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Use of ultrasonographic parameters in preoperative prediction of difficult laryngoscopy in non-suspected difficult airway patients undergoing elective surgery

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Abstract

Background: Ultrasonography represents a valid as well as promising tool for assessing airway preoperatively by detecting identifying upper airways' essential sonoanatomy. The aim of this work was aimed at assessing the ultrasonographic parameters [distance from skin to epiglottis (DSE) as well as distance from skin to vocal cords (DSVC)] measured in the parasagittal plane, and determine if they could be preoperative indicators for assessing difficult laryngoscopy among cases having non-suspected difficult airway who undergo elective surgical procedure under general anesthesia.

Methods: Our prospective observational study involved 100 cases whose ages fell between eighteen and sixty-five yrs, both genders, not suspected to develop a difficult airway following airway evaluation preoperatively utilizing traditional clinical tests and undergoing for elective surgical procedure under GA. While performing direct laryngoscopy: laryngoscopic view underwent grading utilizing the modified Cormack and Lehane grading where grade I and II a deemed to be easy laryngoscopy (group A) while grade IIb, III as well as IV considered to be difficult laryngoscopy (group B).

Results: According to DSE, the cut off value was >1.94 with sensitivity 82.35%, specificity 78.31%, PPV (43.7%) as well as NPV (95.6%). The area under the curve exhibited 0.884 indicating statistical significance (p<0.001), Based on DSVC, the cut off value exhibited ≤1.22 with sensitivity 64.71%, specificity 57.83%, PPV 23.9% and NPV 88.9%. AUC exhibited 0.704 indicating statistical significance (P = 0.008). Combining both DSE and DSVC show that sensitivity 70.59%, specificity 100%, PPV 100% and NPV 94.3%. AUC was 0.921 with statistical significance (p<0.001).

Conclusion: DSE as well as DSVC measured in the parasagittal plane, are independent valuable US parameters while predicting difficult laryngoscopy among cases having non-suspected difficult airway patients. DSE possesses a better predictive value for difficult laryngoscopy. DSE >= 2.1 -+ 0.17 could predict a difficult laryngoscopy with PPV 43.7% and AUC of 88%, compared with DSVC ≤ 1.19 -+0.09 with PPV 23.9% and AUC of 70%. Combination of both DSE and DSVC provides the ideal prediction as regards difficult laryngoscopy, possessing a PPV of 100% along with AUC of 92%.

Keywords: Ultrasonographic parameters, laryngoscopy, non-suspected difficult airway, elective surgery

Introduction

Airway management represents a crucial component of general anesthesia. The primary objective is aimed at keeping the patients' airway protected, thus providing sufficient breathing as well as oxygenation for cases having surgeries while under general anesthesia [1].

Inefficient airway management as a result of unanticipated laryngoscopy's challenges represents a critical condition, resulting in morbidity as well as death [2].

Proper preoperative assessment of the patient's airway is very important. It provides good planning and management that decreases chances of adverse events related to unexpected difficult airway [3].

Several traditional clinical tests are utilized for preoperatively assessing airways, involving modified Mallampati (MMP) classification, Thyro-mental distance (TMD), inter-incisor distance (IID), cervical mobility (CM), as well as neck circumference (NC). They are often employed while predicting airways' difficulties [4], yet they exhibit reduced validity with poor sensitivity as well as specificity [5].

Predicting difficult laryngoscopy depending on preoperative evaluation remains challenging utilizing traditional clinical tests. Some cases exhibit an easy airway with clinical tests, however, they could develop unanticipated laryngoscopy's difficulties [6-7].

The patients' laryngeal view could undergo assessment as well as grading while performing direct laryngoscopy utilizing the Cormack and Lehane grading scale and its modification. Thus determining whether laryngoscopy could be easy or difficult [8].

Ultrasonography represents a beneficial as well as promising tool while assessing airway preoperatively. It detects essential upper airway sonoanatomy, including epiglottis, thyroid cartilage, as well as vocal cords [9-10].

Despite the ultrasonography is a safe quick portable non-invasive reliable widely available procedure, its use for airway assessment along with predicting laryngoscopy's difficulties remains restricted [11].

Many ultrasonographic parameters of the airway can be measured but it is still unclear which parameters are effective while predicting difficult laryngoscopy. Additionally, it needs more studies [12-13].

