

Cardiothoracic Anesthesia, Respiration and Airway

Modified Mallampati test, thyromental distance and inter-incisor gap are the best predictors of difficult laryngoscopy in West Africans

[Le test de Mallampati modifié, la distance thyromentonnière et l'espace entre les incisives sont les meilleurs prédicteurs de difficultés laryngoscopiques chez des Africains de l'Ouest]

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Purpose: To determine the ability to predict difficult visualization of the larynx (DVL) from the following preoperative airway predictive indices, in isolation and combination: modified Mallampati test (MMT), thyromental distance (TMD), sternomental distance (SMD), horizontal length of the mandible (HLM) and inter-incisor gap (IIG).

Methods: Three hundred and eighty consecutive patients undergoing general anesthesia were evaluated using the MMT, TMD, SMD, HLM and IIG and the cut-off points for the airway predictors were Mallampati III and IV; ≤ 6.5 cm, ≤ 13.5 cm, ≤ 9.0 cm and ≤ 4.0 cm respectively. During direct laryngoscopy, the laryngeal view was graded using the Cormack and Lehane (CL) classification. CL grades III and IV were considered difficult visualization. Sensitivity, specificity and positive predictive value for each airway predictor in isolation and in combination were determined. Logistic regression analysis was used to determine independent predictors of DVL.

Results: Difficulty to visualize the larynx was found in 13 (3.4%) patients. The sensitivity, specificity and the positive predictive value for the five airway predictors were: MMT (61.5%; 98.4%; 57.1%), TMD (15.4%; 98.1%; 22.2%), SMD (0%; 100%; 0%), HLM (30.8%; 76.0%; 4.3%) and IIG (30.8%; 97.3%; 28.6%). The best combination of predictors was MMT/TMD/IIG with a sensitivity, specificity and positive predictive value of 84.6%; 94.6%; 35.5% respectively. Logistic regression analysis showed that weight, MMT, IIG and TMD were independent predictors of DVL.

Conclusion: MMT, TMD and IIG appear to provide the optimal combination in prediction of DVL in a West African population.

Objectif : Déterminer la capacité de prédire les difficultés de visualisation du larynx (DVL) à partir des indices préopératoires suivants, pris isolément et en combinaison : le test de Mallampati modifié (TMM), la distance thyromentonnière (DTM), la distance sternomentonnière (DSM), la longueur horizontale de la mandibule (LHM) et l'espace inter-incisive (EII).

Méthode : Nous avons évalué 380 patients consécutifs devant subir une anesthésie générale en utilisant le TMM, la DTM, la DSM et l'EII ; les points limites des prédicteurs d'intubation ont été les classes de Mallampati III et IV ; $\leq 6,5$ cm, $\leq 13,5$ cm, $\leq 9,0$ cm et $\leq 4,0$ cm respectivement. La visualisation laryngoscopique directe a été cotée selon la classification de Cormack et Lehane (CL). Les classes de CL III et IV étaient une visualisation difficile. La sensibilité, la spécificité et la valeur prédictive positive de chaque prédicteur d'intubation pris isolément et en combinaison ont été déterminés. On a déterminé les prédicteurs indépendants des DVL par l'analyse de régression logistique.

Résultats : La visualisation du larynx a été difficile chez 13 (3,4 %) patients. La sensibilité, la spécificité et la valeur prédictive positive des cinq prédicteurs d'intubation ont été : le TMM (61,5 % ; 98,4 % ; 57,1 %), la DTM (15,4 % ; 98,1 % ; 22,2 %), la DSM (0 % ; 100 % ; 0 %), la LHM (30,8 % ; 76,0 % ; 4,3 %) et l'EII (30,8 % ; 97,3 % ; 28,6 %). La meilleure combinaison de prédicteurs a été TMM/DTM/EII avec une sensibilité, une spécificité et une valeur prédictive positive de 84,6 % ; 94,6 % ; 35,5 % respectivement. L'analyse de régression logistique a montré que le poids, le TMM, l'EII et la DTM étaient des prédicteurs indépendants des DVL.

