Sternal Distance Ratio as a Predictor of Difficult Laryngoscopy: A Prospective, Double-Blind Pilot Study

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Abstract

Background: No single test has shown to be an accurate predictor of difficult laryngoscopy. Aims: This study aims to evaluate the effectiveness of the ratio of the sternal distance (SMD) in neutral and full neck extension position SMD ratio (SMDR) as a predictor of difficult laryngoscopy and any need of assisted intubation. Setting and Design: Prospective, double-blind pilot study. Materials and Methods: This study included 221 consecutive adult patients scheduled to undergo elective surgery under general anesthesia. Physical and airway characteristics, SMDR, difficult laryngoscopy (using Cormack-Lehane [C/L] scale), and any kind of assisted intubation were assessed. Statistical Analysis: The optimal cutoff point for SMDR was identified using receiver operating characteristic (ROC) analysis. The association between SMDR and the intubation method was evaluated through multiple logistic regression analysis. Results: A SMDR below 1.55 led in 33% of the cases to assisted intubation and 33%–53% of C/L III–IV glottic views for McCoy and Macintosh blades, respectively. On the other hand, SMDR above 1.9 led to no C/L IV glottic views for both blades and 4% and 11% C/L III views glottic views for McCoy and Macintosh, respectively. The best sensitivity and specificity cutoff point as defined by the ROC curve was identified for an SMDR value of 1.7 (area under the curve: 0.815; 95% confidence interval: 0.743–0.887). Assisted intubation rates were significantly higher in patients with an SMDR inferior to 1.7 (30.5% compared to 3.5%, P < 0.001). Conclusions: SMDR is a simple, objective, and easy to perform test. The present study indicates that SMDR may be helpful in predicting difficult laryngoscopy and assisted intubation.

Keywords: Airway, anesthesia, difficult airway, difficult laryngoscopy, sternomental distance ratio

Introduction

Despite the advances in airway management failed endotracheal intubation remains a significant cause of morbidity and mortality in anesthetic practice.[1–3] National and international guidelines and algorithms[4–6] have been developed and are regularly updated to promote and enhance safer management for both anticipated and unanticipated difficult airway. However, there is a lack of consensus on the predictors of a difficult airway, which is the most feared situation of every anesthetist.

Over the years, several predictive scores for difficult airway have been proposed, with the most common being the Mallampati score,[7] the thyromental distance (TMD),[8,9] the sternal distance (SMD),[10] the upper lip bite test (ULBT)[11] and cervical spine mobility.[12–14] Other factors such as body mass index (BMI)[15,16] or protruding incisors[17] have also been assessed. Despite the fact that they can be relative indicators of a difficult airway, none of them can reliably exclude difficult intubation and none of them has exhibited high sensitivity as a single test, and at most cases not even as when combined with another score.[18,19]

Limited cervical spine mobility is an important factor for creating difficult intubating conditions[12–14] and SMD can be another indicator.[10,19,21] Based on personal clinical observations, we tried to combine these two factors into a new one that could at the same time, assess both patient anatomy

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and clinical conditions. Therefore, the aim of the present prospective double-blind pilot study was to assess the ratio of SMD measured with the neck in full extension to the SMD measured with the neck in neutral position as a single predictor for difficult laryngoscopy.

**Materials and Methods**

Following Institutional Ethics Committee approval (Nr01/ January 17, 2013, and Protocol Nr 36 renewal date February 4, 2020) and written informed consent, 221 consecutive adult patients scheduled to undergo elective surgery under general anesthesia were included in this prospective, double-blind pilot study (conducted from May 29, 2013, to November 2, 2013). Emergency cases, patients with the previous history of failed tracheal intubation, patients with the American Society of Anesthesiologists (ASA) physical status Class IV and pregnant patients were excluded from the study. A senior anesthesiologist blinded to the study interventions performed the preoperative patient assessment. Besides the standard preoperative assessment and tests, the following variables were recorded in a separate sheet for the study purposes: age, gender, BMI, Mallampati classification (Mall), ULBT, and TMD. Furthermore, the SMD (the distance from the mentum to the sternal notch) was measured in two different positions: With the neck in full extension as classically described and in a neutral position. The ratio of the full extension to the neutral position distance was recorded. This variable was named SMD ratio (SMDR).