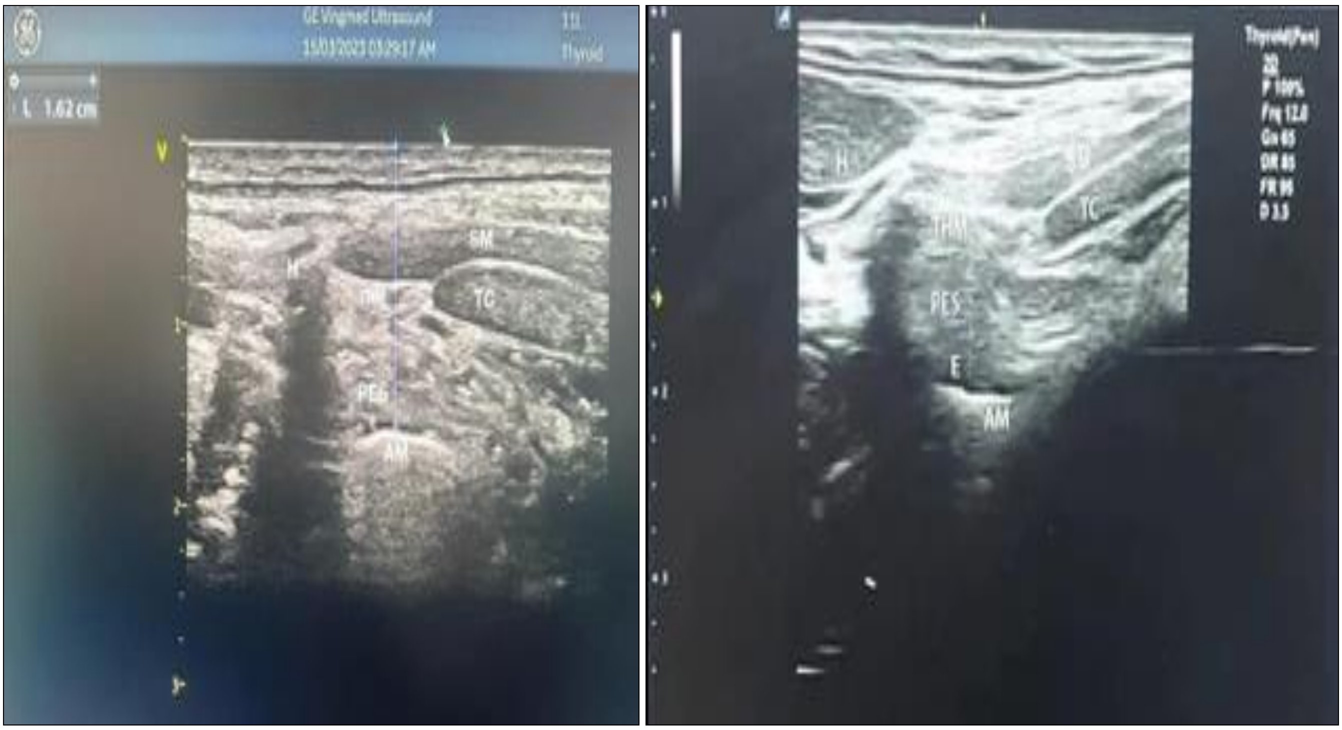
The aim of this work was aimed at assessing the ultrasonographic parameters [distance from skin to epiglottis (DSE) as well as distance from skin to vocal cords (DSVC)] measured in the parasagittal plane, and determine if they could be preoperative indicators for assessing difficult laryngoscopy among cases having non-suspected difficult airway who undergo elective surgical procedure under general anesthesia.

Patients and Methods

Our prospective observational study involved 100 cases whose ages fell between eighteen and sixty-five yrs, both genders, those not suspected to develop a difficult airway following preoperative airway evaluation utilizing traditional clinical tests including modified Mallampati class I and II, TMD >=6 cm, IID >4 cm, CM >=90", and NC =<40 cm, ASA class I, II, and III physical status and undergoing elective surgical procedure under GA. The study was done from May 2022 to May 2023 following the Ethical Committee's approval Tanta University Hospitals, Tanta, Egypt. All participants were asked to fill an informed consent.

We excluded cases having maxillofacial injuries or airway trauma, prior difficult intubation, anatomical abnormalities, neck scarring, swelling, or burn, pregnancy as well as obesity.

