A Comparison of Wilson Risk Sum Score and Combination of Modified Mallampati Classification, Hyomental Distance Ratio, Ratio of Height to Sternomental and Thyromental Distances for Predicting Difficult Laryngoscopy in Indian Population

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ABSTRACT

BACKGROUND

A few patients of apparently normal appearance unexpectedly present with great difficulties during intubation which may lead to potentially serious consequences. Thus, we worked on this area with the aim to determine the ability to predict difficult visualisation of larynx using the following preoperative airway predictors: MMC (Modified Mallampati Classification), RHSMD (Ratio of Height to Sternomental Distance), RHTMD (Ratio of Height to Thyromental) and HMDR (Hyomental Distance Ratio) and comparison of these with WRSS (Wilson Risk Sum Score), in isolation and in combination.

METHODS

A double-blind, prospective study was carried out on 300, ASA grade I or II patients posted for elective surgery in supine position under general anaesthesia. Different parameters were recorded in pre-op period and Cormack-Lehane grading and difficulty of intubation was recorded at the time of intubation. Chi Square test and receiver operating curve were used to assess the association of all the airway tests and various combinations with CL grading. Cohen's kappa was calculated to determine the strength of agreement between laryngoscopy grade and various tests in isolation and combinations.

RESULTS

In our study, highest strength of agreement was found with WRSS of 0.925 (0.873 - 0.976) and only a fair agreement was seen with HMDR (κ = 0.319). RHSMD and combination of RHSMD + MMC showed good strength with kappa of 0.638 and 0.634 respectively.

CONCLUSIONS

No single test or group of tests was able to predict all cases of difficult laryngoscopy at the preoperative airway assessment. Wilson Risk Sum Score was found to be the best predictor of difficult laryngoscopy when compared to MMC, RHTMD, RHSMD and HMDR in isolation and any possible combination.

KEYWORDS

Difficult Laryngoscopy, Difficult Intubation, Wilson Risk Sum Score, Airway, RHSMD, RHTMD

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BACKGROUND

Anaesthesiologists have an important role to maintain adequate gas exchange through a patent airway. Unsuccessfulness in the airway management is the foremost cause of morbidity and mortality in the patients undergoing general anaesthesia.[1] Hypoxia and hypercapnia resulting from an interruption of gas exchange while managing a difficult airway may cause brain damage and cardiovascular activation or depression.[2] Occasionally even an experienced anaesthesiologist, might encounter difficulty in intubation. Difficulty in intubation is associated with difficulty in exposing the glottis by direct laryngoscopy. Numerous parameters have been used by investigators to predict difficult intubation, including the distance from thyroid notch to the mentum (thyromental distance, TMD),[3] modified Mallampati classification (MMC),[4] a simple summation of risk factors (Wilson risk sum score),[5] the distance from the upper border of the manubrium sterni to the mentum (sternomental distance, SMD),[6] and Upper Lip Bite Test (ULBT).[7] However, the diagnostic predictability of these screening tests varies from trial to trial, mainly due to inadequate statistical power, different test thresholds, differences in the incidence of difficult intubation, or differences in patient characteristics. Presumably there is no study to clarify which of the anatomic landmarks and clinical factors have more predictive value in airway assessment during preoperative evaluation and hence, predict difficult laryngoscopy more accurately especially in Indian population.

Objectives

1. To determine the ability to predict difficult visualisation of larynx from the following preoperative airway predictors: modified Mallampati classification (MMC), ratio of height to sternomental distance (RHSMD), ratio of height to thyromental (RHTMD) and hyomental distance ratio (HMDR) and comparison of these with Wilson Risk Sum Score (WRSS), in isolation and in combination, in the Indian population.
2. To calculate the sensitivity and specificity of the measured parameters.
3. To find the best combination of these tests in order to predict difficult laryngoscopy.
4. To determine optimum cut-off points for RHTMD, RHSMD and HMDR for prediction of difficult laryngoscopy.

METHODS

After our Institute's Ethical Committee's approval and getting written informed consent from patients, a double-blind, prospective study was carried out from October 2013 to March 2015 on 300 patients. Different parameters were recorded in pre-op period and Cormack-Lehane grading and difficulty of intubation was recorded at the time of intubation.

Inclusion Criteria

American Society of Anaesthesiologists (ASA) grade I or II patients, aged 18 - 60 years, posted for elective surgery in supine position under general anaesthesia.

