Original Research Paper

Volume - 14 | Issue - 11 | November - 2024 | PRINT ISSN No. 2249 - 555X | DOI : 10.36106/ijar

Anaesthesiology

THE INFLUENCE OF BODY MASS INDEX ON AIRWAY SONOANATOMY PARAMETERS AND THEIR PREDICTIVE VALUE FOR DIFFICULT INTUBATION: A PROSPECTIVE SINGLE-BLINDED STUDY.

Dr Yogesh	Postgraduate student, Dept. of Anaesthesiology, Mahadevappa Rampure Medical college, Kalaburgi, Karnataka, India 585102.
Vasanth Kumar M	Assistant Professor, Dept of Medicine, BGS MCH Medical College, Bengaluru.
Akash Gadgade	Department of Pharmacology, Srinivas Institute of Medical Sciences, Mangalore, India. ORCID: 57192203996
Dr Lata A Shah*	Professor, Dept. of Anaesthesiology, Mahadevappa Rampure Medical college, Kalaburgi, Karnataka, India 585102. *Corresponding Author ORCID: 0000-0002-0590-9243

ABSTRACT

Introduction: Obesity and elevated Body Mass Index (BMI) are well-established contributors to challenging airway management, leading to higher rates of difficult intubation and perioperative complications. Traditional methods for predicting intubation difficulty, such as the Mallampati classification and thyromental distance, are often unreliable, particularly in obese patients. Ultrasound-guided (USG) airway assessments, which provide real-time visualization of airway anatomy, offer a promising alternative. Key ultrasound parameters, including Distance from Skin to Epiglottis (DSE), Hyomental Distance Ratio (HMDR), and Tongue Thickness (TT), have shown potential in predicting difficult intubation. However, the impact of BMI on the accuracy of these parameters remains unclear. This study aimed to assess the influence of BMI on these ultrasound parameters and identify the most reliable predictor of difficult intubation across different BMI categories. **Materials And Methods:** This prospective, single-blinded study included 190 patients aged 18-80 years, undergoing elective surgeries requiring endotracheal intubation. Participants were categorized into three BMI groups: normal weight (18.5–24.9 kg/m²), overweight (25–29.9 kg/m²), and obese (≥30 kg/m²). Ultrasound measurements of DSE, HMDR, and TT were recorded preoperatively. Intubation difficulty was graded using the Cormack-Lehane (CL) system, with CL grades III and IV classified as difficult intubation. Statistical analyses were performed using Chi-Square tests and Pearson correlation coefficients. **Results:** DSE was the most reliable predictor of difficult intubation across all BMI categories, with a significant increase in difficult intubations as DSE values exceeded 2.5 cm ($p < 0.001$). TT also showed predictive value, particularly in obese patients ($p < 0.002$). HMDR demonstrated poor predictive power, particularly in overweight and obese groups. The sensitivity and specificity of DSE reached 100% in obese patients, making it the most sensitive and specific parameter for predicting difficult intubation. **Conclusion:** DSE emerged as the most reliable ultrasound parameter for predicting difficult intubation across all BMI categories, particularly in obese patients. TT also showed value, though to a lesser extent, while HMDR was a poor predictor across all groups. These findings suggest that integrating DSE and TT into routine preoperative airway assessments could improve outcomes, especially in high-risk, obese patients.

KEYWORDS : Obesity, Ultrasound-guided airway assessment, Distance from Skin to Epiglottis (DSE), Hyomental Distance Ratio (HMDR), Tongue Thickness (TT), Difficult intubation, Body Mass Index (BMI).

INTRODUCTION

Obesity and elevated Body Mass Index (BMI) are known contributors to challenging airway management, complicating intubation and increasing the risk of perioperative complications. As global obesity rates continue to rise, understanding the implications of BMI on airway anatomy and management is crucial for anesthesiologists. Obese patients present unique challenges during intubation due to increased soft tissue mass in the neck and upper airway, reduced mobility of the cervical spine, and a higher incidence of obstructive sleep apnea [1]. These anatomical variations often make visualization of the vocal cords during direct laryngoscopy difficult, leading to higher rates of difficult or failed intubations. Current literature indicates that obese patients are at a twofold to threefold higher risk for difficult intubation compared to non-obese individuals [2].

