distance; **TMHT** - Thyromental Height Test; **NC/TMD** - Neck Circumference/Thyromental Distance Ratio; **NC/TMHT** - Neck Circumference/Thyromental Height Ratio; **RHTMD** - Relative Height Thyromental Distance; **IDS** - Intubation Difficulty Scale

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Table 4 describes the predictive validity of various diagnostic parameters in predicting difficult intubation, reveals that **TMHT** (cut-off 7.75 cm) had the highest diagnostic accuracy (**62.00%**), with **60.00% sensitivity** and **62.22% specificity**, making it the most reliable predictor. It also had the highest **NPV** (93.33%), suggesting it is very effective at ruling out difficult intubation. Other parameters like **neck circumference (NC)** and **TMD** showed lower diagnostic accuracy, with **NC** having a **sensitivity of 53.33%** and **TMD** showing a **sensitivity of 40.00%**. **NC/TMHT ratio** and **RHTMD** also exhibited relatively low performance, with **NC/TMHT** showing a **sensitivity of 66.67%** but a lower **specificity (45.19%)**. Overall, **TMHT** outperformed other parameters in identifying difficult intubation cases, while parameters like **TMD** and **RHTMD** demonstrated limited predictive power.

Table 5 shows the comparison of **IDS scores** with various predictors, showing no significant associations between easy and difficult intubation groups for the majority of parameters. For **neck circumference (NC)**, the **p-value** was **0.913**, indicating insignificant difference between those with high and low NC values. Similarly, **TMD** with a **cut-off of 8.43** also showed insignificant difference (**p-value 0.549**). **TMHT** was close to significance (**p-value 0.096**), with a higher proportion of difficult intubation cases in the **low TMHT** group, but the result was not statistically significant. **NC/TMD** and **NC/TMHT ratios** also did not show significant differences (**p-values 0.443** and **0.380**, respectively). Lastly, **RHTMD** demonstrated a **p-value** of **0.137**, suggesting insignificant association between RHTMD levels and intubation difficulty. Overall, none of the predictors showed statistically significant associations with difficult intubation, indicating that these parameters alone may not reliably predict intubation difficulty in this population.

The **ROC analysis** of predictive validity for difficult intubation showed that the **Neck Circumference (NC)** had an area under the curve (**AUC**) of **0.580** with a **p-value of 0.312**, indicating limited predictive ability (Figure 1). **Thyromental Distance (TMD)** performed poorly with an **AUC of 0.496** and a **p-value of 0.955** (Figure 2). The **Thyromental Height**

Table 4: Predictive validity of various diagnostic parameters in predicting difficult intubation (IDS score) (N=150).

	Cut off	Sensitivity	Specificity	FPR	FNR	PPV	NPV	DA
NC (cm)	35.86	53.33%	48.15%	51.85%	46.67%	10.26%	90.28%	48.67%
TMD (cm)	8.43	40.00%	51.85%	48.15%	60.00%	8.45%	88.61%	50.67%
TMHT (cm)	7.75	60.00%	62.22%	37.78%	40.00%	15.00%	93.33%	62.00%
NC/TMD	4.16	46.67%	42.96%	57.04%	53.33%	8.33%	87.88%	43.33%
NC/TMHT	4.5	66.67%	45.19%	54.81%	33.33%	11.90%	92.42%	47.33%
RHTMD	0.912	40.00%	40.00%	60.00%	60.00%	6.90%	85.71%	40.00%

- **FPR** – False Positive Rate; **FNR** – False Negative Rate; **PPV** – Positive Predictive Value; **NPV** – Negative Predictive Value; **DA** – Diagnostic Accuracy; **NC**- neck circumference; **TMD** - Thyromental Distance; **TMHT** - Thyromental Height Test; **NC/TMD** - Neck Circumference/Thyromental Distance Ratio; **NC/TMHT** - Neck Circumference/Thyromental Height Ratio; **RHTMD** - Relative Height Thyromental Distance; **IDS** - Intubation Difficulty Scale

Table 5: Comparison of IDS score with various predictors (N = 150).