Preoperatively, all patients were fasted as per the European Society of Anaesthesiology guidelines. An 18G intravenous (i.v.) cannula was inserted and standard monitoring, including electrocardiogram, SpO₂, and noninvasive blood pressure was applied to all patients. In addition to the above, train-of-four (TOF) monitoring was applied using a peripheral nerve stimulator (Innervator 252, Fisher and Paykel Electronics Ltd., Auckland, New Zealand) placed in the ulnar nerve, in order to assess the degree of neuromuscular blockade. All patients were premedicated with i.v. midazolam 1–2 mg. After preoxygenation with 100% O₂ through face mask, anesthesia was induced with propofol (2–3 mg·kg⁻¹) and fentanyl (1–2 µg·kg⁻¹). Rocuronium 0.6 mg·kg⁻¹ was administered for tracheal intubation. After adequate muscle relaxation was achieved as assessed by a TOF value of 0 in the nerve stimulator, laryngoscopy was attempted by a second senior anesthesiologist blinded to the airway assessment and the study protocol. The glottic views obtained were recorded according to the Cormack/Lehane (C/L) scoring system.

At this point, it has to be noted that to better evaluate the correlation between the airway assessment variables and the possible glottic views, in all patients, two laryngoscopy attempts were performed: One with a classic Macintosh blade and one with a McCoy blade. In order to avoid observation bias, patients were randomly allocated to the order of the laryngoscope blade using a computerized random number generator (Microsoft Office Excel 2007 RANDBETWEEN function) into two groups: Group Mac where a Macintosh blade was used first and Group MacCoy where a McCoy blade was used first. Endotracheal intubation was performed at the second laryngoscopy attempt. Furthermore, any intubation that required any method of assistance (external pressure, backward-upward-rightward manoeuvre, gum elastic bougie, change of anesthetist, and third attempt with a videolaryngoscope) was recorded as “assisted intubation” for the study purposes.

**Statistical analysis**

Continuous variables are presented as mean values ± standard deviation, whereas categorical variables are presented as absolute and relative (%) frequencies. The association between normally distributed continuous variables and binary variables categories was evaluated through Student’s  t-test for independent samples. In case of categorical variables with >2 categories, one-way analysis of variance was applied after checking for homoscedasticity. Because of multiple comparisons, the Bonferroni rule was applied to correct for the inflation of Type-I error. Whether these variables were normally distributed was tested through the P-P plot and equality of variances through Levene’s test. Associations between categorical variables and sample categories were tested by the use of the Chi-squared test. Nonparametric tests (i.e., Spearman’s ρ and Kendal’s tau-b) were applied to estimate the correlations between SMDR with glottic view. The association between SMDR and the intubation method was evaluated through multiple logistic regression analysis. Results are presented as odds ratio (OR) and their corresponding 95% confidence intervals (95% CIs). Given the fact that there are no data in the international literature for this predictive factor, the values obtained were divided into four quadrants for initial evaluation. Afterward, receiver operating characteristic (ROC) curves analysis was used to assess the discriminative ability of the baseline predictor (SMDR) for assisted intubation method. The curves were constructed by plotting sensitivity against (1-specificity) and corresponding area (s) under the curve were compared. The ROC curves designed for assessing the discrimination of the SMDR versus assisted intubation were used to identify the ideal value of the continuous variables in which the best sensitivity and specificity were observed. By using the ratio 1.7 as a cutoff point, we created the binary covariate of SMDR (<1.7 compared to ≥ 1.7). The statistical calculations were performed on the SPSS version 21 (IBM Hellas, Athens, Greece).

**Results**

Two hundred and twenty-one patients were finally included in the study. Table 1 describes patients’ characteristics. No adverse effects were recorded, and all patients were finally intubated with no more than three laryngoscopy attempts. Of the 221 patients, 35 (15.8%) underwent an assisted intubation. As described in the methods section, the SMDR values obtained were initially divided into four quadrants [Table 2],...
where it was noticed that the higher was the SMDR the lower was the C/L class. An SMDR below 1.55 led in 33% of the cases to assisted intubation and to 33%–53% of C/L III–IV glottic views for McCoy and Macintosh blades, respectively. On the other hand, an SMDR above 1.9 led to no C/L IV glottic views for both blades and to 4% and 11% C/L III views glottic views for McCoy and Macintosh, respectively. The best sensitivity and specificity cutoff point as defined by the ROC curve was identified for an SMDR value of 1.7 [Figure 1].