Exclusion Criteria

All the patients with age < 18 years or > 60 years, pregnant women, skeletal abnormalities like kyphoscoliosis, inability to sit or stand erect, significant airway abnormalities like head and neck tumours, cleft lip, inability to open mouth, radiation induced scaring or post burn contracture of peri-oral or neck region, edentulous patients or patients with absent incisors, loose dentures, limitation of movements at cervical spine and in those where rapid sequence induction or awake intubation is needed were excluded from our study.

A detailed pre-anaesthetic check-up including routine investigations was done. A senior anaesthesiologist carried out the following airway assessment tests using common methods of examination.

SMD

It was measured in centimetres as the distance from the bony point of the chin to the upper sternal notch, having the head fully extended backwards and mouth closed.

TMD

It was measured in centimetres as the distance from the bony point of the chin to the palpable prominence of thyroid cartilage, having the head fully extended backwards and mouth closed.

MMC

The patients were made to sit with their heads in neutral position, mouth fully opened, tongue maximally protruded, and no phonation was allowed. The investigator was at the eye level with the patient and gave a grade that best corresponded to his view as follows: Class 1 if soft palate, faucial pillars and uvula were visible, Class 2 if soft palate and uvula were visible, Class 3 if only soft palate and the base of uvula were visible and Class 4 if soft palate is not visible and only hard palate is visible.[4]

HMDR

The patients were kept in supine position with head on a firm surface and were instructed to look straight ahead with mouth closed. HMD was measured with a hard ruler once with head in neutral position and again with head maximally extended. The HMDR was calculated as the ratio of HMD at the extreme of head extension to that in the neutral position. Height was measured in centimetres and weight in kilograms by a digital standard scale. The ratio of height to TMD (RHTMD) and the ratio of height to SMD (RHSMD) were then calculated.

Wilson Risk Sum Score (WRSS)[5]

It combined five physical factors

1) Weight: <90 Kg, 90-110 Kg, and >110 Kg
2) Maximum range of Neck Movement (NM) was calculated by Wilson approach: Patient's head was completely extended backwards, and one pencil was put on his / her forehead vertically, then without any change in the pencil's position, head was flexed completely towards the chest. The angle produced by the pencil's movement was measured using protractor and classified as more than 90 degrees and less or equal to 90 degrees.
3) Jaw movement i.e., inter-incisor gap (IIG) was assessed by asking each patient to open the mouth as much as possible. The distance between upper and lower incisor in the midline was measured using hard plastic scale in centimeters. Subluxation was measured by asking patients to protrude lower jaw in front of upper jaw and graded as: -
   > 0: lower incisors anterior to upper incisors
   = 0: lower and upper incisors at the same level
   < 0: lower incisors posterior to upper incisors.
4) Receding mandible: none, moderate, severe
5) Bucked teeth: none, moderate, severe.

Each risk factor was awarded three possible scores (0, 1, 2). A total score > 2 predicts a chance of difficult intubation.

Anaesthesia Technique

On the day of surgery all the patients received a standard induction sequence (midazolam 0.04 mg / Kg, fentanyl 2 µ / Kg, propofol 1.5 - 2 mg / Kg, succinylcholine 1.5 mg / Kg, 100 % oxygen, isoflurane 0.6 % inspiratory concentration). Bag-mask ventilation was performed for 60 seconds or till disappearance of fasciculations from distal extremities, whichever occurred later. Laryngoscopy was done with the patient's head in the sniffing position with an appropriate size Macintosh blade, by a single experienced anaesthesiologist, blinded to the results of the preoperative airway assessment. Glottis visualisation was assessed using Cook's modified Cormack and Lehane grade (C-L grade)[8] without external laryngeal manipulation as follows:

Grade I - Full view of glottic aperture visible
Grade IIa - Posterior part of glottis and arytenoids visible
Grade IIb - Only arytenoids visible
Grade IIIa - Epiglottis is visible and liftable
Grade IIIb - Epiglottis is visible but adherent to posterior wall
Grade IV - None of the glottic structures visible.

CL grade was notified to the person who had assessed the patient pre-operatively. If difficulty was encountered and first attempt failed to provide a laryngoscopic view, change of laryngoscope blade and external laryngeal pressure, as the situation demands, was allowed. However, for the purpose of study, the CL grade without external manipulation of larynx was recorded. Based on CL grading, laryngoscopy was defined as easy (grade I and IIb) and difficult (IIb, III and IV).

