ORIGINAL ARTICLE

A prospective observational evaluation of an anatomically guided, logically formulated airway measure to predict difficult laryngoscopy

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Context Difficulty during tracheal intubation is the most common cause of serious adverse respiratory events for patients undergoing anaesthesia. Current traditional bedside predictors of difficult laryngoscopy have poor sensitivity. A simple method to accurately predict difficult laryngoscopy could greatly improve patient safety.

Objectives This study examined a novel bedside predictor of difficult laryngoscopy that calculates a ratio of measurements directly affecting the ability to achieve the necessary line of vision (NLV) from the larynx to the operator (NLV ratio).

Design This was a prospective observational study.

Setting A single tertiary care surgical centre.

Patients We enrolled 2046 patients scheduled for elective surgery under general anaesthesia with anticipated tracheal intubation.

Intervention Prior to surgery, patients had their NLV ratio and standard airway measures recorded. The anaesthesiologist who performed the intubation was blind to the airway assessment and recorded the best view of the larynx according to the Cormack and Lehane scale. Difficult laryngoscopy was defined as a grade 3 or 4 view.

Main outcome measure The main outcome measure was the sensitivity and specificity of the NLV ratio measurement for predicting difficult laryngoscopy.

Results Receiver operating characteristics curve analysis of the NLV ratio revealed an optimal sensitivity of only 41% and specificity of 77%.

Conclusion Although our novel measurement performed similarly to traditional bedside predictors of difficult laryngoscopy, the sensitivity was too low for the test to be clinically useful. Numerous factors which may be very difficult to predict at the bedside probably contributed to the poor performance of this novel measurement.

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Keywords: airway management, anaesthesia, endotracheal intubation, measurement, prospective study

Introduction

Difficult intubation is the most common cause of severe respiratory events, resulting in anaesthesia-related death or brain injury.[1] In 60% of cases leading to adverse outcome, the anaesthesiologist did not anticipate difficulty,[2] suggesting that if a more sensitive method of predicting difficult intubation had been available some of these cases may have been avoided. The ability to accurately predict difficult intubation is a critical first step in avoiding airway catastrophes. It allows for proper preparation of alternative techniques and a different, safer approach to airway management.

Numerous bedside physical examination tests have been investigated in attempts to predict difficult laryngoscopy. The most commonly used tests are the Mallampati score,[3,4] the distance from the thyroid notch to the mentum (thyromental distance), and a summation of risk factors.[5] A recent meta-analysis of bedside screening tests for prediction of difficult laryngoscopy found that they score poorly on sensitivity, specificity and positive predictive value.[6] Specifically, the pooled sensitivity for the Mallampati score was 49%, for thyromental distance 20% and for the Wilson risk score 46%.[6]

To try to improve the ability of anaesthesia providers to accurately predict difficult laryngoscopy we developed and tested a new, logically formulated bedside measurement. The design of this measurement was based on an analysis of lateral cervical spine imaging and of the geometry of direct laryngoscopy. We addressed some of the problems encountered by currently used predictors of difficult laryngoscopy including, first, the failure to incorporate the interactions of many anatomic variables and, second, the use of absolute measurement values rather than relating them to the patients' size. Our novel airway measurement was based on the following principles: first, for visualisation of the larynx, there must be a direct line that light will travel between the larynx (superficially represented by the thyroid cartilage) and the upper incisors. We refer to this line as the necessary line of vision (NLV) (Fig. 1). Second, the NLV is obstructed by the tongue. Third, the tongue will have to be pushed anterior to the NLV along the mandibular axis (a line drawn between the angle of the mandible and the mentum) to allow visualisation of the vocal cords. Two factors affect the difficulty of displacing the tongue by their relation to the intercept point of the two lines (NLV and mandibular axis): distance A – the distance between the angle of the mandible (the most posterior insertion of the tongue) and the intercept with the NLV,

