

## Predicting Difficult Intubation with Indirect Laryngoscopy

Ken Yamamoto, M.D.,\* Tsunehisa Tsubokawa, M.D.,† Keizo Shibata, M.D.,‡  
 Shigeo Ohmura, M.D.,‡ Shunichi Nitta, M.D.,‡ Tsutomu Kobayashi, M.D.§

**Background:** It is not always possible to predict when tracheal intubation will be difficult or impossible. The authors wanted to determine whether indirect laryngoscopy could identify patients in whom intubation was difficult.

**Methods:** Indirect laryngoscopy was done in 2,504 patients. The Wilson risk sum score and the modified Mallampati score were also studied in a different series of 3,680 patients for comparison. These predictive methods were compared according to three parameters: positive predictive value, sensitivity, and specificity.

**Results:** Of 6,184 patients studied, the trachea proved difficult to intubate in 82 (1.3%). Positive predictive value (31%) and specificity (98.4%) with indirect laryngoscopy were greater than the other two predictive methods ( $P < 0.01$ ), whereas sensitivity with indirect laryngoscopy (69.2%) was greater than that of the Wilson risk sum score (55.4%) ( $P < 0.01$ ).

**Conclusions:** Although in 15% of patients indirect laryngoscopy could not be performed because of excessive gag reflex, indirect laryngoscopy can serve as an effective method to predict difficult intubation. (Key words: Anesthetic techniques; indirect laryngoscopy. Tracheal intubation. Complications: difficult intubation.)

It is not always possible to predict whether tracheal intubation will be difficult or even impossible. Two of the most popular tests to determine the ease of tracheal intubation are the Wilson risk sum score<sup>1</sup> and the Mallampati score.<sup>2</sup> Although these tests are simple, studies have shown that they have high-false positive rates.<sup>3-7</sup> We pro-

spectively tested indirect laryngoscopy as a predictive method for difficult tracheal intubation. We also compared the test operating characteristics of the Wilson risk sum score and the Mallampati score with indirect laryngoscopy.

### Materials and Methods

We included 7,270 consecutive adult patients who underwent general anesthesia and tracheal intubation for elective surgery. Approval of the institutional ethics committee for the clinical studies was obtained. First, 3,698 patients were included to evaluate the Wilson risk sum score and the modified Mallampati score as predictive methods for difficult direct laryngoscopy (study 1). Second, 3,572 patients were studied to evaluate indirect laryngoscopy as a predictive method for difficult direct laryngoscopy (study 2). All patients consented to join the studies, except for 75 patients in study 2 who refused to accept indirect laryngoscopy. Patients for emergency operations, patients who could not sit upright, and obstetrical patients were excluded from the studies. Patients with known infection (such as positive serological tests for hepatitis B surface antigen, hepatitis C virus, human immunodeficiency virus, syphilis, and pulmonary tuberculosis) were also excluded from study 2. Patients in study 1 and 2 were of similar ages ( $51.8 \pm 15.9$  vs.  $52.5 \pm 17.1$  yr), weights ( $56.5 \pm 10.4$  vs.  $56.8 \pm 10.5$  kg), and heights ( $158.6 \pm 9.2$  vs.  $160.0 \pm 51.3$  cm). Gender ratio (male:female) was 1,887:1,811 in study 1 and 1,780:1,792 in study 2. All predictive studies were carried out at our preanesthetic assessment section 2 days before surgery by the staff anesthesiologists of our department. The number of staff anesthesiologists included was 29 for study 1 and 21 for study 2.

The Wilson risk sum score was calculated according to multiple anatomical parameters.<sup>1</sup> The measured pa-

\* Associate Professor.

† Staff Anesthesiologist.

‡ Assistant Professor.

§ Professor and Chairman.