Assisted intubation rates were significantly higher in patients with a SMDR inferior to 1.7 (28.7% compared to 3.5%, \( P < 0.001 \)), with a higher rate of men 47% compared to 31%, \( P = 0.01 \) [Table 3].

Patients with SMDR > 1.7 had significantly higher likelihood to have a ULBT of I (68% compared to 52%, \( P = 0.04 \)), whereas no difference was observed between either the Mallampati scores or the ASA physical status class and the SMDR range values. Furthermore, BMI values did not differ (\( P = 0.69 \)) irrespective of the SMDR [Table 3].

As the SMDR values were rising, there was a higher likelihood for the patients to be in the lowest C/L Classes (I and II) in both Macintosh and McCoy groups (\( P < 0.001 \)) [Tables 2 and 4]. SMDR was significantly negatively correlated with the C/L class for both laryngoscopy methods as indicated by Spearman’s nonparametric test. Boxplots in Figures 2 and 3 are depicting this correlation. At an SMDR > 1.7, the C/L I glottic views rose from 34% to 64% (\( P < 0.001 \)) when a Macintosh blade was used, compared to SMDR inferior to 1.7. As a matter of fact, good or excellent glottic views (C/L I and II) with the use of Macintosh blade rose from 52% of the cases to 87% when the SMDR was equal or superior to 1.7 (\( P < 0.001 \)). The combination of McCoy and SMDR > 1.7 led to 3% of C/L III and 0% C/L IV glottic views.

After adjustment for various potential confounders (age, sex, BMI, ULBT, TMD, and ASA status), including variables strongly associated with intubation procedure, significant inverse associations were observed. A 1 unit increase from 0.7 to 1.7 to the SMDR, practically indicated no likelihood for assisted intubation (OR 0.002, 95% CI 0.001–0.009, \( P < 0.001 \)), whereas there was no difference observed in the comparison between SMDR changes and Mallampati scores in the multivariate logistic regression analysis (OR 0.274 95% CI 0.014–1.276, \( P = 0.33 \)) [Table 5].

**Discussion**

Several tests have been proposed as prognostic factors for difficult laryngoscopy \(^{17,8,10,11,14,24,25}\) however none of them seems to perform well alone, and different combinations between them have been proposed to improve accuracy.\(^{18,26,27}\) This is also the case of SMD which is a factor that indirectly combines mandibular space, cervical spine mobility, and neck height.\(^{10,20,21}\) Whereas retrognathia, limited cervical spine mobility and short neck have all been individually associated with difficult laryngoscopy,\(^{13,14,17}\) their absence does not indicate an easy laryngoscopy and several other factors such as the Mallampati score have to be also assessed.\(^{14–6}\)

Furthermore, neck mobility as it has been described\(^{12,13}\) it is not an easy measurement to perform and to accurately assess into degrees (<80°, 80–90°, >90°) as all anesthesiots know in everyday practice. The SMDR, on the other hand, can more accurately assess at the same time the cervical spine mobility, neck length, and mandibular space.
Table 2: Patients’ characteristics according to different sternomental distance ratio value ranges

| Patients’ characteristics | SMDR |  |  |  |  |  |  |  |
|--------------------------|------|---|---|---|---|---|---|---|
|                          |     | >1.90 (ν=53) | 1.90-1.73 (ν=56) | 1.72-1.55 (ν=57) | <1.55 (ν=55) |     |
| Age (years)              | 56 (17) | 52 (19) | 50 (14) | 58 (16) | 0.03 |
| Men (%)                  | 38 | 27 | 40 | 47 | 0.16 |
| BMI (kg/m²)              | 27.6 (4.8) | 26.7 (5.3) | 26.6 (5.1) | 27.6 (5.3) | 0.65 |
| TMD (cm)                 | 8.4 (1.2) | 8.4 (1.3) | 8.8 (1.3) | 8.5 (1.5) | 0.38 |
| ULBT (%)                 |  |  |  |  |  |
| I                        | 68 | 68 | 56 | 49 | 0.27 |
| II                       | 30 | 32 | 40 | 49 | 0.27 |
| III                      | 2 | 0 | 4 | 2 | 0.27 |
| ASA status (%)           |  |  |  |  |  |
| ASA-I                    | 43 | 48 | 55 | 49 | 0.42 |
| ASA-II                   | 49 | 45 | 33 | 35 | 0.42 |
| ASA-III                  | 8 | 7 | 12 | 16 | 0.42 |
| Mallampati score (%)     |  |  |  |  |  |
| I                        | 55 | 50 | 44 | 33 | 0.33 |
| II                       | 32 | 38 | 35 | 49 | 0.33 |
| III                      | 9 | 12 | 14 | 15 | 0.33 |
| IV                       | 4 | 0 | 7 | 3 | 0.33 |
| Cormack macintosh (%)    |  |  |  |  |  |
| I                        | 66 | 59 | 47 | 29 | <0.001 |
| II                       | 23 | 27 | 16 | 18 | <0.001 |
| III                      | 11 | 14 | 35 | 47 | <0.001 |
| IV                       | 0 | 0 | 2 | 6 | <0.001 |
| Cormack McCoy (%)        |  |  |  |  |  |
| I                        | 90 | 86 | 58 | 44 | <0.001 |
| II                       | 6 | 12 | 25 | 33 | <0.001 |
| III                      | 4 | 2 | 17 | 23 | <0.001 |
| IV                       | 0 | 0 | 0 | 0 | <0.001 |
| Assisted intubation (%)  | 0 | 7 | 25 | 33 | <0.001 |

