Indian Journal of Clinical Anaesthesia 2025;12(1):118–124

Content available at: https://www.ipinnovative.com/open-access-journals

Indian Journal of Clinical Anaesthesia

Journal homepage: www.ijca.in

Original Research Article

# Height to thyromental distance ratio and height to sternomental distance ratio comparison as difficult airway predictors: A cross-sectional study

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ARTICLE INFO

*Article history:*
Received 13-11-2024
Accepted 30-12-2024
Available online 20-01-2025

*Keywords:*
Sternomental distance
Thyromental distance
Difficult airway
Cormack- lehane grade

ABSTRACT

**Background and Aims**: Difficult airway management is a critical concern in anesthesiology, contributing significantly to perioperative morbidity and mortality. Preoperative evaluation using predictive parameters like the Height-to-Thyromental Distance (RHTMD) ratio and the Height-to-Sternomental Distance (RHSMD) ratio aids in identifying patients at risk of difficult intubation. This study aimed to compare RHTMD and RHSMD as predictors of difficult airways in patients undergoing elective surgeries under general anesthesia.

**Materials and Methods**: A cross-sectional study was conducted involving 150 patients undergoing elective surgeries under general anesthesia. Airway assessments included measurements of Thyromental Distance (TMD), Sternomental Distance (SMD), RHTMD, RHSMD, weight, and height. Direct laryngoscopy was performed using a Macintosh blade by an anesthetist with over three years of experience, and the Cormack-Lehane grade was recorded. Institutional anesthesia protocols were uniformly applied.

**Results:** Using the Cormack-Lehane grade as the reference standard, RHTMD demonstrated a sensitivity of 88.9%, specificity of 97.7%, and accuracy of 96.67%. RHSMD showed a sensitivity of 83.3%, specificity of 95.5%, and accuracy of 94%.

**Conclusions**: The Height-to-Thyromental Distance ratio was found to be a more sensitive, specific, and accurate predictor of difficult airways compared to the Height-to-Sternomental Distance ratio. Combining both parameters further improved the predictive reliability, emphasizing the need for an integrated assessment approach in airway evaluation.



## 1. Introduction

In the field of anesthesiology, a difficult airway is defined as one in which a trained anesthesiologist faces challenges in maintaining ventilation using a face mask, intubating the trachea with a direct laryngoscope, or both. According to the American Society of Anesthesiologists (ASA), a difficult intubation is characterized as requiring three or more attempts with a suitably sized laryngoscope or taking more than 10 minutes to complete the procedure. Various factors, including patient characteristics, medical and surgical history, airway anatomy, and the clinical scenario, contribute to the development of a difficult airway situation.[1]

Difficult airway management is a critical skill for anesthesiologists, as airway-related complications account for up to one-third of anesthesia-related mortalities. These fatalities are often attributed to the inability to secure a patent airway, maintain ventilation, and ensure adequate oxygenation. The ASA Task Force on Management of the Difficult Airway highlights the essential role of preoperative airway assessment in minimizing risks. The incidence of difficult laryngoscopy and intubation ranges from 1% to 8%, with failed intubation occurring in 0.05-0.35% of cases,

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https://doi.org/10.18231/j.ijca.2025.018

emphasizing the necessity of accurate prediction tools for effective airway management.[2]

Preoperative airway evaluation is a fundamental aspect of anesthesia care, enabling providers to systematically identify potential risk factors for difficult laryngoscopy and intubation. Various methods, such as the inter-incisor gap, Mallampati grading, head and neck movement assessment, upper lip bite test, thyromental distance (TMD), and sternomental distance (SMD), are commonly employed for airway evaluation. However, no single test or combination of tests has demonstrated sufficient accuracy to reliably predict difficult intubations, with existing methods often yielding low sensitivity and high false-positive rates.[3,4]

Several factors contribute to the progression from a simple to a difficult airway, including patient characteristics, medical and surgical history, vital signs, current airway status, and the clinical scenario necessitating airway management. The difficulty of airway management can be highly variable and depends on multiple factors, making accurate prediction challenging even for specialist clinicians.[2] In recent years, the height-to-thyromental distance ratio (RHTMD) and the height-to-sternomental distance ratio (RHSMD) have emerged as promising screening tests for predicting difficult laryngoscopy. These ratios integrate height, a readily measurable anthropometric parameter, with established airway assessment techniques, offering a potentially more comprehensive approach to airway prediction. While studies on RHTMD and RHSMD are limited, their potential clinical utility merits further investigation.