After CL grading of glottic view, patient's airway was secured with an appropriate size cuffed endotracheal tube and anaesthesia was maintained on oxygen 40 % + nitrous oxide 60 % + isoflurane 0.6 – 1 % and vecuronium 0.08 mg / Kg initially and subsequently 0.02 mg / Kg was given as required. After completion of surgery, reversal of neuromuscular block was achieved using injection glycopyrrolate 0.01 mg / Kg + injection neostigmine 0.06 mg / Kg. Patient was shifted to recovery room for monitoring.

Statistical Analysis

Data was entered and analysed with Statistical Package for Social Sciences (SPSS software, version 14.0, Chicago, IL, USA). The association between different variables and difficulty in laryngoscopy were evaluated using chi-square test and student t test. P < 0.05 was considered as significant. Strength of agreement was determined using Cohen's kappa (κ). The optimum cut-off points for the prediction of difficult laryngoscopy for RHTMD, RHSMD and HMDR in the Indian population were determined using area under Receiver Operating Characteristic (ROC) curve. Specificity, sensitivity, positive and negative predictive values, accuracy and odds ratio were calculated using standard formulas.

RESULTS

After induction of anaesthesia and assessment of Cormack and Lehane Grade (CL Grade), patients were divided into 2 groups:

EL (Easy Laryngoscopy): CL Grade I and IIa.
DL (Difficult Laryngoscopy): CL Grade IIb, III and IV.

Easy laryngoscopy was observed in 77.0 % patients (n = 231). Difficult laryngoscopy was observed in 23.0 % patients (n = 69). CL grade IIb was seen in 48 patients, grade IIIa and IIIb was seen in 20 and one patient respectively. CL grade IV was not seen in any of the patients (Table 1). Difficult intubation requiring more than two attempts / use of stellate / Backward Upward and Rightward Pressure (BURP) was seen in 30 % patients (n = 27). There was no failed intubation.

The mean age of the patients was 38.56 ± 12.026 years in EL group and 41.49 ± 11.835 years DL group. The mean height of patients in EL group was 159.55 ± 9.783 cm and was significantly higher than the DL group (155.49 ± 8.498 cm). The mean weight of patients was 55.06 ± 12.520 Kg in EL group and 54.61 ± 12.739 Kg in DL group (Table 2).

The optimum cut-off points for RHTMD, RHSMD and HMDR for prediction of difficult laryngoscopy in the Indian population were found to be 21.5 cm, 11 cm and 1.2 respectively (Table 5 and Fig. 1).

CL Grade	N	%	EL/DL
1	126	42.0 %	EL
2a	105	35.0 %	N = 231 (77 %)
2b	48	16.0 %	DL
3a	20	6.7 %	N = 69
4	0	0	(23 %)
Total	**300**	**100.0 %**	

Table 1. Distribution among Various CL Grades

CL: Cormack-Lehane, EL: Easy Laryngoscopy, DL: Difficult Laryngoscopy

Demographic Parameters	EL (CL I, IIa) Mean ± SD	DL (CL II b, III, IV) Mean ± SD	P Value (t test)
Age (years)	38.56 ± 12.026	41.49 ± 11.835	0.076
Height (cm)	159.55 ± 9.783	155.49 ± 8.498	0.002
Weight (Kg)	55.06 ± 12.520	54.61 ± 12.739	0.793

Table 2. Demographic Analysis

t test used, p < 0.05 is significant, EL: Easy Laryngoscopy, DL: Difficult Laryngoscopy

Amongst all the single airway assessment tests, Area Under the Curve (AUC) from the receiver operating characteristic (ROC) curve analysis was highest for WRSS (0.990, 95 % CI 0.982 - 0.999) (Table 4). WRSS was the most useful single predictor of difficult laryngoscopy with the highest sensitivity of 94.2 %, specificity of 98.3 % and positive predictive value of 94.2 % (p < 0.001) (Table 5).

The combination of tests increased the sensitivity to 92.8 % but decreased the specificity and positive predictive value. The combination with the best predictive properties was of the MMC, RHTMD, RHSMD and HMDR with a sensitivity, specificity and positive predictive value of 92.8 %, 64.9 % and 44.1 % respectively (p < 0.0001) (Table 5). Various other two, three and four test combinations yielded a high sensitivity of 80 % - 90 % but at the expense of lowering the specificity and positive predictive value.

