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Research Article

Ultrasonographic Airway Measurements as Predictors of Difficult Laryngoscopy in Patients Undergoing Elective Surgery Under General Anaesthesia: A Cross-Sectional Study

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ABSTRACT

Background: Unanticipated difficult laryngoscopy remains an important cause of airway-related morbidity during general anaesthesia. Conventional bedside airway tests have limited and inconsistent predictive performance. Point-of-care airway ultrasonography, by quantifying anterior neck soft-tissue thickness, has emerged as a potential non-invasive adjunct, but data from South Indian populations are scarce. Methods: This cross-sectional study enrolled 180 adult patients undergoing elective surgery under general anaesthesia at a tertiary care teaching hospital in South India. Preoperative conventional bedside airway assessment (modified Mallampati class, thyromental distance, hyomental distance, neck circumference, body mass index) and ultrasonographic airway measurements (anterior neck soft-tissue thickness at the hyoid and at the epiglottis, and a composite ultrasound airway score, 0–12) were recorded. Laryngoscopy was graded using the Cormack-Lehane classification; difficult laryngoscopy was defined as grade III–IV. Data were analysed using unpaired t-tests, chi-square tests, and receiver operating characteristic (ROC) analysis ($p<0.05$). Results: The incidence of difficult laryngoscopy was 32.2% (58/180; 95% CI 25.4–39.0%). Anterior soft-tissue thickness at the hyoid (14.07 vs 13.03 mm; $p<0.001$), at the epiglottis (23.65 vs 22.41 mm; $p=0.013$), and the composite ultrasound airway score (5.45 vs 3.80; $p<0.001$) were significantly greater in patients with difficult laryngoscopy. Thyromental ($p<0.001$) and hyomental ($p<0.001$) distances were significantly shorter in the difficult group, whereas neck circumference and BMI did not differ. The composite ultrasound airway score had the highest discrimination (AUC 0.692), followed by hyoid soft tissue (0.666) and epiglottic soft tissue (0.616). Conclusion: Greater anterior neck soft-tissue thickness and a higher composite ultrasound airway score were associated with difficult laryngoscopy, with moderate discrimination. Airway ultrasonography is a promising bedside adjunct to conventional assessment.

Keywords: Airway ultrasonography; difficult laryngoscopy; Cormack-Lehane grade; anterior neck soft tissue; thyromental distance; general anaesthesia.

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INTRODUCTION

Management of the airway is a cornerstone of safe general anaesthesia, and the inability to secure a patent airway promptly remains among the most feared and potentially catastrophic complications in anaesthetic practice.

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Direct laryngoscopy and tracheal intubation, despite the increasing availability of videolaryngoscopy and supraglottic devices, continue to be performed routinely, and a difficult laryngoscopic view is a principal antecedent of difficult intubation. Anticipation of a difficult airway permits the anaesthesiologist to prepare appropriate equipment, formulate a contingency plan, and recruit skilled assistance, thereby reducing the likelihood of hypoxaemic injury, oesophageal intubation, dental trauma, and the need for emergency surgical airway access [1]. Conversely, an unanticipated difficult laryngoscopy may precipitate a cascade of failed attempts, airway trauma, and desaturation. Reliable preoperative prediction of difficult laryngoscopy is therefore of substantial clinical importance.

A range of conventional bedside tests has been described and validated to varying degrees, including the modified Mallampati classification, thyromental distance, hyomental distance, mouth opening, sternomental distance, the upper lip bite test, and ratio-based indices such as the ratio of height to thyromental distance [2]. Composite and weighted scoring systems that combine several anatomical and historical variables, such as the MTAO combination and the Simplified Predictive Intubation Difficulty Score, have been proposed to improve discriminatory power over any single test [3]. Nevertheless, the predictive performance of these conventional tests, whether used individually or in combination, is frequently modest, with limited sensitivity and specificity and considerable inter-observer variability [4]. Their accuracy may be further degraded in specific populations, such as patients with cervical spine limitations or endocrine disorders such as acromegaly, in whom soft-tissue and skeletal changes alter airway anatomy in ways that surface examination cannot fully capture [5]. The persistence of unanticipated difficult airways despite decades of bedside test refinement underscores the need for objective, anatomically grounded assessment tools.