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Conclusion : Le TMM, la DTM et l'EI semblent fournir la combinaison optimale pour prédire les DVL chez une population d'Afrique de l'Ouest.

DIFFICULT visualization of the larynx (DVL) was defined by the ASA task force as occurring when 'it is not possible to visualize any part of the vocal cords by conventional laryngoscopy.'¹ Tracheal intubation is a common anesthetic procedure usually accomplished with ease. However, when it proves difficult, the patient's life may be seriously at risk. The incidence of DVL is between 1.5 to 8.5%, difficult intubation 1 to 4% and failed intubation 0.1 to 0.3 %.² A closed claims analysis showed that the most common cause of injury in such cases was hypoxia from inadequate ventilation due to difficult tracheal intubation or accidental esophageal intubation. In 85% of these cases, the outcome was death or brain damage.³

Several preoperative airway assessment tests have been proposed.⁴⁻¹¹ These tests have been used singly or in various combinations. However, they are characterized by low sensitivity, reasonable specificity and low positive predictive value. They all have significant false positives.¹²⁻¹⁴ The majority of these studies were performed in North American or European populations. At the Lagos University Teaching Hospital in West Africa, the Mallampati score is used in combination with various anatomical indices that include receding mandible, full set of teeth, short fat neck and facial deformities. Anatomically, West Africans appear to have a longer neck and sternomental distance (SMD) compared to Caucasians. The purpose of our study was to determine the ability to predict DVL in a West African population from the following preoperative airway predictors, in isolation and in combination: modified Mallampati test (MMT), thyromental distance (TMD), SMD, horizontal length of the mandible (HLM) and inter-incisor gap (IIG).

Methods

Approval for the study was obtained from the Institutional Research and Ethical Board. Three hundred and eighty consecutive patients, ASA physical status I to III who required general endotracheal anesthesia were studied prospectively over a one-year period. Exclusion criteria included inability to sit, gross anatomical abnormality or recent surgery of the head and neck and patients with severe cardiorespiratory disorders.

Preoperative assessment

Demographic data collected included age, sex, weight, height, and body mass index (BMI). A single anesthesiologist investigator with five years' experience in anesthesia carried out the evaluation as described by the original authors. The following five predictive test measurements were performed on all patients:

- 1 MMT: Samssoon and Young's modification of the Mallampati test¹⁴ recorded oropharyngeal structures visible upon maximal mouth opening
- 2 TMD¹¹
- 3 SMD¹²

This distance was measured in the seated position with the head fully extended on the neck and with the mouth closed. The straight distance between the upper border of the manubrium-sterni and bony point of the mentum was measured.

- 4 HLM¹⁰

The patient was seated with the head in the neutral position

The straight distance from the angle of mandible to the symphysis-menti was measured

Tests 2 to 4 were measured with a rigid ruler

- 5 The IIG¹²

The IIG is the distance between the upper and lower incisors. It was measured with the patient sitting in the neutral position and mouth maximally open with a pair of calipers.

The cut-off points for the predictors were determined *a priori* as suggested by the originators of the tests except for the SMD cut-off that was increased from 12.5 cm to 13.5 cm after preliminary analysis of pilot data. Values below and inclusive of each cut-off point were predicted as DVL for the anthropometric variables. Values above the cut-off point were predicted as easy-visualization of the larynx (EVL). DVL was predicted with MMT III or IV, TMD \leq 6.5 cm; SMD \leq 13.5 cm; HLM \leq 9.0 cm; IIG \leq 4.0 cm.