Cohen's kappa was calculated to determine the strength of agreement between laryngoscopy grade and various tests in isolation and combinations. A value of < 0 shows no agreement, 0 to 0.2 slight, 0.2 - 0.4 fair, 0.4 - 0.6 moderate, 0.6 - 0.8 good and 0.8 - 1 very good. (Table 6).

	RHTMD	RHSMD	HMDR
Optimal cut-off points	11 cm	21.5 cm	1.2
Sensitivity (%)	72.5	76.8	69.6
Specificity (%)	80.5	89.6	70.13
PPV (%)	52.6	68.8	41
NPV (%)	90.7	92.8	88.5
Accuracy (%)	78.7	86.7	70
p value	< 0.0001	< 0.0001	< 0.0001

Table 3. Optimal Cut-Off Points for Prediction of Difficult Laryngoscopy in Indian Population

Significant: p value < 0.05, PPV: positive predictive value, NPV: negative predictive value, RHTMD: ratio of height to thyromental distance, RHSMD: ratio of height to sternomental distance, HMDR: hyomental distance ratio.

Test Result Variables	Area Under Curve (AUC)	Standard Error	p- Value	Asymptotic 95% Confidence Interval (CI)	
				Lower Bound	Upper Bound
MMC	.764	.033	< 0.01	.700	.829
RHTMD	.852	.032	< 0.01	.790	.914
RHSMD	.865	.032	< 0.01	.801	.928
WRSS	.990	.004	< 0.01	.982	.999
HMDR	.791	.031	< 0.05	.731	.851

Table 4. The Receiver Operating Characteristic (ROC) Curve Analysis of Airway Assessment Tests for Predicting Difficult Laryngoscopy

P value < 0.05, significant, MMC: Modified Mallampati Classification, RHTMD: ratio of height to thyromental distance, RHSMD: ratio of height to sternomental distance, HMDR: hyomental distance ratio, WRSS: Wilson risk sum score.

Parameters	TP	TN	FP	FN	Sens	Specf	PPV	NPV	Acc	OR	P Value (Test & CL Grade)
MMC	30	218	13	39	43.5	94.4	69.8	84.8	82.67	12.89	< 0.05
RHTMD	50	186	45	19	72.5	80.5	52.6	90.7	78.67	10.88	< 0.05
RHSMD	53	207	24	16	76.8	89.6	68.8	92.8	86.67	28.57	< 0.05
HMDR	48	162	69	21	69.6	70.13	41	88.5	70	5.366	< 0.05
WRSS	65	227	4	4	94.2	98.3	94.2	98.3	97.33	922	< 0.001
MMC + RHSMD	60	196	35	9	87	84.8	63.2	95.6	85.3	37.3	<0.0001
MMC + HMDR	46	199	32	23	66.7	86.1	58.9	89.6	81.7	12.4	<0.0001
RHTMD + RHSMD	58	170	61	11	84.1	73.6	48.7	93.9	76	14.7	<0.0001
RHTMD + HMDR	54	171	60	15	78.3	74	47.4	91.9	75	10.3	<0.0001
RHSMD + HMDR	55	192	39	14	79.7	83.1	58.5	93.2	82.3	19.3	<0.0001
MMC + RHTMD + RHSMD	63	162	69	6	91.3	70.1	47.7	96.4	75	24.7	<0.0001
MMC + RHTMD + HMDR	61	162	69	8	88.4	70.1	46.9	95.3	74.3	17.9	<0.0001
MMC + RHSMD + HMDR	60	181	50	9	87	78.3	54.5	95.3	80.3	24.1	<0.0001
RHTMD + RHSMD + HMDR	59	157	74	10	85.5	68	44.3	94	72	12.5	<0.0001
MMC + RHTMD + RHSMD + HMDR	64	150	81	5	92.8	64.9	44.1	96.8	71	23.7	<0.0001

Table 5. Sensitivity, Specificity, PPV, NPV and Accuracy of Various Tests in Isolation and in Combination and Their Association with CL Grading

Chi Square test was used to assess the association of all the airway test combinations above, with CL grading p<0.05, significant, TP: True positive, TN: True negative, Sens: Sensitivity, Specf: Specificity, PPV: Positive Predictive Value, NPV: Negative Predictive Value, Acc: Accuracy, OR: Odds Ratio, MMC: modified Mallampati classification, RHTMD: ratio of height to thyromental distance, RHSMD: ratio of height to sternomental distance, HMDR: hyomental distance ratio, WRSS: Wilson risk sum score.

