Title: Sex Differences in Predicting Difficult Laryngeal Exposure: Validation and Modification of Predictive Models

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Running title: Sex differences in the Laryngoscore

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Abstract

Objectives/Hypothesis: To determine the presence of sex differences in difficult laryngeal exposure and the Laryngoscore, validate the Laryngoscore, mini-Laryngoscore, and Clarysse's model for predicting difficult laryngeal exposure, and modify the Laryngoscore for improved prediction accuracy.

Study Design: Retrospective study.

Methods: This study included 153 patients who underwent laryngeal microsurgery at a tertiary laryngology center and university hospital. Patients were evaluated using the 11 items of the Laryngoscore, mini-Laryngoscore, and Clarysse's model to predict difficult laryngeal exposure. Difficult laryngeal exposure was defined as the inability to view the anterior commissure through a rigid laryngoscope under counter pressure to the anterior neck. Descriptive statistics and receiver operating characteristic curve analysis were used to assess the diagnostic performance of the predictive models and variables, including sex.

Results: The prevalence of difficult laryngeal exposure was significantly higher in men than in women, despite higher Laryngoscore values in females. The Laryngoscore, mini-Laryngoscore, and Clarysse's model demonstrated good diagnostic performance with C-indexes of 0.751, 0.727, and 0.783, respectively. Based on these findings, we proposed a modified Laryngoscore including treatment history, interincisors gap, upper jaw dental status, thyro-mental distance, degree of neck flexion-extension, and sex, achieving a C-index of 0.835.

Conclusions: Inclusion of sex in the Laryngoscore and related predictive models enhances the accuracy of predicting difficult laryngeal exposure. These findings support the inclusion of sex as a factor in future modifications of these models to improve their predictive performance.

Keywords: Difficult Laryngeal Exposure, Laryngoscore, Predictive Models, Sex Differences, Laryngeal Microsurgery

Introduction

Laryngeal microsurgery is a standard procedure used to treat benign or neoplastic lesions of the larynx. Successful surgery depends on surgical technique and optimal exposure of the larynx viewed through a rigid laryngoscope. If adequate exposure cannot be attained, the procedure can potentially result in incomplete resection or more complications. To anticipate a case of difficult laryngeal exposure (DLE), a thorough preoperative evaluation of the oral cavity and oropharynx as well as airway-related body size is necessary.

The Laryngoscore (LS), introduced by Piazza et al.[1] in 2014, comprehensively assesses factors contributing to DLE. The LS comprises 11 predictors traditionally used by anesthesiologists to gauge intubation difficulty: the interincisors gap (IIG) (score 0, ≥ 4 cm; score 1, < 4 cm), thyro-mental distance (TMD) (score 0, > 6.5 cm; score 1, 6.5-6.0 cm; score 2, < 6.0 cm), upper-jaw dental status (UJDS) (score 0, edentulous; score 1, partially edentulous; score 2, normal teeth; score 3, prominent teeth), trismus (score 0, no; score 1, yes), mandibular prognathism (score 0, absent or reducible; score 1, present and not reducible), macroglossia (score 0, no; score 1, yes), micrognathia (score 0, no; score 1, yes), degree of neck flexion-extension (dFE) (score 0, >90°; score 1, 80°–90°; score 2, <80°), previous treatments of neck radiation therapy or surgery (score 0, no; score 1, yes), Mallampati's modified classes (score 0, hard and soft palate, uvula, and pillars visible; score 1, hard and soft palate, and base of uvula visible; score 2, hard and soft palate visible; score 3, only hard palate visible), and body mass index (BMI) (score 0, ≤ 25; score 1, > 25). The 11 subscores are summed to give the LS, which ranges from 0 to 17, with higher scores indicating a heightened possibility of DLE. The original study[1] revealed that a laryngoscope enabled laryngeal visualization extending to the anterior commissure (AC) in 94% of the cases with an LS <6. However, in cases with an LS ≥6, AC visualization through a laryngoscope was achieved in only 60%, indicating a correlation between the LS and achieving optimal laryngeal exposure.