This study aimed to evaluate the predictive abilities of the height-to-thyromental distance ratio (RHTMD) and the height-to-sternomental distance ratio (RHSMD) as screening tests for difficult airway management. By comparing these parameters, the findings provide valuable insights into improving preoperative airway assessment and enhancing patient safety during airway management.

## 2. Materials and Methods

This cross-sectional study was conducted after obtaining approval from the Institutional Ethics Committee (EC/MGM/ Sept 22/44) and in accordance with the principles outlined in the declaration of Helsinki. A total of 150 patients meeting the inclusion criteria were enrolled, with written informed consent obtained from each participant. The study details were explained in the local vernacular language to ensure comprehension. Patients were included if they were adults aged 18 years or older, undergoing elective surgery, and able to provide informed consent. Those who were excluded had conditions such as the need for rapid sequence induction, limited mouth opening, unstable cervical spine or restricted neck mobility, reactive airway disease, or the presence of a neck mass, as these factors could interfere with the airway assessment and management process.

The sample size was calculated using the formula: $n = [Z^2_{\alpha/2} \cdot p \cdot q]/d^2$

Where $Z_{\alpha/2}$ is the standard normal variate at a 95% confidence interval (1.96), p is the expected prevalence of difficult intubation from prior study by Ray S et al.,[4] $q = 1 - p$ and d is the precision or allowable error. Based on a confidence level of 95% and 80% power, the calculated sample size was determined to be 150 participants.

Preoperative airway assessments were performed by a single investigator to eliminate interobserver bias. These assessments included a detailed history, clinical evaluation, and measurement of specific parameters such as thyromental distance (TMD), Sternomental distance (SMD), ratio of height to TMD (RHTMD), and ratio of height to SMD (RHSMD). Height was measured in centimeters from the vertex to the heel with the patient in a standing position.

The TMD was measured from the mentum to the thyroid notch using a rigid scale with the head fully extended and the mouth closed (Figure 1). The TMD was categorized as Class I (>6.5 cm), Class II (6–6.5 cm), and Class III (<6 cm). Similarly, the SMD, measured from the mentum to the sternal notch in full neck extension, was considered normal if it exceeded 12.5 cm (Figure 2).

**Figure 1:** Measurement of thyromental distance (TMD)

The RHTMD was calculated by dividing the patient's height in centimeters by the TMD, with values <23.5 classified as easy and ≥23.5 classified as difficult. Likewise, the RHSMD was derived by dividing height by SMD, with values <12.5 indicating easy intubation and ≥12.5 suggesting difficulty.

In the operating room, baseline vitals were recorded, and a difficult airway cart was prepared, including essential equipment such as a bougie, stylet, video laryngoscopes, laryngeal mask airways, and fiberoptic bronchoscopes. Monitors were applied for continuous electrocardiogram (ECG), non-invasive blood pressure, pulse oximetry, and

**Figure 2:** Measurement of sternomental distance (SMD)

capnography. Patients were premedicated with intravenous glycopyrrolate (10 mcg/kg) and midazolam (0.05 mg/kg). Preoxygenation with 100% oxygen was administered for three minutes prior to induction. General anesthesia was induced with intravenous fentanyl (2 mcg/kg) and propofol (2–3 mg/kg) until the loss of verbal response. Endotracheal intubation was facilitated with succinylcholine (2 mg/kg).

Direct laryngoscopy was performed using a Macintosh blade, and glottic visualization was classified according to the Cormack-Lehane grading system. Grade I indicated full visualization of the laryngeal field, Grade II signified partial visualization of the laryngeal aperture or arytenoids, Grade III included visualization of only the epiglottis, and Grade IV was limited to the soft palate. Intubation was considered difficult if Cormack-Lehane Grades III or IV were observed, if more than three attempts were required, if the procedure exceeded ten minutes, or if special manoeuvres or devices such as a stylet, bougie, or fiberoptic bronchoscope were necessary.

Following successful intubation, tube placement was confirmed through bilateral air entry, and the endotracheal tube was secured. Further anaesthetic management was done as per the institutional protocol. Hemodynamic parameters were recorded at key stages, including pre-drug administration, post-induction, post-laryngoscopy, and at two and five minutes thereafter. Postoperative complications such as trauma, airway edema, and sore throat were monitored and documented for 24 hours.