All participants went through the following airway evaluation: conventional clinical tests [MMP classification, TMD, IID, CM and NC at the cricoid cartilage level]. In the holding area before entering to the operating room, ultrasonographic scanning was done by anesthesiologist who was experienced in airway ultrasound using a high frequency linear probe including DSE and DSVC in the parasagittal plane (one cm far from the midline) in a supine position, not utilizing a pillow, a neutral head and neck position, looking forward with mouth shut and the tongue resting on the floor of the mouth with no motion]. DSE as well as DSVC were documented. (Figure 1, 2).



(A) **(B)**

Fig 1: (A), (B) Distance from skin to epiglottis (DSE) H (hyoid bone), TC (thyroid cartilage), THM (thyrohyoid membrane), SM (strap muscles), PES (pre-epiglottic space), E (epiglottis), A-M (air mucosal interface)

(C) (D)

Fig 2: (C), (D) Distance from skin to vocal cord (DSVC) TC (thyroid cartilage), VC (vocal cord), SM (strap muscles).

Anaesthesia technique

After arrival at the operating room, participants were attached to the standard monitoring devices including an ECG, non-invasive arterial blood pressure (NIBP), pulse oximetry (SpO_2) as well as temperature probe then the cannula was inserted, and 500 ml isotonic saline infusion was started.

Patients were pre-oxygenated using 80% O_2 by a well-fitted mask for up to three min. aesthetic induction was performed by 1-2 mic/kg fentanyl, 2 mg/kg propofol and 0.5 mg/kg atracurium. Following 3 minutes of mask ventilation, laryngoscopy was conducted through another anaesthesiologist (several years' expertise) being blind to the ultrasound measurements' findings with Macintosh blade sizes three or four in a sniffing head and neck position and a laryngoscopic view of the patients' airway underwent grading utilizing the modified Cormack and Lehane grading scale[8, 16] after position were optimized, full muscular relaxation along with applying external laryngeal manipulation when required and according to this grading scale, participants went through a categorization into two groups: Group A (easy laryngoscopy) including grade I and IIa and Group B (difficult laryngoscopy) including grade IIb, III and IV [14-15].

Modified Cormack and Lehane grading [16]

Grade I: refers to the complete visibility of entire glottis, whereas Grade IIa: only a part of the vocal cord is visible, Grade IIb: the cords' arytenoid cartilage or very posterior origin are visible, Grade III: the only visible structure is the epiglottis. And Grade IV: the epiglottis isn't visible. Then endotracheal intubation was done, and the patient connected to the ventilator. In case of difficult intubation or failed intubation following 3 attempts, we adhered to the ASA difficult airway recommendations for managing difficult tracheal intubation [17].

The primary outcome was aimed at determining the association between the ultrasonographic parameters (DSE as well as DSVC) and the modified Cormack and Lehane grading scale for laryngoscopy as easy or difficult. The secondary outcomes were the ultrasonographic parameters' sensitivity (DSE and DSVC), specificity of the ultrasonographic parameters (DSE and DSVC), cut-off values of the ultrasonographic parameters (DSE and DSVC).

Sample Size Calculation

The sample size as well as power analysis were determined utilizing Epi-Info software statistical package created by the World Health organization and center for Disease Control and Prevention, Atlanta, Georgia, USA version 2002. The utilized criteria for calculating sample size involved: 95% confidence limit, expected difficult laryngoscopy in non-suspected cases going through elective surgical procedure at 30% with a margin of error of 10%, the sensitivity of ultrasonography parameters while predicting difficult laryngoscopy preoperatively in non-suspected patients undergoing elective surgery is 70% with a 10% margin of error. The sample size according to previous criteria was addressed at N>81. We will increase the participants' number to 85 to overcome incomplete results.

Statistical analysis

Data went through a statistical analysis utilizing SPSS v26 (IBM Inc., Chicago, IL, USA). Quantitative variables were displayed as mean as well as SD and compared between the two groups utilizing unpaired Student's t-test. Qualitative variables were displayed as frequency as well as percentage (%) then went through analysis utilizing the Chi-square or Fisher's exact test when appropriate. Receiver Operating Characteristic curve (ROC) analysis was utilized for identifying the overall parameter's predictivity as well as the ideal cut-off value with detection of sensitivity and specificity at this cut-off value. Pearson correlation coefficient (r) was measured to address strength along with direction of association among two numerical variables, both are continuous and a minimum of one is normally distributed. A two-tailed P value of below 0.05 was deemed to exhibit statistically significance.