Predictor	Cut-off Value	Category	Difficult Intubation (N = 15)	Easy Intubation (N = 135)	Chi-square	P-value
NC	≥ 35.86	High	8 (53.33%)	70 (51.85%)	0.012	0.913
	< 35.86	Low	7 (46.67%)	65 (48.15%)		
TMD	≥ 8.43	High	6 (40%)	65 (48.15%)	0.36	0.549
	< 8.43	Low	9 (60%)	70 (51.85%)		
TMHT	< 7.75	Low	9 (60%)	51 (37.78%)	2.778	0.096
	≥ 7.75	High	6 (40%)	84 (62.22%)		
NC/TMD	≥ 4.16	High	7 (46.67%)	77 (57.04%)	0.589	0.443
	< 4.16	Low	8 (53.33%)	58 (42.96%)		
NC/TMHT	≥ 4.50	High	10 (66.67%)	74 (54.81%)	0.77	0.38
	< 4.50	Low	5 (33.33%)	61 (45.19%)		
RHTMD	≥ 0.912	High	6 (40%)	81 (60%)	2.217	0.137
	< 0.912	Low	9 (60%)	54 (40%)		

p-value less than 0.005 is considered **statistically significant; NC**- neck circumference; **TMD** - Thyromental Distance,**TMHT** - Thyromental Height Test; **NC/TMD** - Neck Circumference/Thyromental Distance Ratio; **NC/TMHT** - Neck Circumference/Thyromental Height Ratio; **RHTMD** - Relative Height Thyromental Distance; **IDS** - Intubation Difficulty Scale

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Table 6: ROC Analysis of Predictive Validity for Difficult Intubation (IDS Score, N = 150)

Variable	AUC	Std. Error	P-value	95% Confidence Interval
Neck Circumference (NC)	0.580	0.089	0.312	0.405 – 0.754
Thyromental Distance (TMD)	0.496	0.092	0.955	0.316 – 0.675
Thyromental Height Test (TMHT)	0.604	0.077	0.186	0.453 – 0.756
NC/TMD Ratio	0.513	0.083	0.871	0.350 – 0.676
NC/TMHT Ratio	0.605	0.079	0.183	0.451 – 0.759
RHTMD	0.451	0.105	0.533	0.245 – 0.656

- p-value less than 0.005 is considered **statistically significant**,

-NC- neck circumference; **TMD** - Thyromental Distance,**TMHT** - Thyromental Height Test,**NC/TMD** - Neck Circumference/Thyromental Distance Ratio,**NC/TMHT** - Neck Circumference/Thyromental Height Ratio, **RHTMD** - Relative Height Thyromental Distance,**IDS** - Intubation Difficulty Scale

-AUC -area under curve

Test (TMHT) had a slightly better **AUC of 0.604** and a **p-value of 0.186**, indicating moderate predictive potential (Figure 3). Similarly, the **NC/TMD ratio** and **NC/TMHT ratio** had **AUCs of 0.513** and **0.605**, respectively, with **p-values** of **0.871** and **0.183**, suggesting no strong predictive value (Figure 4,5). The **RHTMD** performed the worst, with an **AUC of 0.451** and a **p-value of 0.533**, indicating poor discriminatory ability for predicting difficult intubation (Figure 6).

Discussion

This cross sectional study investigated the effectiveness **Neck Circumference to Thyromental Distance ratio (NC/TMD)** and **Neck Circumference to Thyromental Height Test ratio (NC/TMHT)**—in predicting difficult intubation (DI) among patients undergoing elective surgery under general anaesthesia, This study examined the performance of traditional airway assessment tools, including **RHTMD**, **neck circumference (NC)**, **thyromental distance (TMD)**, **thyromental height test (TMHT)**, and **inter-incisor gap (IIG)**.

Airway assessment remains a cornerstone of anaesthetic management due to the potentially life-threatening complications associated with unanticipated difficult intubation. While various anatomical parameters and indices have been proposed over the decades, no single test has demonstrated consistently high predictive accuracy. Thus, identifying simple, reproducible, and accurate predictors remains an ongoing challenge, particularly in diverse patient populations.

The study included 150 patients with a mean age of 39 years, a BMI of 26.03 kg/m², and an average neck circumference of 36.16 cm. This finding is particularly noteworthy, although the relatively high BMI in this study reflects a predominantly overweight population, this condition typically associated with anatomical challenges in airway management, yet BMI itself was found to be a significant predictor of difficult intubation.