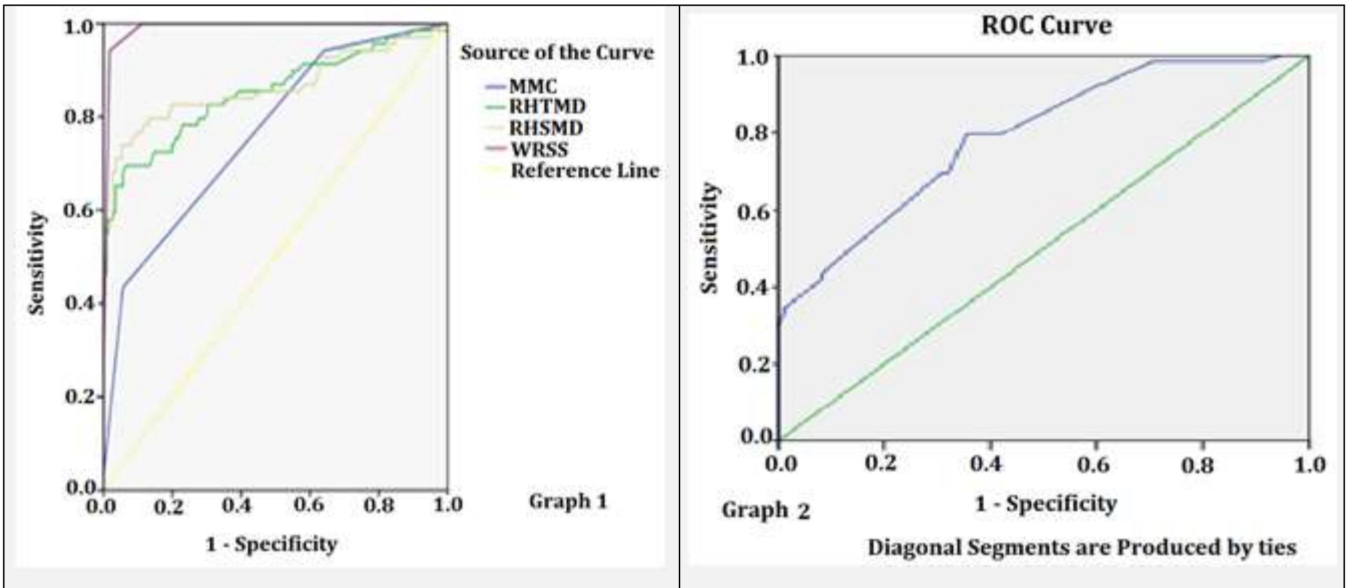

Figure 1. Receiver Operating Characteristic (ROC) Curves for MMC, RHTMD, RHSMD, and WRSS (Graph 1), and HDMR (Graph 2) in Predicting Difficult Laryngoscopy in All Patients

MMC: modified Mallampati classification, RHTMD: ratio of height to thyromental distance, RHSMD: ratio of height to sternomental distance, WRSS: Wilson risk sum score, HDMR: Hyomental distance ratio.

	Measure of Agreement (KAPPA)	95% Confidence Interval (CI)	Strength of Agreement
MMC	0.436	0.311-0.561	Moderate
RHTMD	0.468	0.359-0.577	Moderate
RHSMD	0.638	0.536-0.740	Good
HMDR	0.319	0.213-0.425	Fair
MMC + RHTMD	0.517	0.419-0.616	Moderate
MMC + RHSMD	0.634	0.538-0.731	Good
MMC + HMDR	0.446	0.332-0.560	Moderate
RHTMD + RHSMD	0.460	0.360-0.559	Moderate
RHTMD + HMDR	0.426	0.322-0.529	Moderate
RHSMD + HMDR	0.557	0.454-0.661	Moderate
MMC + RHTMD + RHSMD	0.465	0.372-0.559	Moderate
MMC + RHTMD + HMDR	0.447	0.352-0.542	Moderate
MMC + RHSMD + HMDR	0.540	0.442-0.639	Moderate
RHTMD + RHSMD + HMDR	0.403	0.308-0.499	Moderate
MMC + RHTMD + RHSMD + HMDR	0.416	0.327-0.505	Moderate
WRSS	0.925	0.873-0.976	Very good

Table 6. Measure of Agreement between Laryngoscopy Grade and Various Tests

MMC: modified Mallampati classification, RHTMD: ratio of height to thyromental distance, RHSMD: ratio of height to sternomental distance, HMDR: hyomental distance ratio, WRSS: Wilson risk sum score.