### 2.1. Statistical analysis

The data analysis was conducted using SPSS version 22.0. All subject data was entered into a computer database for calculation and analysis of response frequencies. The prevalence of outcomes was calculated with 95% confidence intervals. Data normality was assessed to determine the appropriate use of parametric or non-parametric tests for analysing quantitative variables. For categorical variables, associations were evaluated using the chi-square test. The Mann-Whitney test was applied for continuous data that did not follow a normal distribution. Statistical significance was set at a p-value $< 0.05$. This threshold indicates that results with a p-value below 0.05 were considered statistically significant, suggesting a low probability that the observed differences occurred by chance.

## 3. Results

This study enrolled 150 patients undergoing elective surgery under general anesthesia, with the majority (30%) aged 21-30 years and a slight male predominance (52.7%). Most patients (76.7%) were ASA grade I, and 74% had normal BMI. The study aimed to compare the efficacy of RHTMD and RHSMD in predicting difficult airways.

### 3.1. Demographic profile

The demographic profile revealed that the 21–30-year age group had the highest representation (30%), while the ≤20-year group had the lowest (6.7%). Males slightly outnumbered females (52.7% vs 47.3%). ASA Grade I patients comprised 76.7% of the sample, with the remainder being Grade II. Regarding BMI, 74% of participants had normal BMI, 24% were overweight, and 2% were underweight (Table 1).

**Table 1:** Demographic profile

| Variable | Group | Frequency | Percent |
|---|---|---|---|
| **Age Group** | ≤20 Years | 10 | 6.7 |
| | 21 to 30 Years | 45 | 30.0 |
| | 31 to 40 Years | 40 | 26.7 |
| | 41 to 50 Years | 30 | 20.0 |
| | 51 to 60 Years | 25 | 16.7 |
| **Sex** | Female | 71 | 47.3 |
| | Male | 79 | 52.7 |
| **ASA Grade** | I | 115 | 76.7 |
| | II | 35 | 23.3 |
| **BMI** | Underweight | 3 | 2.0 |
| | Normal | 111 | 74 |
| | Overweight | 36 | 24 |

### 3.2. Distribution of outcomes

In terms of airway prediction outcomes, RHTMD identified 12.7% of cases as difficult and 87.3% as easy, while RHSMD predicted 14% as difficult and 86% as easy. The gold standard Cormack-Lehane (CL) grading showed 12% of cases as difficult and 88% as easy (Table 2).

**Table 2:** Distribution of outcomes

| Method | Outcome | Frequency | Percent |
|---|---|---|---|
| RHTMD Airway Prediction | D | 19 | 12.7 |
| | E | 131 | 87.3 |
| RHSMD Airway Prediction | D | 21 | 14.0 |
| | E | 129 | 86.0 |
| Cormack Lehane Grade Airway Prediction | D | 18 | 12.0 |
| | E | 132 | 88.0 |

D: Difficult; E: Easy

**Table 3:** Measure of sensitivity and specificity of RHTMD

| RHTMD | | Cormack Lehane Grade | | Total |
|---|---|---|---|---|
| | | Difficult | Easy | |
| Difficult (%) | | 16(88.9%) | 3(2.3%) | 19(12.7%) |
| Easy (%) | | 2(11.1%) | 129(97.7%) | 131(87.3%) |
| Total (%) | | 18(100.0%) | 132(100.0%) | 150(100.0%) |
| Pearson Chi-Square | Value | Df | p value | Result |
| | 107.426[a] | 1 | 0.000 | Sig |
| Sensitivity | 88.90% | | | |
| Specificity | 97.70% | | | |
| PPV | 84.21% | | | |
| NPV | 98.47% | | | |
| Accuracy | 96.67% | | | |

### 3.3. *Sensitivity and specificity of RHTMD*

The RHTMD method demonstrated high diagnostic accuracy when compared to the CL grade. It showed a sensitivity of 88.9%, specificity of 97.7%, positive predictive value (PPV) of 84.21%, negative predictive value (NPV) of 98.47%, and overall accuracy of 96.67%. A statistically significant association was observed between RHTMD and CL grade outcomes, with a chi-square value of 107.426 and a p-value < 0.001 (Table 3).