However, The relationship between body weight and intubation difficulty yielded more meaningful results. Difficult intubation group had a significantly higher mean weight (69.6 kg) compared to those in the easy intubation group (61.84 kg), with a p-value of 0.009, indicating a significant difference statistically. This suggests that weight, independent of BMI, may be more directly associated with the anatomical challenges encountered during intubation. Excess body weight can contribute to increased deposition of adipose tissue around the pharyngeal and cervical structures, that may be obscure key anatomical landmarks necessary for successful laryngoscopy. Moreover, heavier individuals may exhibit reduced neck mobility and increased chest wall resistance, both of which Interfere with the optimal alignment of the airway axes necessary for successful endotracheal intubation.

Difficult intubation was encountered in the following proportion within our study population.. was **10%**, aligning with estimates from prior research that report difficult intubation rates in the range of 5–15% in the general surgical population. This incidence, derived from the **Intubation Difficulty Score (IDS)** classification, supports the reliability of our study population as representative of a typical elective surgical population.

Among the parameters assessed, **NC/TMHT emerged as the most reliable ratio-based predictor**, with a sensitivity of 66.67%, specificity of 45.19%, and a high negative predictive value (NPV) of 92.42%. While the specificity was modest, the elevated NPV indicates that this ratio is particularly valuable in ruling out difficult intubation. These findings are in agreement with the study conducted by Rao et al. [13], TMHT outperformed other predictors in identifying difficult intubation, demonstrating higher sensitivity and specificity [13]. Moreover Jain et al. [20] and Panjiar et al. [21] emphasize the effectiveness of TMH test in evaluating difficult laryngoscopy. These studies support the concept that TMH provides valuable preoperative information regarding airway accessibility [20,21].

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In contrast, **NC/TMD** had a sensitivity of **46.67%** and a specificity of **42.96%**, with an NPV of **87.88%**. Its AUC was **0.513**, which is near the statistical equivalence line, suggesting relatively poor discriminative ability. These findings suggest that although both ratios provide some insight into difficult airway prediction, NC/TMHT is clearly the more reliable and clinically valuable parameter. This contrasts with the findings of Kim et al. [22], who suggested that NC/TMD could outperform TMD and NC individually, particularly in Asian populations. The discrepancy may reflect differences in neck fat distribution or skeletal morphology between East Asian and South Indian populations, as supported by anthropometric studies showing regional anatomical variability [22]. But Studies by Naim et al. [23] and Hirmanpour et al. [24] show the significance of combining neck circumference (NC) with thyromental distance (TM) as a ratio (NC/TM) for predicting intubation complications, especially in cases of obstructive sleep apnea (OSA). This highlighting the importance of a holistic approach that incorporates multiple anatomical predictors for improved diagnostic accuracy [23,24].

The rationale behind using these indices lies in combining two critical dimensions of airway anatomy. Neck circumference is a surrogate for soft tissue mass and is known to correlate with obesity, which itself is a recognized risk factor for difficult intubation. Thyromental distance and thyromental height, on the other hand, reflect submandibular space and laryngeal axis alignment, respectively. The combination of these parameters, as reflected in the NC/TMHT and NC/TMD ratios, aims to integrate soft tissue and skeletal predictors into a unified index. Notably, NC/TMHT includes vertical anatomical assessment, likely contributing to its superior predictive capability. Studies by Shiga et al. [25], Cormack & Lehane [26] compared different predictive tests- Mallampati score, inter-incisor gap, and TM distance and showed the tests have varying degrees of reliability across different patient populations. Integrating multiple tests, such as the TMH test and NC/TM ratio, may improve predictive power and reduce the risk of failed intubation [25,26].

Our study's **secondary objective** focused on comparing these ratios to individual, commonly used predictors of difficult intubation. Among these, **thyromental height test (TMHT)** raised as the most effective single-variable predictor. With a **diagnostic accuracy of 62%**, **sensitivity of 60%**, and **NPV of 93.33%**, TMHT demonstrated strong clinical utility. The AUC **for TMHT** was **0.604**, closely aligning with that of NC/TMHT. This supports prior findings from studies by Etezadi et al. [10] and other researchers who have demonstrated the TMHT to be a useful bedside test for predicting difficult laryngoscopy [10].