Tirelli et al.[2] conducted an external validation of the LS, revealing a good C-index (0.73) on the receiver operating characteristic (ROC) analysis. A cutoff of 4 identified 80.6% of patients with DLE. Arjun et al.[3] also reported that 94% of patients with an LS <6 showed good laryngeal exposure (GLE), and 54% with an LS ≥ 6 showed DLE.

Incandela et al.[4] used ROC analysis with a C-index of 0.74 and an LS cutoff of 5.5 to further validate the LS. They found that IIG, TMD, and UJDS were significant factors contributing to DLE and proposed the mini-Laryngoscore (mLS) using those three items of the LS for an objective measurement; TMD (score 0, ≥ 6 cm; score 1, < 6 cm), IIG (score 0, ≥ 4 cm; score 1, < 4 cm), and UJDS (score 0, edentulous; score 1, normal teeth; score 2, prominent teeth). The mLS ranges from 0 to 4 with the surgical field extending to the AC in 97% of cases with an mLS = 0, in 85% with an mLS ≤1, in 45% with an mLS ≥2, and in 80% with an mLS ≥3.

Furthermore, Clarysse et al.[5] reported that the LS and mLS showed good prediction of DLE, with good C-indexes (0.727 and 0.714, respectively). Univariate analysis showed that IIG and UJDS, but not TMD, were significant factors. They proposed a diagnostic model with only three parameters, a numerical value for IIG, an ordinal value for UJDS, and a treatment history without redundant or ambiguous items, which achieved a sufficient C-index of 0.835.

As mentioned above, the LS and included physical measurements, especially IIG and UJDS, related to DLE.[2, 4, 5] However, these can vary significantly among individuals, especially those related to sex. Typically, female individuals have a shorter stature and a broader range of neck motion.[6] Consequently, there could be sex differences in the LS values and patterns. Nevertheless, sex differences in the LS or its individual items have never been reported. Although several studies have been conducted on the male-to-female ratio in patients with a DLE, a significant difference has seldom been found.[7-15] If sex differences in LS values based on body size differences would be present, female patients would possibly have a higher LS and be more likely to have DLE.

Moreover, the LS comprises 11 items; however, previous studies have detected redundant items and several subjective criteria,[4, 5, 15] prompting efforts to streamline these items. For example, Incandela et al.[4] suggested that variables such as macroglossia, micrognathia, prognathism, and trismus did not represent objective and absolute measures but were useful to obtain comprehensive evaluation of the individual patient. Clarysse et al.[5] also described that the three variables of trismus, macroglossia, and micrognathia were less clearly defined in the original LS study.[1]

The primary study objective was to validate the LS, mLS, and Clarysse's model (http://www.predictdle.be) in a selected cohort. The secondary objective was to assess sex differences in the DLE and LS and their interactions. Finally, we used our results to modify the LS to achieve better prediction of DLE.

Materials and Methods

Evaluation of the Laryngoscore

Prior to performing laryngeal microsurgery, the first author evaluated all 11 items included in the LS in an outpatient consultation room. The patients were in a sitting position during the evaluation.

Procedure of Laryngeal Exposure

Patients received tracheal intubation under general anesthesia. An endotracheal tube with an inner diameter ranging from 6.0–6.5 mm was used. The neck flexion-extension position was set for introducing a rigid laryngoscope (10338504, Nagashima Medical Instruments Co. Ltd., Japan) **(Figure 1)**, which allowed bi-ocular and bi-hand surgery. When the AC visualization was incomplete, an external laryngeal counter pressure was added. A chest support system (GÖTTINGEN model 8575L, KARL STORZ, Germany) was used to support a laryngoscope during the surgery.

Conditions of Laryngeal Exposure

The laryngeal exposure conditions were defined by the AC visualization during the surgery. Cases in which AC visualization was obtained were designated as GLE, while the cases in which AC visualization was not obtained even when external laryngeal counter pressure was applied were designated as DLE.