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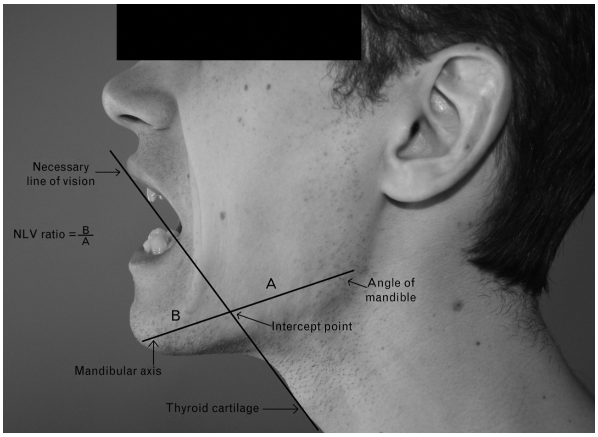
Fig. 1



Measurement of the necessary line of vision (NLV). The NLV for laryngoscopy extends from the patient's thyroid cartilage past their upper incisors. Where this line crosses the mandibular axis is called the intercept. The distance anterior to the intercept 'B' divided by the distance posterior to the intercept 'A' yields the NLV ratio.

reflecting how far the tongue will have to be displaced forward to avoid obstruction of the NLV, and distance B – the distance between the NLV and the mentum, reflecting the space available to accommodate the displaced tongue. Fourth, the longer distance A is, the more difficult it will be to displace the tongue away from the NLV. Fifth, the shorter distance B is, the less amount of space will be available to accommodate the displaced tongue. The ratio of distance B to distance A is the NLV ratio. The smaller the NLV ratio, the more difficult it will be to achieve a clear NLV and visualise the larynx. The use of a measured ratio makes the assessment specific to the patient as opposed to an absolute value. We hypothesised that a preoperative measurement of the NLV ratio would accurately predict the ability to visualise the larynx with direct laryngoscopy.

For the purpose of this study we had to define a difficult intubation. Although repeated attempts at intubation, the use of a bougie or other intubation aids and other combined scores have been applied, the most widely used definition is the appearance of a Cormack and Lehane grade 3 or 4 view on direct laryngoscopy.[7] This is a logical definition as it implies that the anaesthesiologist is unable to fully visualise the vocal cords on direct laryngoscopy. Adopting this definition allowed us to readily compare our results with those of other investigators. In addition, we also calculated the Intubation Difficulty Scale[8] (IDS) which takes into account the other measures listed above including the number of attempts, and additional techniques. An IDS greater than 5 represents moderate to major intubation difficulty. The IDS was considered a secondary outcome measure to reflect the actual implication of the laryngoscopic view.

Methods

Ethical approval for this study (Research Ethics Board number 04-0170-E) was provided by the Research Ethics Board of the Mount Sinai Hospital, Toronto, Canada (Chairperson Dr Ronald Heslegrave) on 2 July 2008. This was a prospective observational study. Following written informed consent, we enrolled patients scheduled for elective surgery with anticipated endotracheal intubation at a single tertiary care hospital. Our centre has a varied surgical practice including general surgery, orthopaedics, otolaryngology, gynaecology, urology, oral maxillo-facial and ophthalmology. Prior to surgery, the patient was evaluated by a trained researcher who measured the NLV ratio as well as standard airway measurements (Mallampati score, thyromental distance, mouth opening and atlanto-occipital extension). One trained researcher performed all the airway measurements.

On the day of surgery, the anaesthetic technique and airway management plan was left to the discretion of the anaesthesiologist with clinical responsibility, who was blinded to the researcher's airway assessment. Following intubation, the anaesthesiologist recorded the grade of laryngoscopic view as well as operator experience, number of attempts, additional techniques, lifting force required, opening of vocal cords and subjective difficulty of intubation (yes, no, awkward). As this study was carried out in a teaching centre, some intubations were performed by trainees. In cases wherein more than one person performed laryngoscopy, data from the most experienced operator was used.