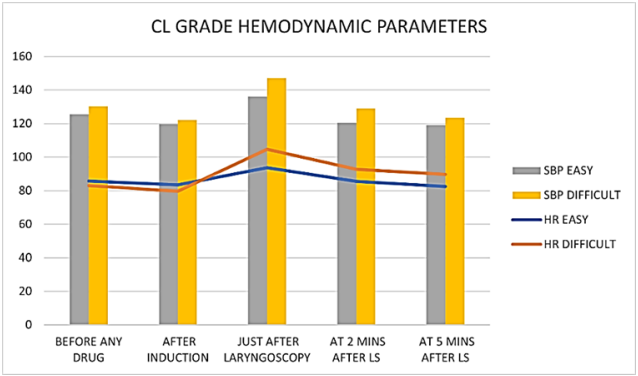
### 3.4. *Sensitivity and specificity of RHSMD*

Similarly, the RHSMD method also showed good performance, although slightly lower than RHTMD. It had a sensitivity of 83.3%, specificity of 95.5%, PPV of 71.43%, NPV of 97.67%, and overall accuracy of 94%. The association between RHSMD and CL grade outcomes was also statistically significant, with a chi-square value of 105.520 and a p-value < 0.001 (Table 4).

### 3.5. *Correlation of HR and SBP with prediction methods*

The results of the correlation between heart rate (HR) and systolic blood pressure (SBP) with different airway prediction methods are illustrated in Graphs 1, 2 and 3.

Graph 1 depicts the correlation of HR and SBP with the Cormack-Lehane (CL) Grade at various time points. The data shows that both HR and SBP increase from baseline to the point of intubation, with more pronounced elevations observed in patients classified as having difficult airways (CL Grade 3-4) compared to those with easier airways (CL Grade 1-2). This indicates a significant cardiovascular response associated with airway difficulty during the intubation process.



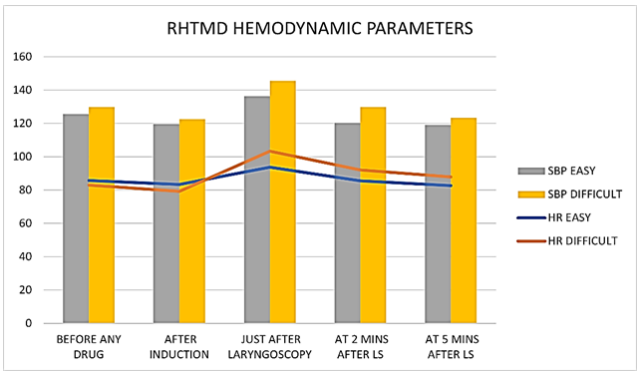

Graph 1: Correlation of HR and SBP to CL Grade at different durations

Graph 2 presents the correlation of HR and SBP with the height-to-thyromental distance ratio (RHTMD) across different durations. Similar to the findings in Graph 1, HR and SBP show an upward trend from baseline to post-intubation, peaking at the time of intubation. Patients predicted to have difficult airways according to the RHTMD method exhibit consistently higher values for both HR and SBP throughout all measured time points compared

**Table 4:** Measure of sensitivity and specificity of RHSMD

| RHSMD | | Cormack Lehane Grade | | Total |
|---|---|---|---|---|
| | | Difficult | Easy | |
| Difficult (%) | | 15 (83.3%) | 6 (4.5%) | 21 (14.0%) |
| Easy(%) | | 3 (16.7%) | 126 (95.5%) | 129 (86.0%) |
| Total (%) | | 18 (100.0%) | 132 (100.0%) | 150 (100.0%) |
| Pearson Chi-Square | Value | Df | p value | Result |
| | 105.520[a] | 1 | 0.000 | Significant |
| Sensitivity | 83.30% | | | |
| Specificity | 95.50% | | | |
| PPV | 71.43% | | | |
| NPV | 97.67% | | | |
| Accuracy | 94.00% | | | |

to those predicted as easy. This suggests that RHTMD is effective in identifying patients who may experience greater hemodynamic stress during airway management.