DISCUSSION

Intubation per se merely defines an endpoint in terms of a success or a failure without actually defining the magnitude of difficulty encountered during the procedure. In our study we chose difficult laryngoscopy as the end point, because that substantially determines the extent of difficulty encountered during the intubation procedure. The incidence of difficult laryngoscopy in our study was 23 % (Table 1). Our findings are comparable to Farzietal[9] who reported a 21 % incidence of difficult laryngoscopy. In contrast, Safavietal[10] reported the incidence of difficult laryngoscopy as 6.8 %. Domietal[11] and Schmitt et al[12] reported the incidence as 8.7 % and 5.9 % respectively. Wilson et al[5] reported the prevalence of 3 - 18 %, and Anna lee et al[13] in their meta-analysis of nine studies reported the prevalence of difficult laryngoscopy in the range of 9 % to 27 %. The wide variations in the incidence of difficult laryngoscopy have been ascribed to various factors, such as head position, anaesthesia technique and degree of muscle relaxation, type and size of laryngoscope blade, the use of external laryngeal manipulation, cricoid pressure, skill and experience of anaesthesiologist performing laryngoscopy,[14] the bias introduced if the anaesthesiologist is aware of the preoperative test results, the lack of standardisation in grading laryngeal views and the definition of difficult laryngoscopy itself. To eliminate the effects of such confounding factors, we followed a standard protocol of induction of anaesthesia. Muscle relaxation was achieved using I.V. suxamethonium 1.5 mg / Kg, following which laryngoscopy was performed after 60 seconds or after cessation of fasciculations, whichever occurred later. Patient's head was supported on a standard pillow of 7 cm height. Laryngoscopy was done with the patient's head in sniffing position, using an appropriate size Macintosh blade, by an experienced anaesthesiologist (minimum 3 years' experience).

The anaesthesiologist was blind to the results of the preoperative airway assessment tests. Glottic visualization was assessed using Cook's modification of Cormack & Lehane classification[8] without the use of any external laryngeal manipulation. If any difficulty was encountered and the first attempt failed to provide adequate visualisation of the glottis, external laryngeal manipulation or change of laryngoscope blade, as per the demand of the situation, was permitted. However, for the purpose of the study, the best CL grade without external laryngeal manipulation was recorded. The manoeuvres used to facilitate laryngoscopy were also noted. One of the important reasons for disparity between our study and other studies regarding incidence of difficult laryngoscopy is that in our study we graded laryngoscopic view according to Cook's modification of Cormack-Lehane classification[8] which includes six grades: I, IIa, IIb, IIIa, IIIb and IV while most of the other studies used the original CL grading which describes glottic view in four grades only i.e. I, II, III and IV. CL grade IIb was seen in large number of patients in our study (n = 48, 16 %), and were classified in difficult laryngoscopy group according to Cook's modification, but according to original CL grading these large number of patients were included in easy laryngoscopy group that has led to increased incidence of difficult laryngoscopy in our study. Considering only grade III and IV in DL group, the incidence of difficult laryngoscopy came to be 7 % which is comparable to most of the studies.

Since its first introduction in 1985, the accuracy of the Mallampati test has been questioned a number of times and there is controversy about its value.[15] The original Mallampati test[16] used three classes (class I - faucial pillars, soft palate and uvula could be visualized, class II - faucial pillars and soft palate could be visualised but the uvula was masked by the base of tongue, class III - only soft palate could be visualised). The modification of Samsoon and Young[4], (MMT) describes four classes and today, this scoring system is usually referred to when talking about the Mallampati test. In our study we used the MMT to describe the visibility of oropharyngeal structures. Mallampati et al[16] reported the sensitivity, specificity and PPV of 50 %, 84 % and 93 % respectively, whereas in the present study, these parameters were found to be 43.5 %, 94.4 % and 69.8 % respectively. The two studies should be cautiously compared as in our study, somewhat different criteria were used for grading laryngeal view and oropharyngeal structures. Savva[6] reported the sensitivity and specificity of 64.7 % and 66.1 % respectively and PPV of 8.9 % and concluded that MMT is too insensitive and insufficiently specific for routine use. Frerk[17] concluded that the MMT used as the sole preoperative assessment tool is sensitive but not very specific. Khan et al[7] reported a higher sensitivity of 82.4 % and specificity of 66.8 % but a low PPV of only 13 %. Gupta et al[18] found MMT to be a useful test for predicting difficult laryngoscopy with the sensitivity, specificity and PPV of 77.5, 98.2 and 48.57 % respectively. Lundstrom et al[19] in a meta-analysis involving 177088 patients found that the MMT is inadequate as a standalone test of a difficult laryngoscopy or tracheal intubation, but it may well be a part of a multivariate model for the prediction of difficult laryngoscopy or intubation. Rudindomi[11] reported a high specificity of 97 % and PPV of 75 % but low sensitivity of 44 %, similar to our study. These wide discrepancies in results regarding MMT may be due to significant interobserver variations while assessing MMT. Many patients phonate during assessment of MMT; others could be the position of head, optimal mouth opening and maximal protrusion of tongue.