Ultrasonography has emerged as an attractive modality for preoperative airway evaluation because it is non-invasive, radiation-free, portable, rapid, and readily repeatable at the bedside [6]. Sonographic imaging of the airway can delineate the soft-tissue structures of the anterior neck that are not accessible to conventional clinical examination, and quantification of anterior neck soft-tissue thickness has been proposed as a marker of difficult laryngoscopy [7]. The conceptual basis is that an increased depth of pretracheal and peri-laryngeal soft tissue impedes the anterior displacement of tissues required to align the oral, pharyngeal, and laryngeal axes during direct laryngoscopy, thereby degrading the glottic view. Pilot investigations have reported associations between increased soft-tissue thickness measured at the level of the hyoid bone, the thyrohyoid membrane, the epiglottis, and the vocal cords and a difficult laryngoscopic or intubation grade [8]. Sublingual ultrasonographic approaches and broader reviews of airway ultrasound have further supported its feasibility and potential role in airway management [9].

Despite this growing interest, the evidence base remains heterogeneous, with variable measurement sites, transducer positions, and threshold values, and the discriminatory performance reported across studies has ranged from modest to good. Importantly, anterior neck soft-tissue dimensions and body habitus vary across ethnic and regional populations, limiting the direct extrapolation of thresholds derived elsewhere. There is a particular paucity of data from South Indian populations, in whom airway anatomy and anthropometry may differ from those in Western or East Asian cohorts. The present cross-sectional study was therefore undertaken at a tertiary care teaching hospital in South India to evaluate ultrasonographic airway measurements, including anterior neck soft-tissue thickness at the hyoid and epiglottis and a composite ultrasound airway score, as predictors of difficult laryngoscopy, and to compare their performance with conventional bedside airway tests in patients undergoing elective surgery under general anaesthesia [10].

Materials and Methods

Study design and setting

This was a cross-sectional, observational, diagnostic predictor study conducted in the Department of Anaesthesiology at tertiary care teaching hospital in South India, over six months.

Study population

Adult patients scheduled for elective surgery under general anaesthesia requiring direct laryngoscopy and tracheal intubation were screened for eligibility. Inclusion criteria were age 18 years or older, American Society of Anesthesiologists physical status I–III, and provision of written informed consent. Exclusion criteria were emergency surgery, pregnancy, known or anticipated difficult airway requiring an awake or alternative intubation technique, anatomical abnormality or pathology of the head and neck (including prior neck surgery, radiotherapy, tumour, trauma, or fixed cervical deformity), and refusal of consent.

Sample size

A total of 180 patients were enrolled. The sample size was considered adequate to estimate the incidence of difficult laryngoscopy with acceptable precision and to permit comparison of ultrasonographic and conventional airway measurements between patients with and without difficult laryngoscopy, as well as receiver operating characteristic analysis of candidate predictors.

Conventional airway assessment

A standardised preoperative airway assessment was performed for every patient by an anaesthesiologist. The modified Mallampati class was assessed with the patient seated, mouth maximally open, and tongue protruded without phonation. Thyromental distance was measured from the mentum to the thyroid notch with the head fully extended, and hyomental distance from the mentum to the hyoid bone. Neck circumference was measured at the level of the thyroid cartilage, and body mass index (BMI) was calculated from measured weight and height[11].

Ultrasonographic airway assessment

Preoperative airway ultrasonography was performed with the patient supine and the head in a neutral position using a high-frequency linear transducer. Anterior neck soft-tissue thickness was measured in the midline as the distance from the skin surface to the anterior aspect of the relevant airway landmark at two levels: the hyoid bone and the epiglottis. A composite ultrasound airway score (range 0–12) was derived by combining graded ultrasonographic measurements of anterior neck soft tissue, with higher scores indicating greater soft-tissue depth and a presumptively more difficult airway. All ultrasonographic measurements were obtained by a single trained operator to ensure consistency of technique.

Anaesthesia, laryngoscopy, and Cormack-Lehane grading

After standard monitoring and preoxygenation, general anaesthesia was induced and neuromuscular blockade established according to institutional practice. Direct laryngoscopy was performed with a Macintosh blade with the patient in the sniffing position by an experienced anaesthesiologist. The best laryngoscopic view obtained was graded using the Cormack-Lehane classification (grade I, full view of the glottis; grade IIa, partial view of the glottis; grade IIb, arytenoids or posterior glottis only; grade III, epiglottis only; grade IV, no glottic or epiglottic structures visible).

Definition of difficult laryngoscopy

Difficult laryngoscopy was defined as a Cormack-Lehane grade III or IV view.