Patients

The following criteria were used to extract eligible surgeries in this study. Inclusion criteria: the laryngeal microsurgery was performed by the first author at JCHO Osaka Hospital from May 2017 to June 2019 (93 surgeries) and at Osaka University Hospital from July 2019 to December 2023 (163 surgeries). Exclusion criteria (in order): 1) no preoperative evaluation of the LS (19 surgeries), 2) no intraoperative trial to expose AC (68 surgeries), 3) surgery using the FK-WO retractor (5 surgeries) because the inability to visualize AC also depended on the complex structure of the FK-WO retractor, 4) repeated surgeries for an individual (12 surgeries). Finally, 153 surgeries for 153 individuals were extracted for the analysis: 72 from JCHO Osaka Hospital and 81 from Osaka University Hospital (**Figure 2**). The institutional review board of each hospital approved this retrospective study (Nos. 2024-008 and 16329-2, respectively).

Statistical Analysis

The results of descriptive statistics of the numeric variables are reported as the median with interquartile range, whereas those of nominal variables are shown as a frequency distribution. In the comparisons of variables between DLE and GLE, the Wilcoxon rank-sum test was performed for numeric variables, and the chi-squared test was performed for nominal variables.

To examine the diagnostic performance of the LS, mLS, Clarysse's model, or other numeric variables to discriminate DLE from GLE, a ROC analysis was performed, and the C-index was used as an indicator of diagnostic performance, which was classified as follows: C-index ≥0.9, excellent; 0.8 ≤C-index <0.9, good; 0.7 ≤ C-index <0.8, fair; and C-index <0.7, poor.[16]

Subsequently, a modified version was proposed to enhance the objectivity of the LS as an evaluation tool by excluding nonobjective items and those that did not exhibit significant differences between GLE and DLE.

JMP Pro version 17.0.0 (SAS Institute Inc., Cary, NC) was used to perform all of the statistical analyses other than comparisons of the C-indexes in the ROC analyses, which were performed using EZR,[17] it is a modified version of R commander designed to add statistical functions frequently used in biostatistics. All results were considered statistically significant at $p \leq 0.05$.

Results

Difference Between DLE and GLE

Table 1 shows descriptive statistics (median and interquartile range) with statistical significance for the LS, mLS, and Clarysse's model, patient demographics (such as age, sex, height, and weight), as well as the LS items.

The medians (interquartile range) of the LS, mLS, and Clarysse's model were 7 (4–10), 2 (1–3), and 0.523 (0.235–0.812) for DLE, respectively, and were 5 (3–6), 1 (1–2), and 0.241 (0.147–0.322) for GLE, respectively, indicating significant differences between DLE and GLE. The ROC analyses showed that the LS, mLS, and Clarysse's model had moderate diagnostic performance for differentiating DLE from GLE, with C-indexes of 0.751, 0.727, and 0.783, respectively. No significant difference was found among the C-indexes of the three models.

Other than the LS, mLS, and Clarysse's model, significant differences between DLE and GLE were found in sex, treatment history, IIG, trismus, UJDS, micrognathia, and dFE, whereas there were no significant differences in age, body size (height, weight, and BMI), mandibular prognathism, macroglossia, Mallampati's modified class, and TMD. Notably, the ROC analysis showed that the C-index of 0.738 for IIG was comparable to those of the LS, mLS, and Clarysse's model.

Differences Between the Male and Female Patients

The prevalence of DLE was significantly larger in the male patients (21.3%) than in the female patients (9.0 %) (**Table 1**). However, in contrast, the median values of the LS, mLS, and Clarysse's model were all significantly smaller in the males (4, 1, 0.228, respectively) than in women (5, 2, 0.291, respectively) (**Table 2**). Among the LS items, BMI and dFE showed significant differences along with increasing LS in the males, whereas IIG and TMD showed significant differences along with increasing LS, mLS, and Clarysse's model in the females.