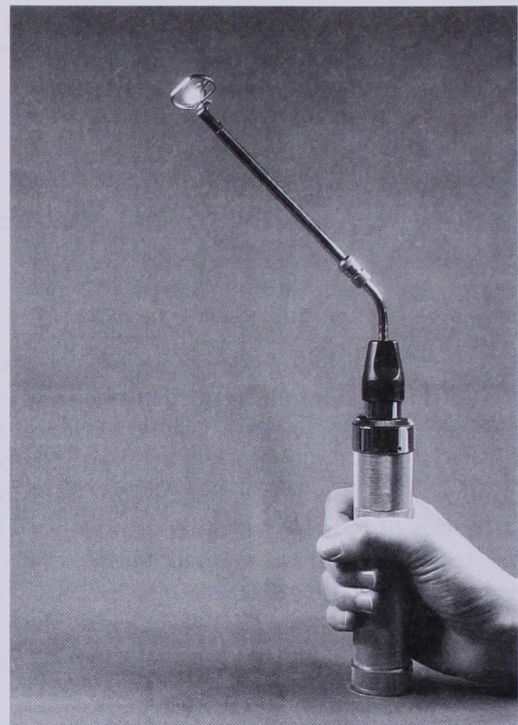
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Address reprint requests to Dr. Yamamoto: Department of Anesthesiology and Intensive Care Medicine, School of Medicine, Kanazawa University, 13-1 Takara-machi, Kanazawa 920, JAPAN. Address electronic mail to: kenyam@med.kanazawa-u.ac.jp.

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rameters included head and neck movement, jaw movement (incisor gap and subluxation of the mandible), receding mandible, prominent maxillary incisors, and body weight. Each parameter was graded as 0-2 risk levels. Patients with a sum of risk levels equal to or greater than 2 were classified as predicted to be difficult to tracheally intubate ("predicted difficult"). Pharyngeal view was observed in the same patients after measuring anatomic parameters. The pharyngeal view was determined according to the modified Mallampati method.<sup>8</sup> Patients were instructed to sit upright with the head in the neutral position. Next they were asked to open their mouth fully and maximally protrude their tongue. The observer sat in front of the patient and inspected the pharynx. The classification is based on the structures seen: class 1, soft palate, fauces, uvula, tonsillar pillars; class 2, soft palate, fauces, uvula; class 3, soft palate, base of uvula; class 4, soft palate not visible. Patients with class 3 and 4 of the modified Mallampati score were classified as "predicted difficult."

Indirect laryngoscopy was carried out in the other series of patients with a portable indirect laryngoscope (Larynx Illuminator, Welch Allyn, Skaneateles Falls, NY; fig. 1). The removable mirror was immersed in 0.5% alkyldiaminoethylglycine hydrochloride for sterilization while the laryngoscope was not being used. We did not use local anesthetics or sedatives for the examination. First, the observer explained the procedure to the patient. Then the patient was asked to sit upright with the back straight, trunk and head forward, jaw protruded, mouth open, and tongue maximally extruded. The patient was instructed to breathe gently through the mouth and to relax. The tongue of the patient was wrapped with a gauze square and was held firmly between thumb and middle finger of the left hand of the observer. After warming the glass surface of the mirror, it was introduced over the middle line of the tongue. The back of the mirror touched and elevated the uvula to observe the larynx. The observer was careful not to touch the dorsum of the tongue or the tonsils, as this may incite a gag reflex. The laryngeal view obtained by indirect laryngoscopy was classified as follows: grade 1, vocal cords visible; grade 2, posterior commissure visible; grade 3, epiglottis visible; grade 4, no glottic structure visible. Patients with grade 1 and 2 of the indirect laryngoscopic view were classified as predicted to be easy to tracheally intubate ("predicted easy"), whereas patients with grade 3 and 4 were classified as "predicted difficult."



**Fig. 1.** Integrated indirect laryngoscope (The Larynx Illuminator, Welch Allyn, Skaneateles Falls, NY). The light is guided from the halogen bulb to the removable mirror through the optic fiber. The metal sleeve is rotated to show the fiber optic light emission.