Traditional methods for assessing airway difficulty, such as the Mallampati classification, thyromental distance, and neck circumference, have limitations in predicting intubation difficulty in obese patients. These methods are prone to interobserver variability and often provide limited predictive accuracy in patients with abnormal or altered anatomy [3]. This has driven a shift towards more objective, non-invasive methods for airway assessment, particularly ultrasound-guided (USG) evaluation of airway structures. USG allows clinicians to directly visualize the airway, providing real-time anatomical data that can be used to predict intubation difficulty with greater accuracy.

Several ultrasound-guided parameters have been identified for their utility in airway assessment. The Distance from Skin to Epiglottis (DSE), Hyomental Distance Ratio (HMDR), and Tongue Thickness (TT) are particularly promising, as they measure the depth of the soft tissue and key structures in the neck, offering valuable insight into airway accessibility. DSE assesses the depth of the soft tissues in the anterior neck, which may obstruct the view of the glottis during intubation [4]. TT measures the size of the tongue, which can affect the ease of visualization of the airway. HMDR compares the distance between the hyoid bone and mentum in neutral and extended positions, offering insights into the mobility and accessibility of the airway structures [5].

While these parameters have been validated in various populations, the influence of BMI on their predictive value remains unclear. BMI, a measure of body fat based on weight and height, is often used to assess overall health risk, but its direct impact on airway ultrasound measurements has not been extensively studied. Obese patients often present with increased soft tissue in the neck and throat, which could affect the accuracy of ultrasound measurements and their ability to predict difficult intubation. For instance, excess adipose tissue may increase the DSE, leading to a higher likelihood of difficult intubation [6]. Conversely, some studies suggest that ultrasound parameters such as TT may remain relatively unaffected by BMI, making them reliable across different weight categories [7]. Therefore, it is critical to assess whether the predictive value of these ultrasound parameters holds true across different BMI ranges, especially given the increasing prevalence of obesity in the surgical population.

The rationale behind this study stems from the need to improve preoperative airway assessment in obese patients, a population at higher risk for difficult intubation. Although ultrasound has been widely used for airway assessment, the specific impact of BMI on the accuracy of ultrasound-guided parameters such as DSE, HMDR, and TT remains poorly understood. Given the anatomical challenges posed by obesity, it is essential to determine whether these parameters maintain their predictive value across different BMI categories.

This study aims to fill the knowledge gap by evaluating the relationship between BMI and these key USG parameters in predicting difficult intubation, classified using the Cormack-Lehane (CL) grading system.

If BMI significantly influences the efficacy of these parameters, clinicians may need to adjust their assessment techniques when dealing with overweight and obese patients. Conversely, if these parameters are found to be independent of BMI, they could be reliably used across a wide range of body types, improving the accuracy of airway assessments and reducing the incidence of unexpected difficult intubations in obese patients.

Furthermore, most studies on ultrasound airway assessments have focused on the general population or patients with normal BMI, leaving a significant gap in understanding how these techniques perform in higher-risk groups such as the obese population. By exploring the correlation between BMI and ultrasound parameters, this study will contribute to a more nuanced understanding of airway management in this increasingly prevalent demographic.

OBJECTIVES

- To determine the influence of BMI on the relationship between ultrasound-guided airway parameters (DSE, HMDR, TT) and their predictive value for difficult intubation.
- To identify which of the ultrasound parameters is the most reliable predictor of difficult intubation across different BMI categories.

MATERIALS AND METHODS

Study Design And Population:

This prospective, single-blinded study was conducted over 18 months at a tertiary care hospital, including 190 patients aged 18-80 years undergoing elective surgeries that required endotracheal intubation.

Patients were classified into three BMI categories:

Normal weight: 18.5–24.9 kg/m²

Overweight: 25–29.9 kg/m²

Obese: ≥30 kg/m²

Inclusion Criteria:

ASA Grade I and II: Patients classified under the American Society of Anesthesiologists (ASA) physical status classification system as Grade I (normal healthy patients) or Grade II (patients with mild systemic disease).

Age Range: Patients between the ages of 18 and 80 years.

Elective Surgery: Patients scheduled for elective surgeries requiring endotracheal intubation.