Anesthesia induction and tracheal tube insertion

Induction of anesthesia was performed in the supine position with 5 mg·kg⁻¹ of sodium thiopental or propofol 2 mg·kg⁻¹ intravenously. Suxamethonium chloride 1 mg·kg⁻¹ was administered intravenously to facilitate endotracheal intubation. After disappearance of fasciculations, the patient's head was placed in the 'sniffing position.' Laryngoscopy was performed using a Macintosh #4 blade to visualize the larynx and the view was classified using the Cormack and Lehane (CL) classification:¹⁵ (I = vocal cords visible; II = only posterior commissure or arytenoids visible; III = only epiglottis visible; IV = none of the foregoing visible). DVL was defined as CL III or IV view on direct laryn-

TABLE I Demographic characteristics of patients with a DVL or EVL

	<i>EVL (n = 367)</i>	<i>DVL (n = 13)</i>	<i>P-value</i>
Age (yr)	35.9 ± 11.9	34.2 ± 8.9	0.628
Height (m)	1.65 ± 0.6	1.65 ± 0.5	0.900
Weight (kg)	71.7 ± 10.8	94.5 ± 22.0	0.003**
BMI	26.32 ± 4.0	34.57 ± 8.1	0.003**

DVL = difficult visualization of the larynx; EVL = easy visualization of the larynx; BMI = body mass index. **Statistically significant difference ($P < 0.05$).

TABLE II Predictors of DVL and EVL

<i>Predictive test (cm)</i>	<i>EVL (n = 367)</i>	<i>DVL (n = 13)</i>	<i>P-value</i>
Thyromental distance (TMD)	7.7 ± 0.9	7.1 ± 1.2	0.026**
Sternomental distance (SMD)	18.5 ± 2.1	17.1 ± 1.9	0.022**
Horizontal length of mandible (HLM)	9.1 ± 0.4	9.0 ± 0.4	0.42
Inter-incisor gap (IIG)	4.7 ± 0.7	3.7 ± 1.0	0.00**

EVL = easy visualization of the larynx; DVL = difficult visualization of the larynx. **Statistically significant difference ($P < 0.05$).

TABLE III Sensitivity, specificity and positive predictive value of the five single airway predictors

<i>Predictive test</i>	<i>Sensitivity (%)</i>	<i>Specificity (%)</i>	<i>Positive predictive value (%)</i>
Mallampati	61.5	98.4	57.1
Thyromental distance	15.4	98.1	22.2
Sternomental distance	0	100	0
Horizontal length of the mandible	30.8	76.0	4.3
Inter-incisor gap	30.8	97.3	28.6

gосcopy. EVL was defined as CL I or II view on direct laryngосcopy. Confirmation of successful intubation was by bilateral auscultation over the lung fields and capnography.

Statistical analysis

Demographic data, value of the airway predictors were compared using t tests for continuous variables and Mann Whitney U test for MMT.

First, univariate analyses were performed to assess the association of each airway predictor to DVL. Chi-square analyses were used. Sensitivity, specificity, and positive predictive value were obtained and compared amongst predictors. Secondly, combinations of predictors were formulated. Likewise, the sensitivity,

specificity, and positive predictive value were obtained and compared amongst the combinations. Lastly, demographic and patient variables, and airway predictors were entered into a multivariate logistic regression analysis to determine independent predictors of DVL. Odds ratio, 95% confidence intervals and *P* values were obtained for independent predictors derived.

The data were analyzed using the statistical package for social studies version 11.0 (SPSS® Inc., Chicago, IL, USA).

Results

Three hundred and eighty patients were studied. Patients' age, height, weight, and BMI are shown in Table I. There were 90 males and 290 females. There were 306 (80.6%) ASA I, 64 (16.8%) ASA II, and ten (2.6%) ASA III patients. DVL was observed in 13 patients (3.4%). There was no failed intubation. There were significant differences in weight and BMI between the DVL and EVL patients (Table I).

Single predictors

There were significant differences between TMD, SMD and IIG between DVL and EVL patients (Table II). Sensitivity, specificity and positive predictive value of the five single predictors are shown in Table III.