All patients were premedicated with intramuscular atropine plus hydroxyzine or midazolam. Anesthesia was induced with intravenous thiopental (3 to 5 mg/kg) and vecuronium bromide (0.15 to 0.20 mg/kg). Direct laryngoscopy was carried out under full muscular relaxation by a staff anesthesiologist not informed about the results of the predictive study. A Macintosh laryngoscope blade size 3 or 4 was used in every case. External compression of the thyroid cartilage was routinely applied by another person before classifying the laryngeal view. When the posterior commissure was not seen with the first direct laryngoscopy, a consultant confirmed the laryngeal view with external compression of the thyroid cartilage. The laryngeal view with direct laryngoscopy was classified according to Cormack and Lehane<sup>9</sup> as follows: grade 1, full view of glottis; grade 2, only posterior commissure visible; grade 3, only epiglottis visible; grade 4, no glottic structure visible (fig. 2). Direct laryngoscopic view of grades 1 and 2 were classified as proved to be easy to tracheally intubate

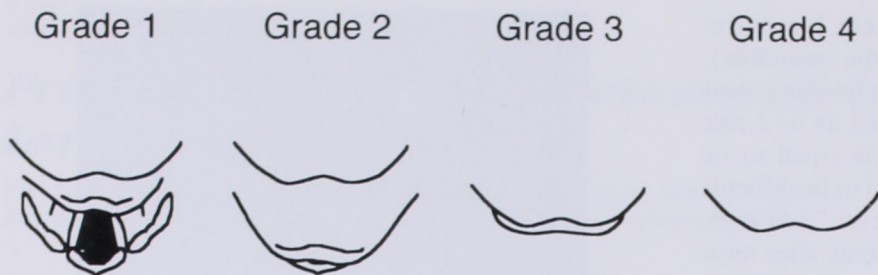


Fig. 2. Classification of laryngeal views for laryngoscopy. With grade 1, a full view of glottis is visible; with grade 2, only the posterior commissure is visible; with grade 3, only the epiglottis is visible; and with grade 4, no glottic structures are visible.

("proved easy"), whereas grades 3 and 4 were classified as proved to be difficult to intubate ("proved difficult").

Positive predictive value (PPV), sensitivity, and specificity of the three predictive methods were compared. Likelihood ratios were also calculated for each of the four categories of indirect laryngoscopy. Fisher's exact test or z test was used to compare proportions.  $P < 0.05$  was considered significant.

## Results

The Wilson risk sum score was successfully measured in 3,608 cases, whereas the modified Mallampati score was obtained in 3,680 of 3,698 cases in study 1. The indirect laryngoscopic view was observed in 2,504 of 3,572 cases in study 2. Age, weight, and height of the patients in two studies were comparable. Of 6,184 patients who accepted predictive tests, the tracheas of 82 patients (1.3%) were difficult to intubate. Direct laryngeal views in 6,184 patients were: grade 1, 4,690 cases (75.8%); grade 2, 1,412 cases (22.8%); grade 3, 63 cases (1%); and grade 4, 19 cases (0.3%). The anatomic abnor-

malities known to make laryngoscopy impossible (e.g., trismus, severe micrognathia, fixed cervical spine) were identified in 17 of 19 patients with grade 4 direct laryngeal view. The incidences of difficult intubation were similar ( $P = 0.11$ ) in study 1, with 56 of 3,680 (1.5%), and in study 2, with 26 of 2,504 (1%) patients.

We abandoned indirect laryngoscopy in 1,068 of 3,572 patients in study 2. The reasons not to apply indirect laryngoscopy were excessive gag reflex (449 cases), viral or bacterial infection (133 cases), inability to sit up (98 cases), poor physical condition of the patient (138 cases), refusal by the patient (75 cases), insufficient time for the observer (49 cases), and unidentified reasons (126 cases). The incidence of difficult intubation in patients with excessive gag reflex (1 of 449, 0.2%) did not differ from those in whom indirect laryngoscopy was possible (26 of 2,504, 1%;  $P = 0.16$ ).

Tables 1 to 3 show the distributions of predicted and proved difficult intubation with the three predictive methods. Positive predictive value, sensitivity, and specificity are summarized in table 4. Positive predictive

Table 1. Prediction of Difficult Intubation with Wilson Risk Sum Score

	Proved Easy (direct laryngoscopy grade 1 and 2)	Proved Difficult (direct laryngoscopy grade 3 and 4)	
Predicted easy (Wilson's score < 2)	3,059	25	3,084
Predicted difficult (Wilson's score ≥ 2)	493	31	524
	3,552	56	3,608

Positive predictive value =  $31/524 = 5.9\%$ ; sensitivity =  $31/56 = 55.4\%$ ; specificity  $3,059/3,552 = 86.1\%$ .