The tendency toward differences between DLE and GLE was also different between the male and female patients (**Table 3, Table 4**). In the male patients, IIG, trismus, UJDS, micrognathia, and TMD were significant factors that discriminated DLE from GLE, while treatment history, weight, IIG, and dFE were significant discriminatory factors in female patients. In particular, a smaller body weight in the female patients was found to be associated with DLE. This finding contrasts with the assumption in the LS, which suggests that a larger BMI is related to DLE. In addition, IIG was the only common factor between the male and female patients.

In TMD as well as height and weight, no overlap of the interquartile ranges was observed, indicating distinctly different distributions between the male and female patients. An additional ROC analysis (**Table 3, Table 4**) of TMD, which discriminated DLE from GLE, showed increased C-indexes in the male or female patients (0.735 or 0.694, respectively) relative to the C-index (0.584) in the combined cohort of male and female patients (**Table 1**).

Modification of LS

The above results showed that sex would be a promising factor for enhancing the diagnostic performance of the LS because the median values of LS in the female patients were 1-point larger than those in the male patients despite the lower prevalence of DLE in the females than in the males. Therefore, we added the item of sex to the LS, namely the 12-item LS, which increased the value by 1-point for the male patients, leading to significantly greater C-index (0.751–0.782, with a p-value of 0.036).

Furthermore, the LS items that showed no significant difference between DLE and GLE in the total, male, or female cohorts (BMI, mandibular prognathism, macroglossia, and Mallampati's modified class) as well as the subjective items (mandibular prognathism, macroglossia, micrognathia, and trismus) were removed from the 12-item LS. Consequently, six items—namely, treatment history, IIG, UJDS, TMD, dFE, and sex—remained as the mod-LS (**Table 5**). This modification increased the C-index to 0.835, with a p-value of 0.006 compared with the original LS. The median value (interquartile range) of the mod-LS also was 3 (3–4) in the male and 3 (2–4) in the female patients.

Discussion

First, this study found that the LS, mLS, and Clarysse's model also had moderate diagnostic performance for detecting DLE in our cohort and their performance was comparable to the performances reported in previous validation studies.[3-5] Moreover, Clarysse's model had the highest performance among the above three multivariate scales, which was attributed to the use of the numeric variable of IIG rather than a dichotomized value. Indeed, the C-index of the numeric value of IIG alone also had a significant effect on diagnosing DLE, close to the effects of the LS and mLS.

Several studies have found that IIG was a significant variable for differentiating between DLE and GLE.[5, 12, 14, 15] Clarysse et al.[5] and Kharrat et al.[12] also reported that prediction was better for an IIG cutoff of 5 cm than for 4 cm in the original LS.[5] However, we did not apply a 5-cm cutoff because our cohort had a greater female percentage.

Second, as expected, the items depending on body size indicated significant differences between the male and female patients. The prevalence of DLE was significantly larger in the male than in the female patients. However, previous studies have never shown a sex difference to be a significant factor.[1-5, 7-15] Because the participants in those studies were predominantly male, sex differences possibly could not be detected as having a significant effect on the predictive factors. However, in the present study, the numbers of male and female participants were similar. The original LS study[1] also did not attempt to detect sex differences. In contrast, a study of DLE in tracheal intubation reported that it was significantly more difficult in the male patients.[18] Therefore, future studies with a larger percentage of female patients will probably reveal a lower female rate of DLE in laryngeal microsurgery.

As expected, the LS was higher in female patients, indicating that despite the higher LS, achieving GLE tended to be easier in the female than male patients. We attributed this sex difference in the LS to body size-dependent items in the LS and observed a significant difference in IIG, BMI, and TMD that all depend on body size, which explains the increase in the LS in the females. Furthermore, sex differences in the laryngeal shape may be responsible for the higher rate of DLE in the male patients. The larynx protrudes more in males than in females, so the AC may be located more anterior in males. Therefore, it is possible that the AC is more difficult to see in male patients because the AC tends to be located beyond the laryngoscope tip. A counter pressure to the anterior neck would be more beneficial for AC visualization in female patients. The larynx is rounder and wider in females than in males, whereas most male larynxes have an acute angle, leading to easier AC visualization in female patients.