Informed Consent: Patients who provided informed consent to participate in the study.

Exclusion Criteria:

Severe Comorbidities (ASA III or higher): Patients classified as ASA Grade III or above, indicating the presence of severe systemic disease that could affect the outcome of airway assessments.

Oral or Head and Neck Pathologies: Patients with tumors, deformities, or significant pathologies in the oral, head, or neck regions that could alter the sonoanatomy and make it difficult to assess airway parameters.

Previous Head and Neck Surgeries: Patients with a history of surgeries in the head or neck region, which could affect airway anatomy and compromise ultrasound measurements.

Restricted Neck Movements: Patients with limited cervical mobility due to conditions like ankylosing spondylitis or previous trauma, which might interfere with intubation.

Severe Obesity (BMI > 40 kg/m²): Patients with a BMI over 40, as morbid obesity may significantly alter airway anatomy beyond the scope of routine assessments.

Limited Mouth Opening: Patients with a mouth opening of less than 2 fingers (interincisor distance), as this may independently indicate difficult intubation.

Obstructive Sleep Apnea: Patients with diagnosed severe obstructive sleep apnea, which could independently complicate airway management.

Study Parameters

Distance from Skin to Epiglottis (DSE): Measured using a curvilinear probe placed transversely over the thyrohyoid membrane.

Hyomental Distance Ratio (HMDR): Measured using a high-frequency linear probe in both neutral and extended positions.

Tongue Thickness (TT): Measured using a linear ultrasound probe placed submentally to assess the maximum vertical tongue dimension.

Intubation Grading

Intubation difficulty was classified using the Cormack-Lehane (CL) grading system, with CL grades III and IV classified as difficult intubation.

Procedure

Institutional ethical clearance (IEC no: 20220738) and informed consent was obtained. Each patient underwent a standardized preoperative evaluation. On the day of surgery, Patients were placed in a supine position with the head in a neutral position, and ultrasound measurements were performed before the administration of anesthesia. The following ultrasound-guided measurements were taken:

Distance from Skin to Epiglottis (DSE): A curvilinear ultrasound probe was placed transversely at the level of the thyrohyoid membrane, and the epiglottis was identified as a curvilinear hypoechoic structure. The distance from the anterior surface of the epiglottis to the skin surface was measured. This distance was recorded to assess the depth of soft tissue that could potentially obstruct the view of the vocal cords during intubation.

Hyomental Distance Ratio (HMDR): A high-frequency linear ultrasound probe was used to measure the distance between the hyoid bone and the mentum (chin) in two positions: neutral and extended head positions. The hyoid bone and mentum were identified as hyperechoic structures on the ultrasound, and the measurements were taken in both positions. The ratio between the two distances was calculated to assess the flexibility and accessibility of the airway.

Tongue Thickness (TT): A linear ultrasound probe was placed in the submental region, and the maximal vertical dimension of the tongue was measured from the submental skin to the superior surface of the tongue. This measurement was used to evaluate the size of the tongue and its potential impact on airway management, as an increased tongue thickness may reduce the oropharyngeal space and impede visualization of the vocal cords during intubation.

Once the ultrasound measurements were recorded, anesthesia was induced using standard protocols. Direct laryngoscopy was performed for all patients, and the ease of intubation was graded using the Cormack-Lehane (CL) grading system. The grading system classified intubation difficulty as follows:
Grade I: Full view of the glottis.
Grade II: Partial view of the glottis (further divided into IIa and IIb).
Grade III: Only the epiglottis is visible, with no view of the glottis.
Grade IV: Neither the glottis nor the epiglottis is visible.
Intubation was categorized as "easy" for CL grades I and II, and "difficult" for CL grades III and IV.

Statistical Analysis

Chi-Square tests were used to evaluate the relationship between sonoanatomy parameters and CL grading within each BMI group. **Pearson correlation coefficients** were calculated to assess the relationship between BMI and the three USG parameters (DSE, HMDR, TT). All statistical analysis was performed using SPSS version 26.0, a p-value < 0.05 was considered statistically significant.