Table 2. Prediction of Difficult Intubation with Modified Mallampati Score

	Proved Easy (direct laryngoscopy grade 1 and 2)	Proved difficult (direct laryngoscopy grade 3 and 4)	
Predicted easy (modified Mallampati class 1 and 2)	1,901	18	1,919
Predicted difficult (modified Mallampati class 3 and 4)	1,723	38	1,761
Total	3,624	56	3,680

Positive predictive value =  $38/1,761 = 2.2\%$ ; sensitivity =  $38/56 = 67.9\%$ ; specificity =  $1,901/3,624 = 52.5\%$ .

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**Table 3. Prediction of Difficult Intubation with Indirect Laryngoscopy**

	Proved Easy		Proved Difficult		Total
	Direct Laryngoscopy Grade 1	Direct Laryngoscopy Grade 2	Direct Laryngoscopy Grade 3	Direct Laryngoscopy Grade 4	
Predicted easy					
Indirect laryngoscopy grade 1	1,063	10	1	1	2,446
Indirect laryngoscopy grade 2	1,335	30	6	0	
Predicted difficult					
Indirect laryngoscopy grade 3	16	21	9	2	58
Indirect laryngoscopy grade 4	0	3	2	5	
Total		2,478		26	2,504

Positive predictive value =  $18/58 = 31.0\%$ ; sensitivity =  $18/26 = 69.2\%$ ; specificity =  $2,438/2,478 = 98.4\%$ .

value with indirect laryngoscopy (31%) was greater than that with the Wilson risk sum score (5.9%;  $P < 0.01$ ) and the modified Mallampati score (2.2%;  $P < 0.01$ ). Sensitivity with indirect laryngoscopy (69.2%) was greater than that of the Wilson risk sum score (55.4%;  $P < 0.01$ ). Specificity with indirect laryngoscopy (98.4%) was greater than that with the Wilson risk sum score (86.1%;  $P < 0.01$ ) and the modified Mallampati score (52.5%;  $P < 0.01$ ). Likelihood ratios for each of the four categories of indirect laryngoscopy were 0.18 (grade 1), 0.42 (grade 2), 28.3 (grade 3), and 222.4 (grade 4). Maximum likelihood ratios for the Wilson risk sum score and the modified Mallampati score were 18.9 and 1.9, respectively.

## Discussion

Prediction of difficult tracheal intubation with indirect laryngoscopy resulted in greatest PPV (31.0%), sen-

**Table 4. Positive Predictive Value (PPV), Sensitivity, and Specificity of Three Predictive Methods**

	PPV (%)	Sensitivity (%)	Specificity (%)
Prediction with Wilson risk sum score	5.9	55.4	86.1
Prediction with modified Mallampati score	2.2	67.9	52.5
Prediction with indirect laryngoscopy	31.0*	69.2†	98.4*

\*  $P < 0.01$  versus Wilson risk sum and modified Mallampati score.

†  $P < 0.01$  versus Wilson risk sum score.

sitivity (69.2%), and specificity (98.4%). Indirect laryngoscopy is a basic technique in the field of otolaryngology to examine the upper airway. Conventional indirect laryngoscopy is, however, difficult for anesthesiologists because they are unaccustomed to using the head and the laryngeal mirrors. We selected an integrated, portable indirect laryngoscope. The light is guided from the halogen bulb to the mirror through the optic fiber, and then it is reflected on the convex mirror to illuminate the larynx. Although this portable indirect laryngoscope eliminates many of the disadvantages of the conventional head mirror system, it took several weeks before we gained confidence with indirect laryngoscopy. Data collected in this learning phase were not included in study 2.

An excessive gag reflex was present in a substantial proportion of patients, even when skilled laryngoscopists were doing the examination. Contrary to what we expected, however, the incidence of difficult intubation in these patients did not differ significantly from that of tolerant patients. Thus an excessive gag reflex is not a predictor of difficult intubation. Because eliciting a gag reflex could increase intracranial and blood pressure through sympathetic stimulation, we also excluded patients with poor physical condition such as severe ischemic heart disease, increased intracranial pressure, and respiratory distress to avoid potential harmful effects of indirect laryngoscopy.