Results

During the research period, 125 patients were evaluated if they are eligible. Of them, 18 patients were excluded [suspected difficult airway by conventional clinical tests (n=5), patients with neck scar (n=1), history of previous difficult intubation (n=1), pregnancy (n=2), BMI >= 30 Kg/m2 (n=9)]. The remaining 107 patients were randomly allocated to the study. Of them, 7 patients were dropped out [change in anesthesia plan (n=3), surgery postponed or cancelled (n=4)]. The remaining 100 patients completed the study and allocated into two groups based on the modified Cormack and Lehane grading scale during direct laryngoscopy, 83 cases within group A (easy laryngoscopy) as well as 17 patients within group B (difficult laryngoscopy). (44) Patients with a modified Cormack and Lehane grade I, (39) cases with a modified Cormack and Lehane grade IIa, forteen cases with a modified Cormack and Lehane grade IIb, three cases with a modified Cormack and Lehane grade III while no cases with a modified Cormack and Lehane grade IV. (Figure 3).

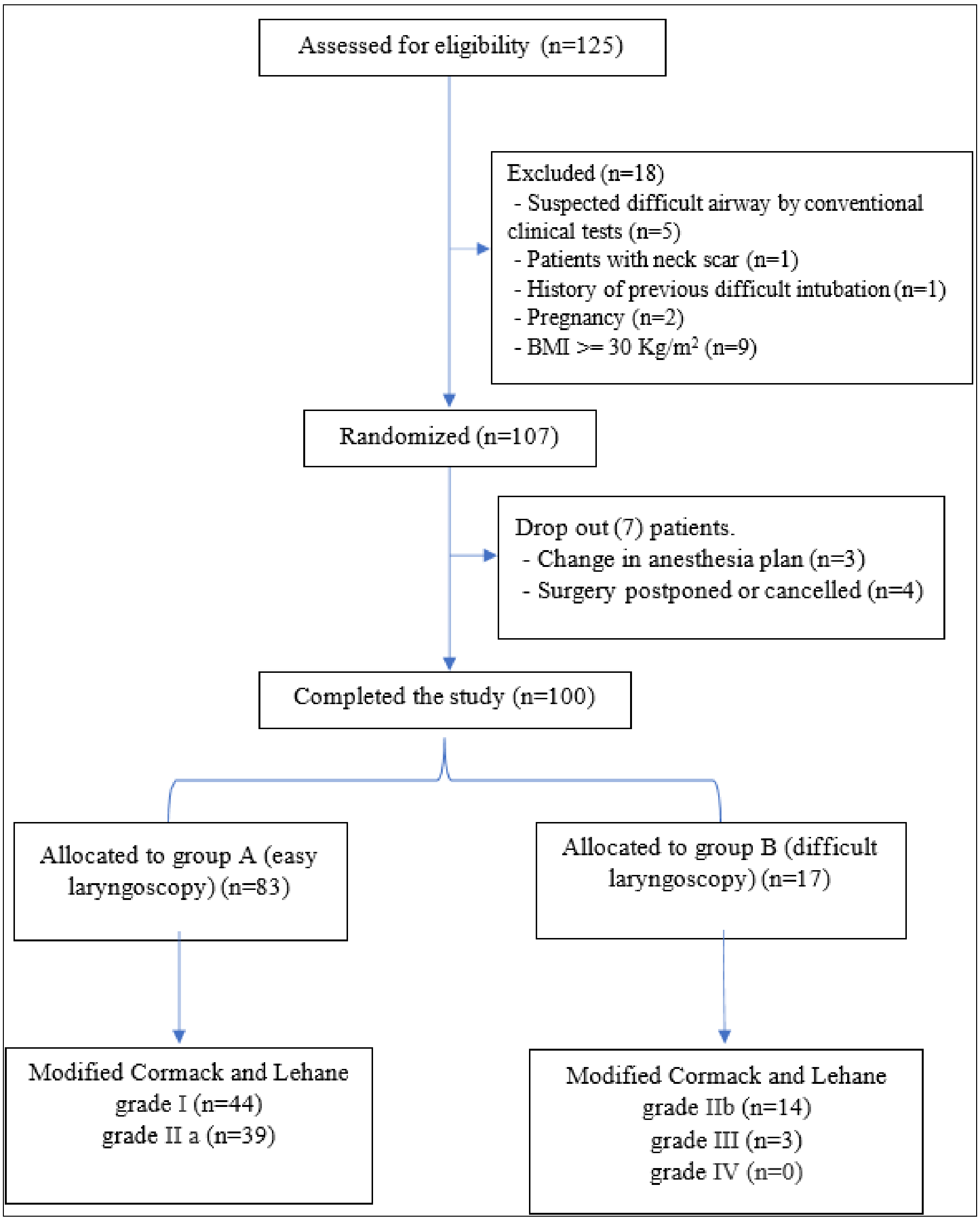


Fig 3: Flow chart of the participants within both studied groups

No significant variation was documented between both groups regarding demographic data, MMP classification, IID, TMD, NC and CM. (Table 1)

Table 1: Comparison among both studied groups based on demographic data, MMP classification, IID, TMD, NC and CM