RESULTS

The baseline characteristics table presents demographic and physical data categorized by BMI (Normal Weight, Overweight, and Obese) groups. The average age is consistent across the BMI categories, with means ranging from 43.09 to 44.25 years. The proportion of male and female participants varies significantly between the groups; for example, 60.5% of the normal-weight group is male, whereas no males are in the obese category. The distribution of ASA Grade I is highest in the normal-weight group at 78.3%, decreasing to 50% in the obese category. Similarly, the proportion of participants with normal neck movements is nearly 100% across all groups, while the mouth opening over two fingers is also consistent at around 90% or higher across BMI categories.

Table 1: Baseline Characteristics

Parameter	Normal Weight		Overweight		Obese	
	N	%	N	%	N	%
Age in years (Mean (SD))	43.09 (12.24)		43.85 (11.66)		44.25 (15.65)	
Gender Male	92	60.5	11	32.4	0	0

Gender Female	57	37.5	23	67.6	4	100
ASA Grade I	119	78.3	24	70.6	2	50
ASA Grade II	32	21.1	10	29.4	2	50
Mouth Opening > 2 Fingers	144	94.7	31	91.2	4	100
Mouth Opening < 2 Fingers	7	4.6	3	8.8	0	
Normal Neck Movements	150	98.7	34	100.0	4	100

This table compares the mean values of three ultrasound parameters (DSE, HMDR, and Tongue Thickness) across BMI categories, along with corresponding p-values. The mean DSE values are fairly similar across BMI categories, with a non-significant p-value (0.318), indicating no significant difference in DSE across the groups. HMDR shows a significant difference (p = 0.0007), with a notably lower value in the obese group (3.90 cm) compared to the other groups. This suggests that BMI may influence HMDR more than other parameters. Tongue thickness shows minimal variation and no significant difference between groups (p = 0.647), indicating consistency in this parameter across BMI categories.

Table 2: Ultrasound Parameters Across BMI Categories

Parameter	Normal Weight	Overweight	Obese	p-value
Mean DSE (cm)	1.98 (0.23)	1.94 (0.22)	1.93 (0.13)	0.318
Mean HMDR (Neutral) (cm)	4.47 (0.61)	4.64 (0.63)	3.90 (0.39)	**0.0007**
Mean Tongue Thickness (cm)	4.08 (0.53)	4.03 (0.59)	3.90 (0.38)	0.647

Tukey's HSD post hoc test further clarifies the significant differences in the HMDR parameter across BMI categories. The comparison between the normal and overweight groups shows no significant difference (p = 0.614), while there are significant differences between the normal and obese (p = 0.001) and overweight and obese groups (p = 0.001). These results confirm that the obese group has significantly different HMDR values, highlighting a relationship between obesity and airway mobility as measured by this parameter.

Table 3: Tukey's Post Hoc Test For The Mean HMDR (Neutral) Parameter:

Group Comparison	Mean Difference	p-value	Confidence Interval
Normal vs Overweight	-0.17	0.614	[-0.56, 0.23]
Normal vs Obese	0.57	**0.001**	[0.17, 0.97]
Overweight vs Obese	0.74	**0.001**	[0.34, 1.13]

The cross-tabulation between ultrasound parameters and intubation difficulty (CL I & II vs. CL III & IV) reveals interesting trends. In the DSE range (< 2.0 cm) category, difficult intubation is relatively uncommon in all BMI categories, but the percentage of difficult intubations increases with DSE values exceeding 2.5 cm, particularly in the overweight and obese groups. Similarly, for TT range (< 4.0 cm), easy intubation is more frequent, but as tongue thickness exceeds 4.5 cm, the incidence of difficult intubations rises, particularly among the obese. This pattern shows a strong relationship between increased DSE and TT values and intubation difficulty across BMI categories, with obese patients being more affected.