Third, we proposed the mod-LS in which each LS item was screened according to its contribution to diagnostic performance. As a result, the mod-LS was based on treatment history, IIG, UJDS, TMD, dFE, and sex. Of these items, IIG, UJDS, TMD, and dFE have been shown to be useful for predicting DLE in previous studies.[3-5, 11-13, 15] These studies proposed their own modified LS, such as the mLS, Clarysse's model, and recently, Teixeira's model, [4, 5, 15] which uses the three items of IIG, UJDS, and TMD, the three items of IIG, UJDS, and previous treatment, and the three items of IIG, presence of upper teeth (surrogate of UJDS), and neck circumference, respectively. The mod-LS included most of those items, and its diagnostic performance was further enhanced by including sex.

Finally, the mod-LS used six items, which required more effort than used in the models with fewer items, such as the mLS, Clarysse's model, and Teixeira's models. However, we believe that a comprehensive evaluation of the dental, oral, neck, and cervical spine involved in laryngeal exposure, as in the original LS, is essential as a preoperative survey to laryngeal microsurgery.

Limitations

This was a retrospective un-blinded study. A single surgeon evaluated the LS and performed laryngeal microsurgery with reference to the LS value. Predicting a DLE is recommended before surgery to prevent complications and avoid unexpected surgical interruptions. Therefore, we perform this essential step before every laryngeal microsurgery. We believe that any distortion of results due to our study design was minimal because we made our best efforts to achieve AC visualization in all cases.

This study simplified the definition of DLE to focus on AC visualization with a rigid laryngoscope. Ideally, validation should have employed the same laryngoscope as used in the original study.[1] Nevertheless, we assert that our findings are generalizable because LS-related validation studies[1-5, 15] have used different laryngoscopes across various investigations.

Conclusion

We confirmed that the LS, mLS, and Clarysse's model were useful predictors of DLE and revealed that fewer females than males had DLE. Therefore, more accurate prediction of DLE could be expected by including sex as a factor in predictive models.

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The authors report no conflicts of interest.

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Table 1. Comparisons between DLE and GLE.

Indexes	DLE	GLE	p-value	C-index (p-value)	Cutoff
Laryngoscore, mean (IQR)	**7 (4–10)**	**5 (3–6)**	**0.0001**	**0.751 (reference)**	**7**
Mini-Laryngoscore, mean (IQR)	**2 (1–3)**	**1 (1–2)**	**0.0002**	**0.727 (0.622)**	**3**
Clarysse's model, mean (IQR)	**0.523 (0.235–0.812)**	**0.241 (0.147–0.322)**	**<0.0001**	**0.783 (0.455)**	**0.415**
Age, mean (IQR)	63 (43–71)	55.5 (43–68.25)	0.5536		
Sex (male : female)	**16 : 7**	**59 : 71**	**0.0307**		
Treatment history (present : absent)	**9 : 14**	**11 : 119**	**0.0004**		
Height, mean (IQR), cm	169 (160–174)	162 (156–169.25)	0.1121		
Weight, mean (IQR), kg	62.9 (50–78)	61 (52–71.025)	0.7188	0.524	78
Body mass index, mean (IQR)	22.3 (20.6–26.1)	23.1 (20.6–26.0)	0.5385		
Mandibular prognathism (present : absent)	2 : 21	3 : 127	0.1669		
Interincisors gap, mean (IQR), mm	**44 (37–46)**	**48 (44–53)**	**0.0003**	**0.738**	**46**
Trismus (present : absent)	**5 : 18**	**3 : 127**	**0.0014**		
Upper-jaw dental status (0-3), mean (IQR)	**3 (2–3)**	**2 (2–3)**	**0.0047**	**0.665**	**3**
Macroglossia (present : absent)	1 : 22	0 : 130	0.0504		
Mallampati's modified class (0-3), mean (IQR)	1 (1–2)	1 (1–2)	0.1755		
Micrognathia (present : absent)	**11 : 12**	**22 : 108**	**0.0021**		
Thyro-mental distance, mean (IQR), mm	68 (58–72)	69 (62.75–79)	0.1988	0.584	73
Degree of neck flexion-extension, mean (IQR), °	**91 (81–100)**	**100 (91–110)**	**0.0026**	**0.697**	**84**