		Modified Cormack and Lehane grade (N=100)		P
		Group A Easy laryngoscopy (n = 83)	**Group B Difficult laryngoscopy (n = 17)**	
Age		37.20 ± 10.94	39.76 ± 8.79	0.367
<30		22(26.5%)	2(11.8%)	0.284
30 – 40		36(43.4%)	7(41.2%)	
>40		25(30.1%)	8(47.1%)	
Sex	Male	47(56.6%)	11(64.7%)	0.539
	Female	36(43.4%)	6(35.3%)	
Weight (Kg)		72.29 ± 9.11	71.94 ± 4.83	0.822
Height (m)		1.70 ± 0.08	1.71 ± 0.05	0.487
BMI (kg/m^2)		24.90 ± 1.97	24.33 ± 1.76	0.264
ASA	I	54(65.1%)	9(52.9%)	0.062
	II	19(22.9%)	2(11.8%)	
	III	10(12.0%)	6(35.3%)	
MMP	I	31(37.3%)	5(29.4%)	0.534
	II	52(62.7%)	12(70.6%)	
IID (cm)		4.76 ± 0.37	4.73 ± 0.13	0.614
TMD (cm)		6.57 ± 0.32	6.61 ± 0.10	0.324
NC (cm)		35.93 ± 1.50	36.26 ± 1.31	0.356
CM (degree)		100.48 ± 5.61	101.18 ± 3.76	0.532

Data exhibited as mean ± SD or frequency (%), *significant p value <0.05, BMI: Body mass index, BSA: Body surface area, ASA: American Society of Anesthesiologists, MMP: modified Mallampati, IID: inter-incisor distance, TMD: thyromental distance, NC: neck circumference, CM: cervical mobility.

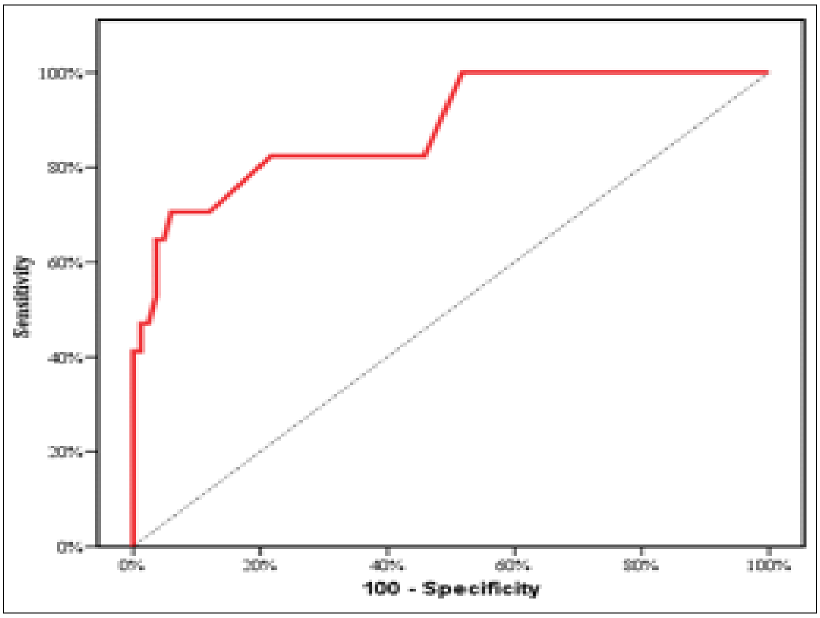
Significant variation was documented among both groups as regards DSE that show significant rise within Group B (*p*<0.001). Also, significant variation was documented among both groups regarding DSVC that show significant reduction within Group B (P = 0.010). (Table 2)