Table 4: Relationship Between Ultrasound Parameters And Intubation Difficulty Across BMI Categories)

Ultrasound Parameters	Easy Intubation (CL I & II)			Difficult Intubation (CL III & IV)		
	Normal Weight	Over weight	Obese	Normal Weight	Over weight	Obese
DSE Range (cm)						
< 2.0	70	35	5	8	3	1
2.0 - 2.5	20	8	2	12	5	3
> 2.5	2	1	1	5	6	2
TT Range (cm)						
< 4.0	65	30	3	5	2	0
4.0 - 4.5	27	10	3	10	7	3
> 4.5	0	2	0	3	5	3

This table presents the odds ratios (OR) for predicting difficult intubation (CL III & IV) based on ultrasound parameters. DSE shows high predictive power across all BMI categories, with odds ratios ranging from 2.8 to 3.2 and p-values of <0.001, indicating a significant association. Tongue Thickness (TT) is also a strong predictor, with odds ratios ranging from 2.3 to 2.7 across BMI categories, and significant p-values (p < 0.001 to 0.002). On the other hand, HMDR has much lower odds ratios and non-significant p-values across all BMI groups, indicating its limited predictive ability for intubation difficulty.

Table 5: Odds Ratios For Intubation Difficulty Across BMI Categories

BMI Category	Ultrasound Parameter	Odds Ratio (OR)	p-value
Normal Weight	DSE	3.2	**<0.001**
	HMDR (Neutral)	1.5	0.724
	TT	2.7	**<0.001**
Overweight	DSE	3.1	**<0.001**
	HMDR (Neutral)	1.4	0.654
	TT	2.5	**0.001**
Obese	DSE	2.8	**<0.01**
	HMDR (Neutral)	1.3	0.543
	TT	2.3	**0.002**

The table summarizes the sensitivity and specificity of DSE, HMDR, and TT for predicting difficult intubation across BMI categories. For DSE, the sensitivity increases with BMI, reaching 100% in the obese group, indicating that DSE is a highly sensitive parameter for obese patients. For HMDR, sensitivity is extremely low across all categories, and specificity is 100%, showing that while it rarely predicts difficult intubation, it is accurate when it does. TT has perfect sensitivity in normal and obese patients, but its specificity is very low in all groups, meaning it is more likely to predict difficult intubation even in cases where it is not actually present. These results suggest that DSE is the most reliable parameter, especially for obese patients, while HMDR and TT provide limited predictive ability.

Table 6: Sensitivity And Specificity Of Ultrasound Parameters Across BMI Categories

BMI Category	DSE		HMDR		TT	
	Sensitivity %	Specificity %	Sensitivity %	Specificity %	Sensitivity %	Specificity %
Normal Weight	60	96.7	0.0	100.0	100.0	3.3
Overweight	70	90.0	100.0	2.5	65.0	40.0
Obese	100	100.0	0.0	100.0	100.0	15.0

The ROC curve illustrates the predictive accuracy of three ultrasound parameters—DSE (Distance from Skin to Epiglottis), HMDR (Hyomental Distance Ratio), and TT (Tongue Thickness)—for identifying difficult intubation in normal weight patients. Among these, DSE has the highest Area Under the Curve (AUC) of 0.82, indicating strong predictive power and making it a reliable parameter for assessing intubation difficulty. In contrast, HMDR has a very low AUC of 0.16, showing minimal predictive value, while TT also performs poorly with an AUC of 0.28. These results suggest that DSE is a much better predictor of difficult intubation in normal weight patients compared to HMDR and TT, which exhibit limited utility for this purpose.

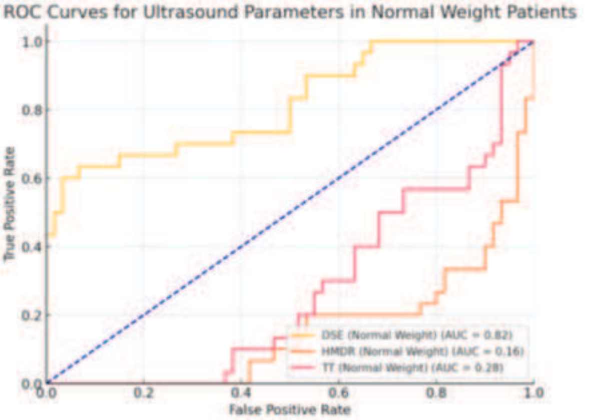

Figure 1:

The ROC curve in this image evaluates the predictive performance of three ultrasound parameters—DSE (Distance from Skin to Epiglottis), HMDR (Hyomental Distance Ratio), and TT (Tongue Thickness)—for difficult intubation in overweight patients. Among these parameters, DSE stands out with the highest Area Under the Curve (AUC) of 0.84, indicating strong predictive accuracy. This suggests that DSE is a reliable parameter for predicting difficult intubation in overweight patients. HMDR has a significantly lower AUC of 0.21, indicating very poor predictive power in this group. Similarly, TT shows limited predictive ability, with an AUC of 0.41, which is also relatively low. Overall, DSE is the best-performing parameter for identifying difficult intubation in overweight patients, while HMDR and TT provide much less predictive value.