Necessary line of vision ratio measurement

The NLV ratio was measured with the patient simulating the optimal intubating position. The patient was asked to assume the sniffing position (lower cervical spine partially flexed and head extended at the atlanto-occipital joint), open the mouth as wide as possible and maximally protrude their mandible (Fig. 1). While in this position, the researcher examined the patient's head and neck in profile and placed a thin, straight metal bar such that it overlapped the superior margin of the thyroid cartilage and the inferior margin of the upper incisors (or gums in a patient with no upper teeth). The point where this bar crossed the mandible was marked and this point is referred to as the 'intercept'. The researcher then measured the distance from the posterior margin of the angle of the mandible to the intercept (distance A), and from the intercept to the anterior margin of the chin (distance B). Distance B divided by distance A is the NLV ratio.

Data analysis

As the NLV ratio is a continuous variable we constructed a receiver operating characteristics (ROC) curve with 95% confidence intervals to determine the ratio that would achieve the optimal sensitivity and specificity. On the basis of the meta-analysis by Shiga *et al.*,[6] the most sensitive simple preoperative airway examination manoeuvre that has been sufficiently studied is the Mallampati score with a sensitivity of only 49%. Therefore, if the NLV were found to have a sensitivity of 75% or greater this would represent a significant improvement; hence, we chose a minimally acceptable sensitivity of 75% for this test to be considered useful. In order to be of value in clinical practice, the test would need additionally sufficient specificity to avoid unnecessary use of resources or procedures. We believe that, in the interest of patient safety, most anaesthesiologists would be willing to accept a positive predictive value of 50%, that is, when the test predicts difficult laryngoscopy, it would in fact be difficult only 50% of the time. The exact specificity required will depend on the prevalence of difficult laryngoscopy in our patient group. On the basis of the results of our initial pilot study, we expected that the test would require a specificity of approximately 90% to have a positive predictive value of 50%. To minimise the likelihood of a type II error, we performed a sample size analysis assuming a power of 0.8. Using results from a pilot study, we calculated that we would require 130 individuals with difficult laryngoscopy. To obtain this number of participants with a difficult laryngoscopy, we anticipated the need to enrol approximately 2100 individuals.

Results

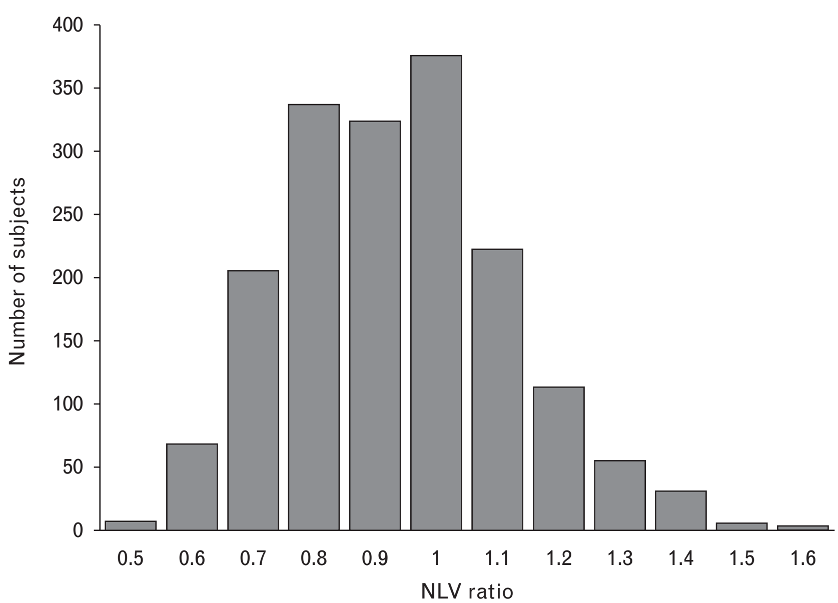
A total of 2046 patients were enrolled in the study. Two hundred and ninety-seven were excluded because direct laryngoscopy was not attempted. Of those 297, 162 were managed with a supraglottic airway, had a regional technique or did not have the laryngoscopic view recorded. The remaining 135 were intubated using a variety of indirect laryngoscopy techniques. Of the 1749 participants who had direct laryngoscopy, 133 had a Cormack and Lehane grade 3 or 4 view on direct laryngoscopy, yielding an 8% prevalence of difficult laryngoscopy. Fifty-three patients had an IDS of greater than 5. The mean NLV ratio was 0.9 ± 0.2. The distribution of the NLV ratio is shown in Fig. 2.