Table 2: Comparison among both groups based on DSE as well as DSVC

	Modified Cormack and Lehane grade (N=100)		P
	Group A Easy laryngoscopy (n = 83)	**Group B Difficult laryngoscopy (n = 17)**	
DSE (cm)	1.83 ± 0.13	2.10 ± 0.17	<0.001*
DSVC (cm)	1.24 ± 0.08	1.19 ± 0.09	0.010*

Data exhibited as mean ± SD or frequency (%), *significant p value <0.05, DSE: distance from skin to epiglottis, DSVC: distance from skin to vocal cords.

Based on DSE, the cut off value exhibited >1.94 with sensitivity 82.35%, specificity 78.31%, PPV 43.7% and NPV 95.6%. The area under the curve exhibited 0.884 indicating statistical significance (*p*<0.001), Based on DSVC, the cut off value exhibited ≤1.22 with sensitivity 64.71%, specificity 57.83%, PPV 23.9% and NPV 88.9%. AUC exhibited 0.704 indicating statistical significance (P = 0.008). Combination of both DSE and DSVC show that sensitivity 70.59%, specificity 100%, PPV 100% and NPV 94.3%. AUC was 0.921 with statistical significance (*p*<0.001). (Figure 4).



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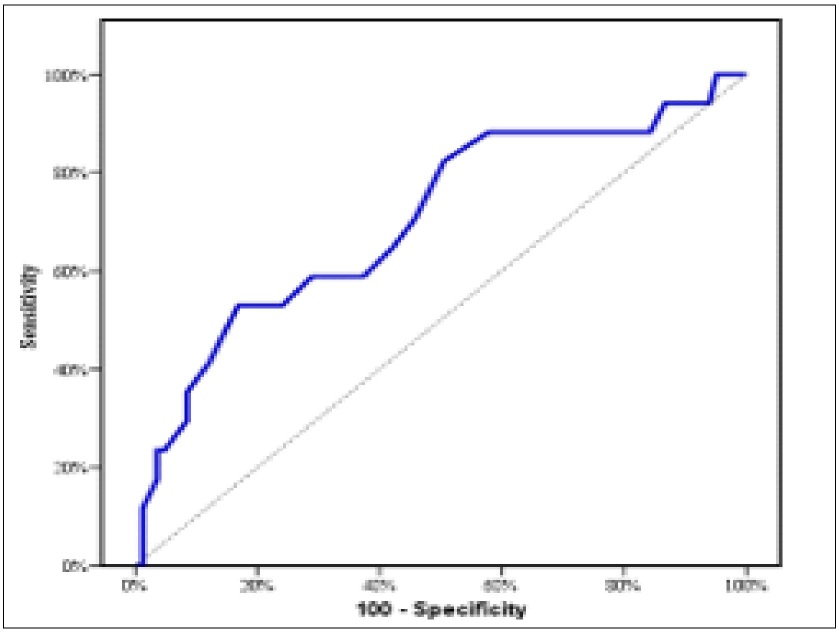

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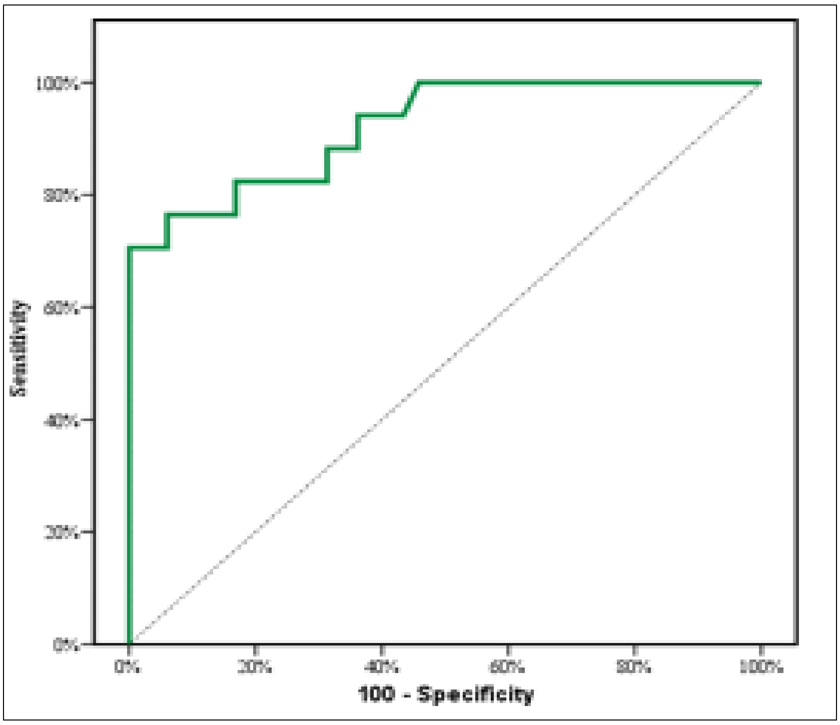