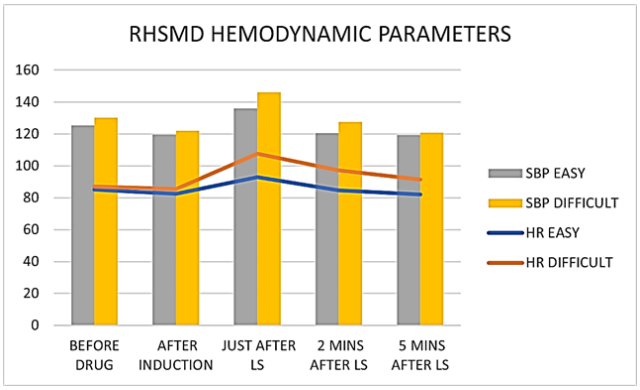



Graph 2: Correlation of HR and SBP to RHTMD at different durations

Graph 3 illustrates the correlation of HR and SBP with the height-to-Sternomental distance ratio (RHSMD) at various durations. The trends observed are consistent with those seen in the previous graphs, where HR and SBP increase progressively from baseline to post-intubation, reaching their highest levels during intubation. Patients identified as having difficult airways by RHSMD also demonstrate elevated HR and SBP values compared to those predicted as easy.

### *3.6. Association between complications and outcomes*

The study also examined the association between complications and outcomes across different airway prediction methods. For the CL Grade, among cases identified as difficult, 27.8% had trauma/bleeding, 61.1% had airway edema, and 61.1% reported postoperative sore throat. RHTMD-predicted difficult cases reported 26.3% trauma/bleeding, 57.9% airway edema, and 57.9% postoperative sore throat. RHSMD-predicted difficult cases showed 23.8% trauma/bleeding, 52.4% airway edema, and 47.6% postoperative sore throat (Table 5). All methods




Graph 3: Correlation of HR and SBP to RHSMD at different durations

demonstrated statistically significant associations between complications and airway difficulty outcomes ($p<0.001$). Table 5 provides a comparison of complications across different airway prediction methods. All methods showed statistically significant associations between complications and airway difficulty outcomes ($p < 0.001$).

## 4. Discussion

The anticipation and management of difficult airways are integral to anaesthetic practice, as failure to predict airway difficulties can lead to catastrophic outcomes, including significant morbidity and mortality. Various preoperative airway assessment methods, including inter-incisor gap, mouth opening, Mallampati grading, head and neck movement, upper lip bite test, Sternomental distance (SMD), and thyromental distance (TMD), have been used to predict difficult intubation. However, their sensitivity and accuracy remain limited, often yielding high false-positive results.[5,6] Based on existing literature, the Ratio of Height to Thyromental Distance (RHTMD) and Ratio of Height to Sternomental Distance (RHSMD) are considered useful screening tools for predicting airway difficulties.[5,7] These methods are especially relevant due to their simplicity

**Table 5:** Association between complications and outcomes

| Airway Prediction Method | | Trauma/ Bleeding | Airway Edema | Post Op Sore Throat |
|---|---|---|---|---|
| **CL Grade** | E (132) | 0(0.0%) | 5(3.8%) | 18(13.6%) |
| | D (18) | 5(27.8%) | 11(61.1%) | 11(61.1%) |
| | Total (150) | 5(3.3%) | 16(10.7%) | 29(19.3%) |
| | Chi Square Test | Chi Sq = 37.93 p = 0.000 (S) | Chi Sq = 54.62 p = 0.000 (S) | Chi Sq = 22.89 p = 0.000 (S) |
| **RHTMD** | E (129) | 0(0.0%) | 5(3.8%) | 18(13.7%) |
| | D (21) | 5(26.3%) | 11(57.9%) | 11(57.9%) |
| | Total (150) | 5(3.3%) | 16(10.7%) | 29(19.3%) |
| | Chi Square Test | Chi Sq = 35.662 p = 0.000 (S) | Chi Sq = 50.925 p = 0.000 (S) | Chi Sq = 20.74 p = 0.000(S) |
| **RHSMD** | E (129) | 0(0.0%) | 5(3.9%) | 19(14.7%) |
| | D (21) | 5(23.8%) | 11(52.4%) | 10(47.6%) |
| | Total (150) | 5(3.3%) | 16(10.7%) | 29(19.3%) |
| | Chi Square Test | Chi Sq = 31.773 p = 0.000 (S) | Chi Sq = 44.59 p = 0.000(S) | Chi Sq = 12.53 p = 0.000(S) |

and clinical applicability. The present study was designed to compare these ratios and determine a more effective predictor of difficult intubation during routine anaesthetic practice, contributing to safer airway management protocols in the future.