To determine the value for the NLV ratio that had the best sensitivity and specificity we constructed a ROC curve for Cormack and Lehane score 3 or 4 (Fig. 3) and IDS greater than 5 (Fig. 4). The ROC curves revealed that the NLV ratio test was unable to yield useful test characteristics at any value. All NLV ratio values were associated with a sensitivity or specificity that was too low to make the test clinically useful. Similarly, the positive predictive value was poor (<20%), unless the NLV ratio was very low in which case the sensitivity was extremely poor. The negative predictive value ranged from 92 to 94% depending on the NLV ratio. Given that the prevalence of difficult laryngoscopy in our study population was 8%, a negative predictive value of 92–94% is not clinically useful. The Mallampati score was also not predictive of difficult laryngoscopy. A Mallampati score of 3 or 4 had a sensitivity of $33 \pm 7\%$ and a specificity of $88 \pm 2\%$. Despite the high specificity, the positive predictive value was only $18 \pm 5\%$.

Discussion

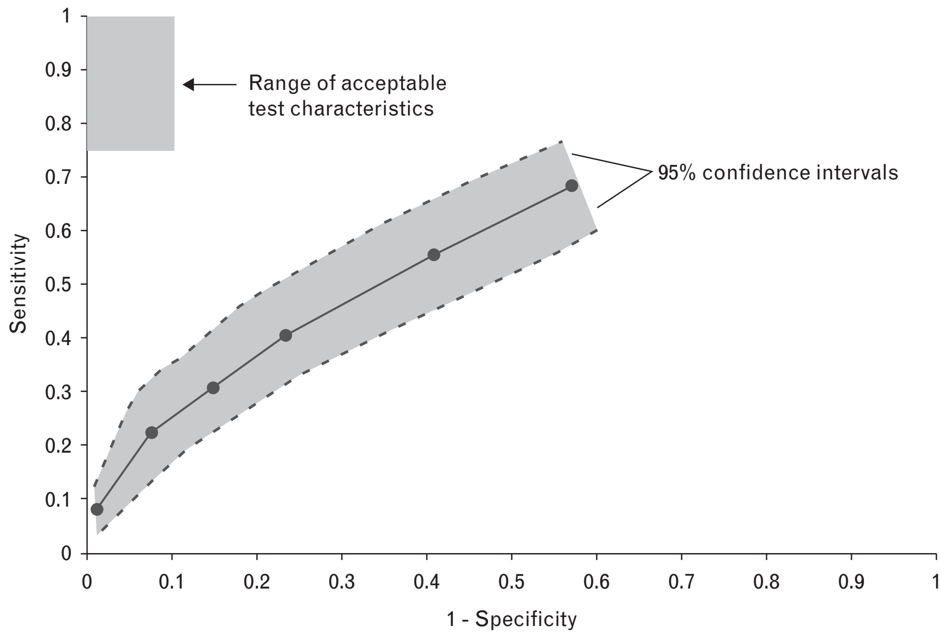
Despite addressing some of the weaknesses of traditional bedside predictors of difficult intubation, our novel

Fig. 2



Distribution of the necessary line of vision (NLV) ratio measurement.