C

Fig 4: Receiver operating characteristic curve for A) DSE, B) DSVC and C) Combination of both DSE and DSVC to predict difficult laryngoscopy

Discussion

Effective airway management represents an essential element of providing anaesthetic care. Anaesthesiologists must manage patients' airway throughout any surgical procedure under GA, thus ensuring proper oxygen supply as well as ventilation. This could possess substantial risks resulting in morbidity and death, mostly as a result of insufficient/impossible ventilation, and/or intubation. Hence, it is crucial to optimizing techniques for predicting a difficult airway along with ensuring the required means for intervention [18].

Our current study showed that there were 36 patients with MMP class I and 64 patients with MMP class II and show that in Group A, there were 31 patients with MMP class I (37.3%) and 52 patients with MMP class II (62.7%) while in Group B, there were 5 patients with MMP class I (29.4%) and 12 patients with MMP class II (70.6%). The comparison among both groups showed insignificant difference (P = 0.534). However, a prior research by Agarwal *et al.* [19] the easy intubation group exhibited significantly lower MMP grades as opposed to the difficult intubation group. In contrast to our results, study of Udayakumar *et al.* [20] addressed statistically significant variation among easy as well as difficult laryngoscope as regard MMP.

Our results did not address statistically significant variation among the two groups regarding IID, TMD, NC and CM.

Statistically significant variation was documented among the two groups as regard the DSE that show significant increase in Group B and the DSVC that show significant decrease in Group B.

Using ROC curve; according to DSE, the cut off value was >1.94 with sensitivity 82.35%, specificity 78.31%, PPV 43.7% and NPV 95.6%. AUC exhibited 0.884, indicating statistical significance (p<0.001). Based on DSVC, the cut off value was ≤1.22 with sensitivity 64.71%, specificity 57.83%, PPV 23.9% and NPV 88.9%. AUC exhibited 0.704, indicating statistical significance (P = 0.008). Combination of both DSE and DSVC show that sensitivity 70.59%, specificity 100%, PPV 100% and NPV 94.3%. AUC was 0.921 with statistical significance (p<0.001). Our findings aligned with study of Parameswari *et al.* [21] addressing that among the ultra-sonographic predictors, the skin to epiglottis distance exhibited the highest sensitivity (75%) as well as specific (63.6%) while predicting difficult laryngoscopy. The ROC curve represents a graphical sensitivity and specificity display. Additionally, the AUC is deemed to be an efficient measure while assessing the test's inherent validity. The maximum AUC of 1 demonstrates an ideal diagnostic test. The AUC for the skin to epiglottis distance reached 0.693 and approaching 1 among the sonographic parameters, indicating that they have the highest validity among the parameters studied. Also, Wu *et al.* [22] addressed that both the skin to hyoid distance and DSE exhibited high predictive values for difficult laryngoscopy.

A prior research by Gomes *et al.* [23] showed that hyo mental distance in the neutral position represents the predominant valid parameter while assessing airway preoperatively utilizing ultrasound.

Yadav *et al.* [24] found the effectiveness of the sonographic parameters ANS-hyoid (anterior neck soft tissue thickness at the level of the hyoid), ANS-VC (anterior neck soft tissue thickness at the vocal cords' level), and pre-E/E-VC (the pre-epiglottis space depth to distance from the epiglottis to the vocal cords' midpoint distance). Additionally, clinical parameters included Mallampati classification, thyromental distance, as well as hyomental distance. Their study revealed a significant statistical variation among cases having easy and others with difficult laryngoscopy, and the highest sensitivity was shown by the ANS-VC, while the hyomental distance showed the highest specificity. Statistically significant variations among cases having difficult as well as easy laryngoscopy were documented for about five of six parameters.