The incidence of difficult intubation in nonobstetric surgical patients has been reported as varying from 0.05% to 2%.<sup>1,4,8,10</sup> In our study, the incidence of grade

3 and 4 intubations, as noted by direct laryngoscopic view with routine external compression of the thyroid cartilage, was 1.3%. We could not visualize any glottic structure (grade 4) in 19 cases. However, at least one of the anatomic abnormalities known to make laryngoscopy impossible was identified in 17 of 19 grade 4 cases. Unanticipated grade 4 direct laryngeal view was encountered in only 2 of 6,184 cases (0.03%). In other words, the epiglottis was visible in almost every case of unanticipated difficult intubation in our study.

We compared predictive methods according to PPV, sensitivity, and specificity. Because PPV indicates how often the "predicted difficult" laryngoscopies were actually found to be "proved difficult," it would be the most valuable parameter to evaluate the test operating characteristics of a method. On the other hand, sensitivity indicates how effectively a predictive method anticipated difficult laryngoscopies in all "proved difficult" laryngoscopies. Specificity shows how effectively the predictive method anticipated easy laryngoscopies in all "proved easy" laryngoscopies.

Likelihood ratios are another useful way to express the characteristics of a diagnostic test result. A very high likelihood ratio (more than 20) is useful for confirming a disease or condition, whereas a likelihood ratio close to zero is useful in ruling out a disease or condition. There were remarkable likelihood ratios, especially for grades 1, 3, and 4 of indirect laryngoscopy. On the other hand, the likelihood ratios for the Wilson risk sum score and the modified Mallampati score did not exceed 20.

We evaluated two predictive scores and indirect laryngoscopy in different series of patients. Although a possibility that the high test operating characteristics of indirect laryngoscopy occurred because of a difference in the two groups, the incidence of difficult intubation and the demographic characteristics of the two groups of patients were not significantly different. We conclude that the highest PPV, sensitivity, and specificity in study 2 were produced by indirect laryngoscopy itself, not by the difference of the samples.

Wilson *et al.*<sup>1</sup> proposed a risk sum score that predicts difficult intubation using multiple anatomic measurements. Their original data yielded a PPV of 8.7%, sensitivity of 75%, and specificity of 87.9%. Oates *et al.*<sup>4</sup> evaluated the Wilson risk sum score in 675 cases. Positive predictive value was 8.9% with a low sensitivity (42%) and high specificity (92%). Laplace *et al.*<sup>7</sup> found high PPV (25%) and specificity (91.6%) at the cost of

low sensitivity (35%) for the score. Our evaluation of the Wilson risk sum score yielded low PPV (5.9%), low sensitivity rate (55.4%), and high specificity rate (86.1%), similar to the results reported by Oates *et al.*<sup>4</sup>

The Mallampati score<sup>2</sup> estimates the size of the base of the tongue to predict difficult intubation. Because the tongue is the largest structure in the mouth, its size might partly affect the ease of direct laryngoscopy. Frerk<sup>5</sup> reported that the modified Mallampati score had a PPV of 17.3%, a sensitivity rate of 81.2%, and a specificity rate of 81.5%, in 244 cases. In the report, however, patients with grade 2 Cormack and Lehane classification were included in the difficult intubation. When grade 3 and 4 of the Cormack and Lehane classification were applied as the definition of difficult intubation, PPV may decrease from 17.3% to 5.8%. Other reports<sup>4,6,7</sup> have agreed that the Mallampati score is not sensitive enough for clinical practice. Our result also indicates that even the modified Mallampati score is not clinically reliable because of its low PPV (2.8%).

Although the line of vision of the observer in indirect laryngoscopy may not precisely correspond to that obtained at direct laryngoscopy, our results showed that indirect laryngoscopy is an excellent method for predicting difficult intubation. Furthermore, it provided valuable information about the obstacles in the patient's pharynx and larynx that could not be determined whenever the Wilson or the modified Mallampati scoring systems were used.

Visualization of the larynx by indirect laryngoscopy requires that anesthesiologists not familiar with the technique acquire some experience to become proficient. In addition, about 15% of patients cannot tolerate indirect laryngoscopy because of an excessive gag reflex. Nevertheless, this technique might be considered as an integral part of preoperative evaluation and assessment of patients contemplating surgery and anesthesia and requiring tracheal intubation.

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