Abbreviations: DLE; difficult laryngeal exposure, GLE; good laryngeal exposure.

Bold letter shows a significant difference. Parentheses show an interquartile range.

Table 2. Comparisons between male and female patients.

Indexes	Male	Female	p-value
Laryngoscore, mean (IQR)	**4 (3–6)**	**5 (4–6)**	**0.0137**
Mini-Laryngoscore, mean (IQR)	**1 (1–2)**	**2 (1–2)**	**0.0005**
Clarysse 's model, mean (IQR)	**0.228 (0.103–0.388)**	**0.291 (0.198–0.415)**	**0.0160**
Age, mean (IQR)	57 (46–70)	53 (41–68.25)	0.1243
Treatment history (present : absent)	12:63	9:69	0.4223
Height, mean (IQR), cm	**170 (165–174.1)**	**156.65 (153–161)**	**<0.0001**
Weight, mean (IQR), kg	**69.2 (61.6–78)**	**53.5 (48–61.25)**	**<0.0001**
Body mass index, mean (IQR)	**24 (22.1–26.2)**	**21.8 (19.6–24.6)**	**0.0006**
Mandibular prognathism (present : absent)	1:74	4:74	0.1716
Interincisors gap, mean (IQR), mm	**50 (45–54)**	**45.5 (42–51.25)**	**0.0204**
Trismus (present : absent)	5:70	3:75	0.4314
Upper-jaw dental status (0-3), mean (IQR)	2 (2–3)	2 (2–3)	0.1509
Macroglossia (present : absent)	1:74	0:78	0.2313
Mallampati's modified class (0-3), mean (IQR)	1 (1–2)	1 (1–2)	0.5764
Micrognathia (present : absent)	18:57	15:63	0.4732
Thyro-mental distance, mean (IQR), mm	**75 (70–83)**	**63 (57–68)**	**<0.0001**
Degree of neck flexion-extension, mean (IQR), °	**94 (85–101)**	**105 (93.75–115)**	**<0.0001**

Bold letter shows a significant difference. Parentheses show an interquartile range.

Table 3. Comparisons between DLE and GLE in male patients.

Indexes	DLE	GLE	p-value	C-index	Cutoff
Laryngoscore, mean (IQR)	**6.5 (4–9)**	**4 (3-5)**	**0.0010**	**0.766**	**7**
Mini-Laryngoscore, mean (IQR)	**2 (1–2.75)**	**1 (1-2)**	**0.0029**	**0.719**	**2**
Clarysse's model, mean (IQR)	**0.415 (0.220–0.700)**	**0.198 (0.093-0.303)**	**0.0012**	**0.766**	**0.604**
Age, mean (IQR)	60.5 (43.5–68)	57 (46-70)	0.9742		
Treatment history (present : absent)	5 : 11	7 : 52	0.0784		
Height, mean (IQR), cm	170 (164.95–175.75)	170 (165-174)	0.7511		
Weight, mean (IQR), kg	70 (61.475–78.75)	69.2 (61.6-76)	0.8209		
Body mass index, mean (IQR)	22.9 (21.8–27.1)	24.2 (22.2-26.1)	0.8512		
Mandibular prognathism (present : absent)	1 : 15	0 : 59	0.0790		
Interincisors gap, mean (IQR), mm	**45 (39–47.5)**	**50 (45-55)**	**0.0008**	**0.775**	**46**
Trismus (present : absent)	**4 : 12**	**1 : 58**	**0.0033**		
Upper jaw dental status (0-3), mean (IQR)	**2.5 (2–3)**	**2 (2-2)**	**0.0153**	**0.678**	**3**
Macroglossia (present : absent)	1 : 15	0 : 59	0.0764		
Mallampati's modified class (0-3), mean (IQR)	1.5 (1–2)	1 (0-2)	0.1088		
Micrognathia (present : absent)	**8 : 8**	**10 : 49**	**0.0092**		
Thyro-mental distance, mean (IQR), mm	**70.5 (66.25–72.75)**	**77 (71-84)**	**0.0042**	**0.735**	**73**
Degree of neck flexion-extension, mean (IQR), °	90 (79–100)	94 (86-103)	0.2285	0.599	83