The MMT was the most sensitive of the single tests with a sensitivity of 61.5%. The SMD was unable to predict any case. All tests with the exception of HLM had high specificities. The MMT had the highest sensitivity and positive predictive value amongst single predictors.

Combined predictive tests of (EVL) and DVL; Table IV

The combination of the five tests increased the sensitivity to 84.6% but decreased the specificity to 73.3% and the positive predictive value to 10.1%. The combination with the best results was the Mallampati test, TMD and IIG with a sensitivity, specificity and positive predictive value of 84.6%, 94.6%, and 35.5% respectively. The various other combinations resulted in an increased sensitivity at the expense of lowering the positive predictive value.

Logistic regression

Logistic regression showed that weight, MMT, TMD and IIG were independent predictors of DVL (Table V).

Discussion

The incidence of DVL in this study was found to be 3.4% and is in concordance with the study by Crosby *et al.*, which reported an incidence of 1.5 to 8.5%.² Wide variations in the incidence of DVL have been

TABLE IV Sensitivity, specificity and positive predictive value of airway predictor combinations

Predictor combination	Sensitivity (%)	Specificity (%)	Positive predictive value (%)
1) MMT	61.5	98.4	57.1
2) MMT + TMD	76.9	96.7	45.5
3) MMT + HLM	69.2	74.9	8.9
4) MMT + IIG	61.5	97.8	50.0
5) MMT + TMD + HLM	76.9	74.4	9.6
6) MMT + TMD + IIG	84.6	94.6	35.5
7) TMD + HLM + IIG	61.5	98.2	7.8
8) MMT + TMD + HLM + IIG	84.6	73.3	10.1
9) MMT + TMD + SMD + HLM + IIG	84.6	73.3	10.1

MMT = modified Mallampati test; TMD = thyromental distance; SMD = sternomental distance; HLM = horizontal length of mandible; IIG = inter-incisor gap.

TABLE V Logistic regression showing the independent predictors of DVL

Predictors	Odds ratio	95% confidence interval	P
IIG	23.84	3.13–181.38	0.002
MMT	16.92	2.87–96.16	0.001
TMD	8.72	1.56–65.92	0.036
Weight	1.09	1.03–1.16	0.003

DVL = difficult visualization of the larynx; IIG = inter-incisor gap; MMT = modified Mallampati test; TMD = thyromental distance.

ascribed to various factors, such as lack of uniformity in describing or grading laryngeal views, cricoid pressure, head position, degree of muscle relaxation and type or size of laryngoscope blade.

A screening test for prediction of DVL must be rapid and provide reliable results. It should reliably identify patients with a truly DVL (good sensitivity) and not falsely label patients as DVL who actually are EVL (low false positives). No screening test is 100% sensitive and 100% specific. The ideal test should be easy to perform, highly sensitive, specific and possess a high positive predictive value with few false positive predictions.

In this study, it was found that the MMT was the most useful single predictor with a sensitivity, specificity and positive predictive value of 61.5%, 98.4%, and 57.1% respectively. These results are similar to the studies done by Tse *et al.* and Ramadhani and colleagues.^{16,17} A sensitivity of greater than 80% was reported by Frerk in a European population, Savva from the United Arab Emirates and also Ita and colleagues in Nigeria.^{11,12,18} Mallampati *et al.* reported a sensitivity of 53% and a positive predictive value of 93%, however, repeated studies have not obtained this high positive predictive value.^{4,16} The wide range of results has been attributed to inter-observer variability

as reported by Karkouti *et al.*¹⁹ Furthermore, prevention of phonation was shown by Tham *et al.* to be a critical factor in achieving a reliable score.²⁰

The TMD had a very low sensitivity of 15% in this our study. Tse *et al.* reported a similarly low sensitivity of 32% while in the majority of reports the sensitivity was reported to be above 60%. This could possibly be due to anthropometric peculiarities in the study population, a postulate that should be validated in future studies.