Thyromental distance has been used as a useful predictor of difficult laryngoscopy but some found its role to be controversial. Schmitt et al[12] suggested that since TMD would vary with size, using the Ratio of Height to Thyromental Distance (RHTMD) may have better predictive value than TMD alone. They found that the AUC of RHTMD was significantly greater ($p < 0.007$) when compared to TMD, indicating a more accurate prediction by RHTMD. A ratio of 25 for the RHTMD was found to be the optimal cut-off value to predict difficult laryngoscopy. When the sensitivity of both the tests was 0.81, the RHTMD had a significantly greater specificity (0.91) than the TMD (0.73). They recommended that the RHTMD should be used instead of TMD. Krobbuaban et al[20] compared RHTMD versus four other tests for prediction of difficult laryngoscopy, namely mouth opening, TMD, MMT, and neck movement. They found that RHTMD had a higher sensitivity, PPV and fewer false negative than the other variables tested. The optimal cut-off points for RHTMD for predicting difficult laryngoscopy was 23.5 cm (sensitivity 77 %, specificity 66 %). Safavi et al[10] found that the optimal cut-off points for the RHTMD for predicting difficult laryngoscopy was > 21.06 cm (sensitivity 75.6 %; specificity 58.5 % and PPV of 96.2 %). They stated that since RHTMD depends on accurate measurement of patient's TMD and height, it lessens simplicity of this method. Also, the cut-off point of RHTMD for prediction of difficult laryngoscopy is race dependent, so cut-off points should be calculated for each population separately. In our study, we found the optimum cut-off point of 21.5 cm, with the sensitivity, specificity and PPV of 72.5 %, 80.5 % and 52.6 % respectively (Table 5). The Area under Curve for RHTMD in our study was 0.852 (95 % confidence interval: 0.790 to 0.914) (Table 6), that is comparable to findings of Schmitt et al (AUC 0.861; 95 % CI from 0.735 to 0.987). Although there are variations in statistical values from other studies, the conclusion is comparable.

Farzi et al[9] introduced a new parameter for predicting difficult laryngoscopy that is the Ratio of Height to Steno Mental Distance (RHSMD). They found that RHSMD ≥12.5 cm is a useful predictor of difficult laryngoscopy with a sensitivity, specificity and PPV of 73 %, 81.9 % and 52.1 % respectively. In our study, we found the cut-off point of 11 cm with a sensitivity, specificity and PPV of 76.8 %, 89.6 % and 68.8 % respectively, which is comparable to the findings of Farzi et al (Table 5). The cut-off point might vary in different races so calculations should be done for each population separately.

Tekenakaetal[21] devised a new method, the hyomental distance ratio (HMDR), for preoperatively identifying patients with a reduced occipito atlantoaxial extension capacity. Later, Jin Huh et al[22] used this method to predict DVL in apparently normal patients. They studied MMT, HMD in neutral position, HMD and TMD in extreme head extension and HMDR and found that the HMDR using an optimal cut-off point of 1.2 had the highest diagnostic accuracy for predicting DVL, with an AUC of 0.782 (95 % CI; 0.720 - 0.835). They found sensitivity and specificity of 88 % and 60 % respectively but a low PPV of 23 %. In our study we found an optimum cut-off value of 1.203, with sensitivity, specificity and PPV of 69.6 %, 70.13 % and 41 % respectively, and an AUC of 0.791 (95 % CI; 0.731 - 0.851) which are comparable to the findings of Jin Huh et al (Table 5 and Table 6). Although HMDR test alone had greater diagnostic accuracy, it had relatively low specificity and a higher number of false positive results. Therefore, it should be used in combination with other predictors, rather than using it alone.