SMDR=Sternomental distance ratio, BMI=Body mass index, ASA=American Society of Anesthesiologists, TMD: Thyromental distance, ULBT: Upper lip bite test

Figure 2: Box plot indicating the relationship between sternomental distance ratio values and Cormack Grades when using a Macintosh blade.

Figure 3: Box plot indicating the relationship between sternomental distance ratio values and Cormack Grades when using a McCoy blade.

The results of the present study indicate that the SMDR correlates well with the glottic view. However, a good glottic view does not necessarily translate into an easy intubation. That is why in the present study, any form of assistance during the intubation attempt was recorded and compared to the glottic views obtained and to the SMDR. An SMDR above 1.7 was a good prognostic factor for good and excellent glottic views with a percentage of assisted intubation as low as 4%.
Furthermore, when the SMDR rose to values above 1.9, the percentage of good and excellent glottic views rose even more, and the percentage of assisted intubation dropped to zero.

To the best of our knowledge, this is the first study in the international literature that assesses SMD and neck mobility in a more accurate way using the ratio of SMD in full neck extension to the SMD with the head in neutral position. Only one other study in the literature, by Prakash et al.,[29] based practically on the same hypothesis but with a different rationale, tried to assess the difference of the absolute values of SMD in full extent and neutral position as a predictor of difficult laryngoscopy. The authors reported that an SMD difference of <5.25 cm was a good predictor of difficult laryngoscopy indicating thus that there is indeed a significant predictive value in combining SMD and neck mobility in a single predictive factor. On the other hand, the difference in absolute values may not be accurate enough. The authors reported that an SMD of <14.75 cm was a good cutoff point for predicting difficult laryngoscopy. However, several other studies have indicated different SMD values as cutoff points, the fact that implies that the SMD difference in absolute numbers may not be as accurate as the sternomental ratio in depicting neck mobility.

In this study, we decided to also use a McCoy blade not only as a safety measure since unpredicted difficult intubation might have occurred[40] but also as a means to assess blindly whether the SMDR could predict really difficult laryngoscopy conditions even when a nonroutine advanced laryngoscopy method was used. As a matter of fact, even when a McCoy blade was used, poor glottic views (C/L III and IV) declined from 23% to 3% when SMDR exceeded 1.7 compared to <1.7.

In our study, patients with SMDR >1.7 when compared to those with SMDR <1.7 had 15% chances (67% compared to 52%, \( P = 0.04 \)) to have a ULBT I, which is a factor associated with easy laryngoscopy. Male sex was associated with difficult laryngoscopy in accordance with the study by Prakash et al.[29] SMDR did not seem to correlate with BMI (despite the fact that patients in our study were rather obese, mean BMI: 27.1), also in accordance with the aforementioned study,[29] and this fact comes to concur with other studies which failed to establish a correlation between BMI and difficult laryngoscopy.[15,16] The same applies for Mallampati score as previously reported.[18,20,24] In contrast to the study by Prakash et al.,[29] where the sternomental difference was associated with age, SMDR was not associated with age. There is evidence[16,18,30] in the international literature that age may correlate with difficult intubation, but the ethnicity effect cannot be excluded and further data from larger studies are necessary.