Fig. 3

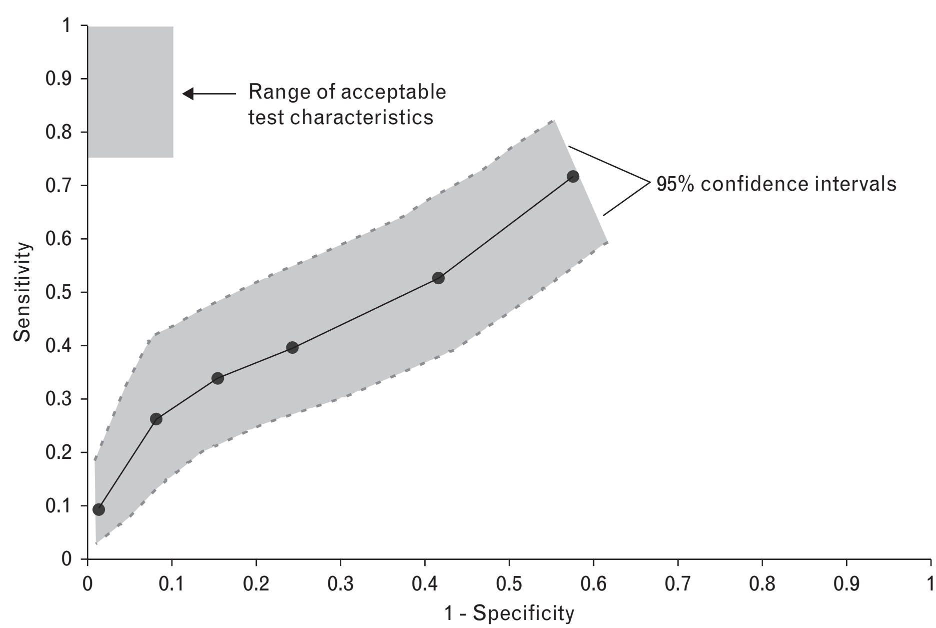


ROC curve demonstrating the necessary line of vision (NLV) ratio's performance for predicting a Cormack and Lehane view of grade 3 or 4.

measurement performed poorly. We believe that there are several possible reasons why our test did not perform as well as anticipated.

Measurement of the NLV ratio relies on the correct identification of the angle of the jaw, as well as the thyroid cartilage, which may be difficult in more obese patients. The measurement also relies on the correct placement of a thin bar exactly above the patient's thyroid cartilage and upper incisors. Small changes in the identification of the angle of the jaw, the patient's positioning or the angle of the bar could have resulted in

Fig. 4



ROC curve demonstrating the necessary line of vision (NLV) ratio's performance for predicting an intubating difficulty score of greater than 5.

an inaccurate measurement. A sufficient number of inaccurate measurements may have caused the predictive ability of the test to suffer.

Many of the laryngoscopies were performed by trainees which may have resulted in some patients being classified as difficult laryngoscopies when in fact, in more experienced hands the patient would not have been considered difficult at all. Of the 1749 laryngoscopies, 967 were performed by experienced anaesthesiologists of which 99 (10%) were considered difficult. Trainees performed 782 laryngoscopies, of which only 14 (2%) were considered difficult. The probable reason for the small number of difficult laryngoscopies for trainees was because when trainees were faced with a grade 3 or 4 view, a more experienced anaesthesiologist would usually repeat the laryngoscopy. When the data were reanalysed using data from experienced anaesthesiologists only, there was no significant change in the results.

In this study, the clinical anaesthesiologists were free to manage the airway as they saw fit. This resulted in 297 patients being excluded because direct laryngoscopy was not performed. In 135 cases, the anaesthesiologist used an alternative technique to direct laryngoscopy such as a videolaryngoscope or fiberoptic scope. Alternative intubating techniques were probably often used for teaching purposes, but may have also been used in cases in which the clinical anaesthesiologist anticipated a difficult intubation. This would have resulted in these participants being excluded from our study. Although this may have introduced bias into our patient group, we nevertheless allowed the clinical anaesthesiologist full discretion in managing the airway because, first, we did not want to risk patient safety and, second, we wanted to simulate real world practice. Predicting difficult laryngoscopy in patients who would be managed with alternative techniques anyway would not improve patient safety.

Our novel measurement performed no better than previous bedside predictors of difficult intubation, all of which have performed poorly. This raises the question of why difficult intubation is so difficult to predict. We designed our NLV ratio measurement to take into account most of the factors involved in laryngoscopy, although we knew there were some factors for which it could not account. For example, the shape, size and orientation of the patient's epiglottis, the compressibility of the tongue and the degree to which a given patient's airway anatomy may be affected by muscle relaxation are all very difficult to predict at the bedside. A more advanced measurement, which could account for some of these factors, may be able to improve the prediction of difficult intubation.

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None of the authors has any conflict of interest.

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