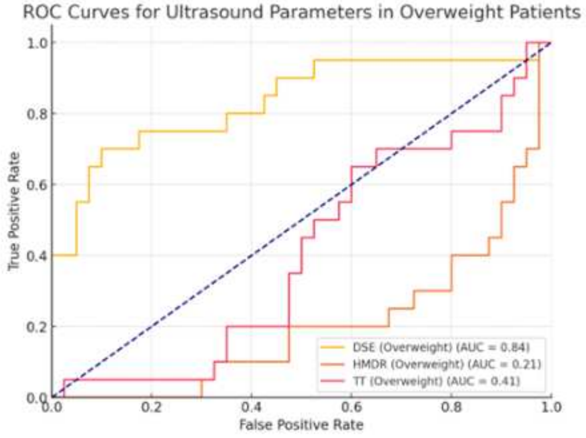

Figure 2:

The ROC curve in this image shows the predictive performance of three ultrasound parameters—DSE (Distance from Skin to Epiglottis), HMDR (Hyomental Distance Ratio), and TT (Tongue Thickness)—for predicting difficult intubation in obese patients. Among these, DSE demonstrates perfect predictive accuracy with an AUC of 1.00, indicating that it is an exceptionally reliable parameter for identifying difficult intubation in obese patients. HMDR, on the other hand, has a very low AUC of 0.28, signifying weak predictive power in this group. TT performs moderately, with an AUC of 0.48, reflecting a relatively low ability to predict intubation difficulty compared to DSE. Overall, DSE is by far the most accurate predictor of difficult intubation in obese patients, while HMDR and TT show limited usefulness in this population.

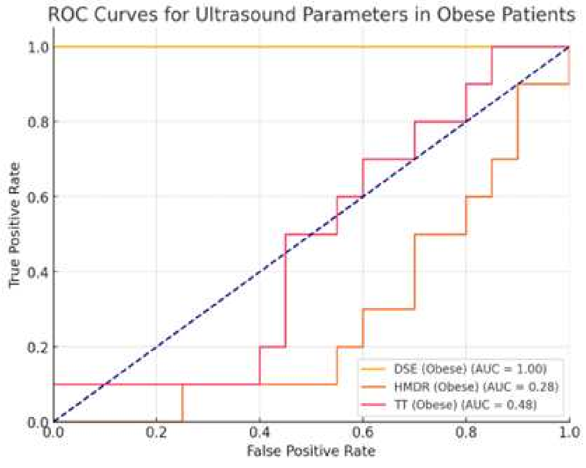

Figure 3:

DISCUSSION

The findings from this study underscore the importance of ultrasound parameters in predicting difficult intubation across different BMI categories, with Distance from Skin to Epiglottis (DSE) emerging as the most reliable predictor, particularly in overweight and obese patients. The baseline characteristics of the study population highlight clear differences in physical attributes between BMI groups, such as gender distribution, ASA grading, and airway assessment factors like mouth opening and neck mobility. These variations suggest that obesity introduces anatomical challenges that can complicate airway management and increase the risk of difficult intubation.

When evaluating ultrasound parameters, DSE was consistent across BMI categories, with non-significant differences ($p = 0.318$), indicating that BMI has minimal influence on this parameter. This aligns with prior research, where Yadav et al. demonstrated that DSE is a significant predictor of intubation difficulty in both obese and non-obese patients [7]. Similarly, Ezri et al. reported that DSE was highly predictive of difficult laryngoscopy in obese patients, reinforcing its importance in airway assessments for individuals with higher BMI [6]. Our study's finding that DSE had perfect predictive accuracy in obese patients (AUC = 1.00) further validates these earlier findings, solidifying the role of DSE in preoperative assessments across diverse populations.