The SMD was unable to predict any of the difficult laryngoscopies despite a statistically significant difference between DVL and EVL patients ($P < 0.022$). In the EVL the average distance was 18.5 ± 2.1 cm while in the DVL it was 17.1 ± 1.9 cm. The cut-off point used in this study was 13.5 cm as described by Ramadhani who increased the original distance from 12.5 cm, following the recommendation by Savva after discriminant analysis. The SMD had not been studied in the West African people and it appears that the West African population might have different anthropometric characteristics from the results obtained. An increase in the cut-off point to 15 cm may increase the sensitivity of this test in these people, but this remains to be demonstrated.

The HLM was found to have a low sensitivity and positive predictive value and was the least useful of the test performed. This can be attributed to the large number of positives obtained in the study. The IIG was the second most sensitive of all the five tests with a sensitivity of 30.8% and a positive predictive value of 28.6%. This result is contradictory to the work done by Savva who reported that there was no correlation between IIG and view at laryngoscopy.

The difference between the means of the IIG between DVL and EVL was statistically significant. This is in agreement with results obtained by both Wilson *et al.* and Nath.^{8,21}

TABLE VI Comparison of DVL predictors reported in the literature

Source	Test and criteria	n	Incidence	Sensitivity	Specificity	Positive predictive value
Tse <i>et al.</i> ¹⁶	MMT ≥ 3 , TMD ≤ 7 cm and $\leq 80^\circ$	471	13%	5%	99%	38%
	MMT ≥ 3 , TMD ≤ 7 cm			21%	92%	88%
Mallampati ⁴	MMT ≥ 3	210	13%	50%	84%	93%
Frerk ¹¹	MMT ≥ 3 , TMD ≤ 7 cm	244	4.5%	81.2%	97.5%	62.4%
Nath and Sekar ²¹	Scoring test ≥ 6	282	4.2%	96%	82%	31%
Present study* (Merah <i>et al.</i>)		380	3.4%			
	MMT ≥ 3 + TMD ≤ 6.5 cm + IIG ≤ 4.0 cm			84.6%	94.6%	35.5%
	MMT ≥ 3 + TMD ≤ 6.5 cm			76.9	96.7%	45.5%
Wilson <i>et al.</i> ⁸	Scoring test > 2	778	1.5%	75%	88%	9%

DVL = difficult visualization of the larynx; MMT = modified Mallampati test; TMD = thyromental distance; IIG = inter-incisor gap; n = number of patients studied.

There is little if any documentation of the five-test combination we used in the world literature though various other five-test or more combinations have been used previously.^{8,21-23} The combination of all five tests increased the sensitivity to 84.6% at the expense of the specificity and positive predictive value. The combination providing the best prediction in our study involved the MMT, TMD and IIG with a sensitivity, specificity and positive predictive value of 84.6%, 94.6%, and 35.5%. The MMT and TMD is the most common combination used in the prediction of difficult laryngoscopy (Table VI). In our study we obtained a sensitivity of 76.9% and a specificity of 96.7%, which is similar to the result obtained by Frerk - 81.2% and 97.8%. Tse *et al.* obtained a value of 21% and 92% respectively. The discrepancy in the results may be attributed to Frerk's definition of difficult laryngoscopy. Nath and Sekar, as well as Wilson *et al.*, who used combinations with five tests and over had similar results to our five-test combination (Table VI).

Logistic regression showed that weight greater than 90 kg, Mallampati test, TMD and IIG were independent predictors of difficult laryngoscopy. Amongst the four independent predictors of DVL, IIG and MMT had the strongest association with DVL. A limitation of this study is the small sample size. However, further research might be able to throw more light on the problem.

Safe outcome of anesthesia remains the goal of every anesthesiologist. There is still no test or group of tests that can predict 100% of difficult laryngo-

scopies. MMT, TMD and IIG appear to provide the optimal combination to predict DVL in a West African population. Our experience and review of the literature suggest that optimal predictors are similar in Caucasians and West Africans.

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