Neck circumference (NC) as a standalone parameter demonstrated **moderate predictive value**. While its **NPV was 90.28%**, the **specificity was only 48.15%**, and **diagnostic accuracy** was **48.67%**. Although easy to perform, NC alone lacks the anatomical specificity to predict airway difficulty effectively and may be affected by factors such as gender, height, and fat distribution. Therefore, its utility may be limited unless incorporated into a composite score.

Thyromental distance (TMD) and **RHTMD** performed relatively poorly. The AUC for TMD was **0.496**, indicating a lack of significant predictive power. Diagnostic accuracy was **50.67%**, and NPV was **88.61%**. While traditionally considered a useful predictor, the TMD is susceptible to variation in head position and mandibular anatomy, which can limit its reliability. Similarly, **RHTMD**, despite being proposed as a normalized predictor that accounts for body habitus, had a **low** AUC **of 0.451** and **diagnostic accuracy of only 40%**. Its sensitivity and specificity were both 40%, with a very low positive predictive value (6.90%). These results challenge its clinical relevance, particularly in Indian or ethnically diverse populations where anatomical proportions may differ from those in Western populations where the index was initially validated.

Interestingly, the study also explored high thresholds for the NC/TMHT ratio (≥6), where specificity increased dramatically to **95.20%**, and diagnostic accuracy reached **87.86%**. However, the sensitivity dropped to **26.67%**, highlighting a trade-off between detecting all difficult intubations and minimizing false positives. This again reinforces the utility of NC/TMHT primarily as a **screening tool with high NPV**, rather than as a diagnostic tool.

These findings are in agreement with a growing body of literature emphasizing the superiority of multi-dimensional or ratio-based indices over single-variable assessments. Studies by Riad et al. [27], Aslam et al. [28], and others have similarly demonstrated the limitations of traditional measurements like TMD, IIG, and Mallampati class in predicting difficult intubation [27,28]. According to Selvi et al. [29], reliability of the Cormack-Lehane score and Mallampati test can be limited by the operator's skill and patient-specific factors. A comprehensive, multi-faceted assessment involving a combination of tests might offer better predictive outcomes [29]. The inclusion of neck circumference in combination with mandibular and laryngeal axis measures offers a more comprehensive anatomical evaluation.

From a practical standpoint, the **NC/TMHT and TMHT tests require minimal equipment and training**, making them well-suited for high-volume, resource-constrained environments. The use of these tools in peripheral and rural settings can enhance early identification of at-risk patients, improve anesthesia planning, and potentially reduce the incidence of unexpected difficult airways and associated complications.

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Limitations

Despite the strength of the results, this study presents some methodological constraints. Firstly, it was carried out at a single tertiary care centre, and the sample size of 150, while adequate for initial observations, the full diversity of anatomical variation in the wider population was not captured. Secondly, all measurements were operator-dependent, which may introduce subjectivity and measurement error. While the study attempted to standardize techniques, inter-operator variability cannot be entirely excluded. Thirdly, while validated scoring system for intubation difficulty (IDS), is there, some element of subjectivity in scoring is noted, especially for intermediate grades.

Recommendation

In future studies, incorporating imaging modalities such as ultrasound or MRI to correlate soft tissue and skeletal landmarks may provide deeper anatomical insights. Further validation of the NC/TMHT ratio in a larger multicenter cohort, ideally with stratified analysis by BMI, gender, and comorbidities, would also help generalize its applicability. Additionally, evaluating combinations of these indices in multivariable prediction models may improve diagnostic performance further.

Conclusion

This study concludes and underscores that the limitations of traditional single-parameter airway assessments and highlights the potential of composite indices, particularly **NC/TMHT**, as more reliable predictors of difficult intubation. Among all parameters tested, **NC/TMHT emerged as the most clinically useful**, followed closely by **TMHT**. **Weight** was higher in the difficult intubation group (**69.6 kg**) compared to the easy intubation group (**61.84 kg**), with a **p value** of **0.009**, indicating a significant difference. Hence a study with focus on overweight and obese patients could yield highly significant results. These simple, non-invasive, and easily reproducible bedside tools can play a role in enhancing the efficiency of airway management. Given their high negative predictive values, they are especially useful in ruling out difficult intubation and should be considered for routine use in pre-anesthetic evaluations. Their incorporation into airway assessment protocols, particularly in high-risk populations and resource-limited settings, holds promise for improving anesthetic care and patient outcomes.

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