TMD also did not seem to correlate with SMDR cutoff points, which is in accordance with the results of previous studies reporting that it cannot be used as a single predictor for difficult

### Table 3: Sociodemographic and clinical characteristics of sample based on sternomental distance ratio cutoff of 1.7 \( (n=221) \)

| SMDR          | \( <1.7 \) (\( n=108 \)) | \( \geq 1.7 \) (\( n=113 \)) | \( \text{P} \) |
|---------------|--------------------------|-----------------------------|--------------|
| Men (%)       | 47                       | 31                          | 0.01         |
| Age (years)   | 55 (16)                  | 53 (18)                     | 0.46         |
| BMI (kg/m\(^2\)) | 27.28 (5.37)          | 27.00 (4.98)                | 0.69         |
| TMD (cm)      | 8.62 (1.38)              | 8.44 (1.26)                 | 0.32         |
| ULBT, \( n \) % | I 56 (52)               | 77 (68)                     | 0.04         |
|              | II 49 (45)               | 35 (31)                     | 0.04         |
|              | III 3 (3)                | 1 (1)                       | 0.04         |
| ASA criteria (%) | ASA-I 53                | 45                          | 0.08         |
|              | ASA-II 33                | 47                          | 0.08         |
|              | ASA-III 14               | 8                           | 0.08         |
| Mallampati test (%) | I 38                     | 51                          | 0.10         |
|              | II 42                    | 35                          | 0.10         |
|              | III 14                   | 12                          | 0.10         |
|              | IV 6                     | 2                           | 0.10         |
| Assisted intubation, \( n \) % | 31 (28.7)               | 4 (3.5)                     | <0.001       |

SMDR=Sternomental distance ratio, BMI=Body mass index, ULBT=Upper lip bite test, ASA=American Society of Anesthesiologists, TMD=Thyromental distance

### Table 4: Cormack/Lehane grades and assisted intubation rates based on sternomental distance ratio 1.7 cutoff point

| Group | Cormack/Lehane Grade (percentage of the patients) | SMDR          | \( <1.7 \) (\( n=108 \)) | \( \geq 1.7 \) (\( n=113 \)) | \( \text{P} \) |
|-------|--------------------------------------------------|---------------|--------------------------|-----------------------------|--------------|
| Mac (%) | I 34.3 | 63.7 | <0.001 |
|       | II 17.6 | 23 | <0.001 |
|       | III 44.4 | 13.3 | <0.001 |
|       | IV 3.7 | 0 | <0.001 |
| MacCoy (%) | I 46.3 | 87.6 | <0.001 |
|       | II 30.6 | 8.8 | <0.001 |
|       | III 23.1 | 3.5 | <0.001 |
|       | IV 0 | 0 | <0.001 |
| Assisted intubation (%) | 28.7 | 3.5 | <0.001 |

SMDR=Sternomental distance ratio
Table 5: Multivariate logistic regression analysis to evaluate the association between Mallampati, sternomental distance ratio, and assisted intubation likelihood, in the sample

| Dependent variable | SMDR (per 1 unit raise) | OR    | 95% CI  | P       |
|--------------------|-------------------------|-------|---------|---------|
| Mallampati         |                         | Model 1 | 0.323   | 0.029-1.578 | 0.36 |
|                    |                         | Model 2 | 0.274   | 0.014-1.276 | 0.33 |
| Assisted intubation|                         | Model 1 | 0.004   | 0.001-0.015 | <0.001 |
|                    |                         | Model 2 | 0.002   | 0.001-0.009 | <0.001 |

Model 1=Crude model, Model 2=Adjusted for age, sex, BMI, ULBT, ASA classification, TMD, mandible length. SMDR=Sternomental distance ratio, OR=Odds ratio, CI=Confidence interval, BMI=Body mass index, ULBT=Upper lip bite test, ASA=American Society of Anesthesiologists, TMD=Thyromental distance.

However, what may apply with SMD may also apply with TMD. The TMD ratio may be a better indicator for difficult laryngoscopy, but this was not in the aims of the present study.

There are several limitations in this prospective pilot study. First of all, no sample size calculation was performed as the cutoff points for SMDR assessment were not known in advance. Furthermore, the sample was too small to perform subgroup analysis to see whether other factors such as thyroid disease or dentition where associated with SMDR even though such patients were not excluded from the study.

**Conclusion**

SMDR is a simple, objective, and easy to perform test. The results of the present study indicate that it may be helpful in predicting difficult laryngoscopy and assisted intubation. However, larger data are necessary taking also into account ethnicity parameters to obtain more solid results.

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**Conflicts of interest**

There are no conflicts of interest.

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