Wilson Risk Sum Score (WRSS) was introduced in 1988 by Wilson et al[5] to predict difficult intubation. It included three levels (0, 1, 2) of five risk factors, namely weight, head and neck movement, jaw movement, receding mandible and bucked teeth. They found that a score of > 2 predicts 75 % of difficult intubation at the cost of falsely identifying 12 % of the "not difficult" patients. Rudin Domietal[11] compared WRSS and combinations of MMT, TMD and SMD for predicting difficult intubation in 426 patients. They found that WRSS predicted 33 cases (82.5 %) of difficult intubation whereas the combination of Mallampati with thyromental and sternomental distances predicted only 9 patients (22.5 %). Naguib M. et al[23] compared the predictive performance of three multivariate difficult intubation models and found that WRSS has a low sensitivity and PPV of 40.2 % and 25.6 % respectively but high specificity of 92.8 %. These discrepancies could be the result of higher cut-off point of ≥ 4 in their study compared to > 2 used in rest of the studies. Wanderley et al[24] evaluated MMT, WRSS and ASA difficult airway algorithm in 81 patients and found that WRSS predicted 100 % (n = 4) of the patients in whom laryngoscopy proved difficult, showing good sensitivity of the test at cost of falsely identifying 34 % (n = 28) of the "not difficult" patients. In our study, WRSS > 2 was found to be the best predictor of difficult laryngoscopy with high sensitivity, specificity, PPV, NPV and accuracy of 94.2 %, 98.3 %, 94.2 %, 98.3 % and 97.33 % respectively (Table 5). WRSS correctly predicted difficult laryngoscopy in 65 of the 69 patients with difficult laryngoscopy. This discrepancy from the previous studies can be explained by two reasons, first the cut-off point of WRSS for difficult intubation is taken as > 2, as described in original study by Wilson et al. Secondly, we classified the laryngoscopic view according to Cook's modification of CL grade[8], in which grade IIb, III and IV were included in difficult laryngoscopy group whereas in other studies only grade III and IV were considered under difficult laryngoscopy group.

Since none of the tests in isolation have a high discriminative power for the prediction of difficult laryngoscopy, we studied the various combinations of MMC, RHTMD, RHSMD and HMDR for prediction of difficult laryngoscopy. Among the combination of two factors, the combination of MMC and RHSMD was found to be best predictor with a sensitivity, specificity, PPV and accuracy of 87 %, 84.8 %, 63.2 % and 85.3 % respectively and a significant association with CL grade ($p < 0.05$). Combination of MMC, RHTMD and RHSMD was found to be the best among three test combinations, with a sensitivity, specificity, PPV and accuracy of 91.3 %, 70.1 %, 47.7 % and 75 % respectively. The four-test combination of MMC, RHTMD, RHSMD and HMDR yielded highest sensitivity of 92.8 %, but at the cost of lower specificity (64.9 %), PPV (44.1 %) and accuracy of 71 % (Table 5). While managing airway, the consequences of a false negative result, i.e., an unanticipated difficult laryngoscopy may be injurious and jeopardizes life. Therefore, decreasing false negative takes precedence over decreasing false positive prediction. Hence, sensitivity is far more important than specificity for airway assessment tests.

In our study, we calculated Cohen's kappa (κ) to determine the strength of agreement between laryngoscopic grading and various tests and test combinations. We found a "very good" strength of agreement with WRSS (κ = 0.925) (Table 6). RHSMD and combination of MMC + RHSMD showed "good" strength of agreement with kappa of 0.638 and 0.634 respectively. Only "fair" strength of agreement was found with HMDR (κ = 0.319). Rest other test and combinations showed a "moderate" degree of strength of agreement with kappa value ranging 0.4 to 0.6. A limitation of our study is that our sample size is not very large. In addition, we followed a standardised protocol of induction of anaesthesia and laryngoscopy. Although, this methodology is useful for scientific comparison, it does not take into account the heterogeneity of clinical practice.

CONCLUSIONS

No single test or group of tests was able to predict all cases of difficult laryngoscopy at the preoperative airway assessment. Wison Risk Sum Score was found to be the best predictor of difficult laryngoscopy when compared to MMC, RHTMD, RHSMD and HMDR in isolation and any possible combination.

The combination of MMC + RHTMD + RHSMD and MMC + RHTMD + RHSMD + HMDR was found to be the best option for the prediction of difficult laryngoscopy, but at the cost of large number of false positive cases. Based on our findings, we suggest that simple and easy airway assessment test, the WRSS is better in predicting difficult laryngoscopy.

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