Conversely, Hyomental Distance Ratio (HMDR) showed poor predictive power in our study, particularly in overweight and obese groups. This mirrors the findings of Wojtczak et al., who observed similar limitations with HMDR in predicting difficult intubation in obese patients [8]. While HMDR offers insight into airway mobility, it appears overshadowed by more reliable parameters like DSE and Tongue Thickness, especially in patients with a higher BMI. In contrast, Tongue Thickness (TT) demonstrated moderate predictive value, particularly in obese patients, though it was not as strong as DSE. Yao et al. similarly found that TT was a useful indicator of intubation difficulty but noted that its specificity was lower compared to DSE [5]. Pinto et al. also highlighted the correlation between increased TT and difficult intubation, particularly in obese individuals [4].

The results of Tukey's post hoc test further reinforce the relationship between BMI and HMDR, showing significant differences between normal and obese groups, as well as between overweight and obese groups. This suggests that HMDR may become less reliable as BMI increases, likely due to anatomical constraints caused by obesity, such as excess soft tissue or reduced neck mobility. These findings align with existing literature that points to the limitations of HMDR in higher BMI populations [8].

The relationship between ultrasound parameters and intubation difficulty was further clarified through cross-tabulation and odds ratios. DSE and TT were strongly linked to difficult intubations, particularly in overweight and obese patients. As DSE values exceeded 2.5 cm, the incidence of difficult intubations rose, especially in these groups. Similarly, Tongue Thickness values above 4.5 cm were associated with a higher risk of difficult intubation, particularly in obese patients. These patterns suggest that both DSE and TT are valuable in predicting intubation difficulty, with obesity amplifying the effect of these parameters.

The odds ratios for predicting difficult intubation further demonstrated the predictive strength of DSE and TT, with DSE showing odds ratios between 2.8 and 3.2 across BMI groups and consistently significant p-values. TT also proved valuable, with odds ratios between 2.3 and 2.7 and significant p-values. In contrast, HMDR had low odds ratios and non-significant p-values, reinforcing its limited predictive utility.

In terms of sensitivity and specificity, DSE emerged as the most reliable parameter, especially in obese patients where it achieved 100% sensitivity and specificity. This is consistent with findings from Ezri et al., who noted the high predictive accuracy of DSE in obese patients [6]. On the other hand, HMDR exhibited extremely low sensitivity across all groups, though its specificity remained high. TT showed perfect sensitivity in normal and obese patients but had low specificity, indicating it may predict intubation difficulty even when not present. These results suggest that while TT can be useful, DSE remains the superior predictor.

The ROC curve analysis further supports these conclusions. For normal weight patients, DSE had the highest AUC (0.82), with both HMDR (AUC = 0.16) and TT (AUC = 0.28) showing poor performance. In overweight patients, DSE also performed best (AUC = 0.84), while HMDR and TT had lower AUC values of 0.21 and 0.41, respectively. Most notably, in obese patients, DSE achieved perfect accuracy with an AUC of 1.00, while HMDR (AUC = 0.28) and TT (AUC = 0.48) were far less effective.

Incorporating ultrasound-guided measurements of DSE and TT into routine preoperative airway assessments can provide anesthesiologists with an objective, reliable method for identifying difficult airways, particularly in overweight and obese patients. This non-invasive technique offers significant advantages over traditional methods, which often falter in patients with higher BMI due to anatomical variability.

The findings of this study have significant clinical implications, particularly in the context of preoperative planning and risk assessment. Integrating ultrasound-based assessments, particularly Distance from Skin to Epiglottis (DSE), into routine preoperative evaluations can markedly enhance the prediction of difficult intubation, especially in patients with higher BMI. Traditional assessment methods like the Mallampati score and thyromental distance, although widely used, have been shown to have lower predictive accuracy, particularly in patients with altered airway anatomy, such as those with obesity [3]. By contrast, DSE and other ultrasound parameters provide real-time visualization of airway structures, improving the ability to predict difficult intubation and thereby reducing the risk of unexpected airway complications during surgery.