This study demonstrated that RHTMD emerged as a more reliable predictor of difficult intubation compared to RHSMD. Among the 18 patients classified as having difficult intubation using the Cormack-Lehane (CL) grading system as the gold standard, 16 were identified using RHTMD with a cut-off value of ≥23.5. This yielded a sensitivity of 88.9%, specificity of 97.7%, and an overall accuracy of 96.67%. Similar findings have been reported by Schmitt et al., who found that the specificity of RHTMD was significantly higher (0.91) compared to Thyromental Distance (TMD) (0.73), suggesting its superiority as a predictor of difficult laryngoscopy.[8] In alignment with our findings, Kaniyil et al. also reported RHTMD as the single best test with a sensitivity of 62.5% and specificity of 96.1%, affirming its clinical value in predicting difficult airways.[9]

In comparison, RHSMD correctly identified 15 out of 18 cases of difficult intubation, with a cut-off value of ≥12.5. This method showed a sensitivity of 83.3%, specificity of 95.5%, and an overall accuracy of 94% (Table 4). These results align with Farzi et al., who demonstrated the utility of RHSMD as a valuable screening tool, with minimal false negatives and high predictive value in assessing airway difficulty.[10] The study also highlighted that both RHTMD and RHSMD are statistically significant predictors of difficult intubation. However, the higher sensitivity, specificity, and accuracy of RHTMD make it a more robust tool, especially when used alongside RHSMD, as the combination further enhances predictive reliability.

The demographic profile of patients in this study showed that the majority were aged between 21 and 30 years (30%), with a slightly higher proportion of males (52.7%) compared to females (47.3%). Most patients belonged to ASA Grade I (76.7%) and had a normal BMI (74%), as summarized in Table 1. These characteristics are consistent with those reported in similar studies, where factors such as age, sex, and ASA grading were not significant predictors of airway difficulty. The incidence of difficult intubation in this study was 12%, with no cases of failed intubation. These results fall within the range reported in the literature, where the incidence of difficult intubation varies between 1% and 18%, and failed intubation ranges from 0.05% to 0.35%.[11] The variation in incidence can be attributed to factors such as ethnic differences in anthropometry, operator expertise, and techniques employed during laryngoscopy.[12]

The correlation of hemodynamic parameters, such as heart rate and systolic blood pressure (SBP), with predicted airway difficulty was also assessed. Significant changes in these parameters were observed in patients classified as difficult intubation. For those predicted as difficult using CL grading, RHTMD, and RHSMD, higher heart rates and SBP were recorded after laryngoscopy and at 2–5 minutes post-laryngoscopy. These findings highlight the physiological stress and complications associated with difficult intubation, necessitating close monitoring of hemodynamic parameters during airway management.

Complications such as trauma/bleeding and airway edema were more frequently observed in patients with difficult intubation across all predictive methods. For example, CL grading identified 27.8% of difficult cases with trauma/bleeding and 61.1% with airway edema. Similarly, RHTMD and RHSMD also showed significant associations between complications and predicted airway

difficulty. These findings emphasize the clinical importance of preoperative airway assessment to minimize risks associated with difficult intubation. The American Society of Anesthesiologists (ASA) Task Force on Difficult Airway Management has recommended limiting conventional laryngoscopy attempts to three to reduce airway trauma.[13] This recommendation, although based on expert consensus rather than evidence-based data, highlights the need for accurate predictive tools to guide airway management.[14]

The study's results should be interpreted in light of certain limitations. The findings may not be generalizable to other populations due to anthropometric variations across ethnic groups. The cut-off values for RHTMD and RHSMD, which were 23.5 and 12.5, respectively, in this study, may differ in other populations. This variability highlights the need for population-specific validation of these predictive indices.[15] Additionally, the diagnostic value of airway predictors varies across clinical settings and patient demographics, presenting an ongoing challenge for anaesthesiologists. Thorough preoperative airway assessments and adherence to established difficult airway algorithms remain essential for optimizing patient outcomes and reducing airway-related complications.[16]

## 5. Conclusion

Ratio of Height to Thyromental Distance (RHTMD) is a more accurate and reliable predictor of difficult intubation compared to Ratio of Height to Sternomental Distance (RHSMD). When used together, these methods provide an enhanced predictive framework, aiding in the early identification of patients at risk for difficult airway management. Future studies should focus on validating these findings in diverse populations to establish universally applicable cut-off values and further refine airway assessment protocols.

## 6. Sources of Funding

None.

## 7. Conflicts of Interest

None.

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**Cite this article:** Pal R, Agrawal A, Valecha D, Banjare M. Height to thyromental distance ratio and height to sternomental distance ratio comparison as difficult airway predictors: A cross-sectional study. *Indian J Clin Anaesth* 2025;12(1):118-124.