Abbreviations: DLE; difficult laryngeal exposure, GLE; good laryngeal exposure.

Bold letter shows a significant difference. Parentheses show an interquartile range.

Table 4. Comparisons between DLE and GLE in female patients.

Indexes	DLE	GLE	p-value	C-index	Cutoff
Laryngoscore, mean (IQR)	**8 (6–10)**	**5 (4–6)**	**0.0044**	**0.823**	**8**
Mini-Laryngoscore, mean (IQR)	**3 (3–3)**	**2 (1–2)**	**0.0002**	**0.902**	**3**
Clarysse's model, mean (IQR)	**0.583 (0.478–0.933)**	**0.276 (0.192–0.371)**	**<0.0001**	**0.955**	**0.469**
Age, mean (IQR)	64 (40–77)	53 (41–68)	0.4679		
Treatment history (present : absent)	**4:3**	**5:66**	**0.0015**		
Height, mean (IQR), cm	160 (150–162)	156.3 (153.6–161)	0.9930		
Weight, mean (IQR), kg	**48 (42–54)**	**54 (48.5–62)**	**0.0491**		
Body mass index, mean (IQR)	20.6 (17.4–21.5)	22.2 (19.6–24.9)	0.0867		
Mandibular prognathism (present : absent)	1:6	3:68	0.3279		
Interincisors gap, mean (IQR), mm	**35 (32–44)**	**46 (43–52)**	**0.0088**	**0.802**	**35**
Trismus (present : absent)	1:6	2:69	0.2255		
Upper jaw dental status (0-3), mean (IQR)	3 (2–3)	2 (2–3)	0.0502	0.700	3
Macroglossia (present : absent)	0:7	0:73	-		
Mallampati's modified class (0-3), mean (IQR)	1 (1–2)	1 (1–2)	0.8493		
Micrognathia (present : absent)	3:4	12:59	0.1297		
Thyro-mental distance, mean (IQR), mm	58 (49–64)	63 (58–68)	0.0926	0.694	58
Degree of neck flexion-extension, mean (IQR), °	**91 (83–102)**	**108 (95–115)**	**0.0251**	**0.758**	**91**

Abbreviations: DLE; difficult laryngeal exposure, GLE; good laryngeal exposure.

Bold letter shows a significant difference. Parentheses show an interquartile range.

Table 5. The 6 items in the mod-LS.

Items	Scores
Interincisors gap	
≥ 4 cm	0
< 4 cm	1
Thyro-mental distance	
> 6.5 cm	0
6-6.5 cm	1
< 6 cm	2
Upper jaw dental status	
Edentulous	0
Partially edentulous	1
Normal teeth	2
Prominent teeth	3
Degree of neck flexion-extension	
> 90˚	0
80˚-90˚	1
< 80˚	2
Previous treatment (RT, open-neck surgery)	
No	0
Yes	1
Sex	
Female	0
Male	1
Total	0–10

Figure legends

Figure 1

A: The laryngoscope used in this study. B: Endolaryngeal view through the laryngoscope. C: Bi-hand surgery under a flexible video endoscope.

Figure 2

The participant flow diagram used in this study.