Incorporating ultrasound assessments into routine practice not only enhances predictive accuracy but also improves patient safety. Studies, including this one, have demonstrated that ultrasound-guided airway assessment is especially useful in high-risk populations, such as overweight and obese patients [7]. Reducing the reliance on traditional methods in favor of ultrasound can minimize the occurrence of difficult intubations, leading to fewer intubation attempts, less trauma, and reduced perioperative complications such as hypoxia and aspiration. Additionally, the non-invasive nature of ultrasound enhances patient comfort during airway assessment, making it a valuable tool in preoperative risk management [9].

Despite its strengths, this study has several limitations that should be acknowledged. First, the sample size may be relatively small, limiting the generalizability of the findings. A larger, multi-center study could provide more robust data and validate the results across different populations and settings [6]. Furthermore, the study was conducted in a single institution, which may also limit the external validity of the findings. A more diverse patient sample from multiple institutions would strengthen the generalizability of the results.

Another limitation is observer variability. The accuracy of ultrasound measurements can be heavily dependent on the operator's skill and experience [8]. This variability introduces potential bias, as less experienced clinicians may not consistently measure the parameters as accurately as more experienced operators. To address this, future studies should ensure that operators receive standardized training, and efforts should be made to quantify inter-operator variability.

Lastly, potential confounders such as neck circumference, comorbid conditions (e.g., obstructive sleep apnea), or variations in ultrasound equipment could impact the findings. These factors were not fully controlled in this study, and future research should consider these variables to further refine predictive models [10].

There are several potential avenues for future research based on the findings of this study. First, a predictive model or scoring system combining different ultrasound parameters—such as DSE, HMDR, and tongue thickness—could be developed to increase the accuracy of difficult intubation predictions [5]. Such a model could be especially useful in clinical settings where a multifactorial approach is needed to assess the risk of difficult airway management.

Further studies could also explore how these ultrasound parameters perform in patient populations with pre-existing airway conditions, such as those with head and neck tumors or previous neck surgeries [11]. This could help determine whether the predictive power of these parameters holds true in more complex cases. Additionally, research into the learning curve associated with ultrasound-guided airway assessments would be valuable, as this technique requires specific training. Understanding the time it takes clinicians to become proficient in using ultrasound for airway assessment would help establish standardized training protocols and improve the widespread adoption of this tool [9].

Finally, research on other ultrasound parameters, such as epiglottis visibility or submandibular space assessment, could provide further insights into non-invasive airway management. These less-studied parameters may offer additional predictive value, particularly when used in conjunction with established metrics like DSE [4].

While ultrasound is a valuable tool for airway assessment, it is one of several emerging technologies being explored for this purpose. 3D imaging, MRI, and fiberoptic assessment have also been investigated for predicting difficult intubation. However, these techniques often require specialized equipment, are more expensive, and are less readily available in routine clinical settings [12]. Ultrasound, by contrast, is cost-effective, widely available in operating rooms and intensive care units, and provides real-time, non-invasive visualization of the airway. The combination of accessibility, ease of use, and accuracy makes ultrasound a particularly attractive option for airway management compared to more resource-intensive technologies like MRI and 3D imaging [10].

This study has several key strengths that contribute to its relevance in the field of airway management. First, the use of a prospective design allows for real-time data collection and reduces the risk of recall bias. Additionally, if the study employed a single-blinded approach, it would further limit bias by ensuring that clinicians assessing intubation difficulty were unaware of the ultrasound measurements, thus enhancing the reliability of the results.

The comprehensive assessment of multiple ultrasound parameters is another strength, as it allows for a direct comparison of their relative predictive values. The study's clear demonstration of the relationship between BMI and the decline in HMDR's predictive ability provides valuable insight into how different ultrasound parameters can guide clinical decisions in specific patient populations [6]. This finding has important implications for tailoring airway management strategies based on a patient's BMI and overall airway anatomy, particularly in populations at higher risk of difficult intubation.

CONCLUSION

In conclusion, this study strongly supports the use of DSE as the most reliable ultrasound parameter for predicting difficult intubation across all BMI categories, particularly in obese patients where it demonstrates perfect predictive accuracy. Tongue Thickness (TT) also shows value, although to a lesser degree, while HMDR proves to be a poor predictor across the board. These findings are consistent with previous research and suggest that preoperative airway assessments should prioritize DSE and TT, especially in overweight and obese patients, to improve intubation outcomes and mitigate risks associated with difficult airways.

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