The diagnostic validity profiles exhibited a range of sensitivity, from 26.5% to 87.5%, along with favorable specificity, ranging from 58.9% to 94.2%, as well as NPV, ranging from 88.8% to 97.03%. The ANS-VC measurement possessed the greatest sensitivity (87.50%) and area under the curve value (0.887). On the other hand, the hyomental distance ratio (HMDR) demonstrates the greatest specificity (94.2%) as well as accuracy (89.60%), indicating lower rates of false-positive predictions. When tests are combined, this enhanced the diagnostic validity profile, achieving the highest AUC at 0.897.

In the study of Agarwal *et al.* [19] the tongue thickness (TT), SH, ST, as well as invisibility of hyoid bone (VH) exhibited these accuracies (78.4%, 85.0%, 84.7%, and 84.9%, respectively). The TT, SH, and ST optimal values for DI prediction exhibited more than 5.8 cm (sensitivity: 84.5%, specificity: 78.1%, AUC: 0.880), above 1.4 cm (sensitivity: 81%, specificity: 85.2%, AUC: 0.898) as well as above 2.4 cm (sensitivity: 75.9%, specificity: 85.2%, AUC: 0.885) respectively. VH exhibited a sensitivity of (72.4%) while a specificity of (85.6%) as well as (AUC: 0.790). The five models' AUC values (according to combining 3 or 4 parameters) fell between 0.975-0.992. ST as well as VH possessed a marked effect on the individual models.

In meta-analysis conducted by Giordano *et al.* [25] 31 observational studies, involving around forty-one single parameters along with twelve various combinations of clinical and ultrasound. The variables most strongly correlated with difficult laryngoscopy or difficult intubation involve the DSE midway in a neutral head and neck position, the distance from the hyoid bone to the skin surface when the head and neck are in a neutral posture, as well as the ratio of the extended/neutral hyo-mental distance. Utilizing both clinical and ultrasonography parameters, namely the MMP score and the measurement of the distance from the skin to the epiglottis with the head and neck in a neutral posture, demonstrated greater accuracy levels.

In meta-analysis conducted by Carsetti *et al.* [12] 15 studies were involved for summary receiver operating characteristic (SROC) quantitative analysis. The DSE, DSHB, as well as DSVC sensitivity exhibited 0.82 (0.74–0.87), 0.71 (0.58–0.82), and 0.75 (0.62– 0.84), respectively. While the DSE, DSHB, as well as DSVC specificity exhibited 0.79 (0.70–0.87), 0.71 (0.57–0.82), and 0.72 (0.45–0.89), respectively. The AUC related to DSE, DSHB, DSVC, as well as ratio between the depth of the pre-epiglottic space and the distance from the epiglottis to the vocal cords (Pre-E/E-VC) exhibited 0.87 (0.84–0.90), 0.77 (0.73–0.81), 0.78 (0.74–0.81), and 0.71 (0.67–0.75), respectively. Cases having difficult direct laryngoscopy possessed greater DSE, DSVC, as well as DSHB values as opposed to others having easy laryngoscopy, addressing a mean difference of 0.38 cm (95% [CI], 0.17–0.58 cm; P = .0004), 0.18 cm (95% CI, 0.01–0.35 cm; P = 0.04), as well as 0.23 cm (95% CI, 0.08–0.39 cm; P = .004), respectively.

Limitations: A single-centered study with a modest sample size.

Conclusion

DSE as well as DSVC measured in the parasagittal plane, are independent valuable US parameters while predicting difficult laryngoscopy among cases having non-suspected difficult airway patients. DSE possesses a better predictive value for difficult laryngoscopy. DSE >= 2.1 -+ 0.17 could predict a difficult laryngoscopy with PPV 43.7% and AUC of 88%, compared with DSVC ≤ 1.19 -+0.09 with PPV 23.9% and AUC of 70%. Combination of both DSE and DSVC provides the ideal prediction as regards difficult laryngoscopy, possessing a PPV of 100% along with AUC of 92%.

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Conflict of Interest: Nil

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