Statistical analysis

Continuous variables were summarised as mean and standard deviation (SD), and categorical variables as frequencies and percentages. The incidence of difficult laryngoscopy was reported with a 95% confidence interval (CI). Ultrasonographic and conventional measurements were compared between the difficult and not-difficult laryngoscopy groups using the unpaired (independent samples) t-test for continuous variables and the chi-square test for categorical variables. Receiver operating characteristic (ROC) curves were constructed and the area under the curve (AUC) calculated to assess the discriminatory ability of each candidate predictor for difficult laryngoscopy. A two-sided p-value of less than 0.05 was considered statistically significant.

Results

Patient characteristics

A total of 180 adult patients were studied. The mean age was 47.3 (SD 15.1) years, and the mean BMI was 26.6 (SD 4.3) kg/m². There were 92 women (51.1%) and 88 men (48.9%). The distribution of modified Mallampati class and Cormack-Lehane grade is summarised in Table 1.

Difficult laryngoscopy (Cormack-Lehane grade III–IV) occurred in 58 patients, giving an incidence of 32.2% (95% CI 25.4–39.0%). On the Cormack-Lehane scale, 52 patients had grade I, 54 grade IIa, 35 grade IIb, 26 grade III, and 13 grade IV. The modified Mallampati distribution comprised 40 patients in class I, 77 in class II, 42 in class III, and 21 in class IV.

Table 1. Patient characteristics and airway class distribution (N=180)

Variable	Value
Age, years, mean (SD)	47.3 (15.1)
Female, n (%)	92 (51.1)
Male, n (%)	88 (48.9)
BMI, kg/m², mean (SD)	26.6 (4.3)
Modified Mallampati class I, n	40
Modified Mallampati class II, n	77
Modified Mallampati class III, n	42
Modified Mallampati class IV, n	21
Cormack-Lehane grade I, n	52
Cormack-Lehane grade IIa, n	54
Cormack-Lehane grade IIb, n	35
Cormack-Lehane grade III, n	26
Cormack-Lehane grade IV, n	13
Difficult laryngoscopy (grade III–IV), n (%)	58 (32.2)

Ultrasonographic measurements by laryngoscopy difficulty

All three ultrasonographic measures were significantly greater in patients with difficult laryngoscopy than in those without (Table 2). Anterior neck soft-tissue thickness at the hyoid was 14.07 mm in the difficult group versus 13.03 mm in the not-difficult group (t=3.50, p<0.001). Anterior soft-tissue thickness at the epiglottis was 23.65 mm versus 22.41 mm (t=2.50, p=0.013). The composite ultrasound airway score was 5.45 versus 3.80 (t=4.44, p<0.001).

Table 2. Ultrasonographic airway measures by

laryngoscopy difficulty

Ultrasound measure	Difficult (grade III–IV)	Not difficult (grade I–II)	t	p
Anterior soft tissue at hyoid, mm	14.07	13.03	3.50	<0.001
Anterior soft tissue at epiglottis, mm	23.65	22.41	2.50	0.013
Composite ultrasound airway score (0–12)	5.45	3.80	4.44	<0.001

Conventional measurements by laryngoscopy difficulty

Among conventional measures, both thyromental and hyomental distances were significantly shorter in patients with difficult laryngoscopy (Table 3). Thyromental distance was 5.69 cm in the difficult group versus 6.09 cm in the not-difficult group (t=-3.43, p<0.001), and hyomental distance was 2.72 cm versus 2.97 cm (t=-3.54, p<0.001). Neck circumference (37.38 vs 37.75 cm; p=0.45) and BMI (25.89 vs 27.00 kg/m²; p=0.11) did not differ significantly between the groups.

Table 3. Conventional airway measures by laryngoscopy difficulty

Conventional measure	Difficult (grade III–IV)	Not difficult (grade I–II)	t	p
Thyromental distance, cm	5.69	6.09	-3.43	<0.001
Hyomental distance, cm	2.72	2.97	-3.54	<0.001
Neck circumference, cm	37.38	37.75	—	0.45 (NS)
BMI, kg/m²	25.89	27.00	—	0.11 (NS)

Discriminatory performance (ROC analysis)

The discriminatory ability of the candidate predictors is shown in Table 4. The composite ultrasound airway score demonstrated the highest area under the curve (AUC 0.692), followed by anterior soft tissue at the hyoid (AUC 0.666) and anterior soft tissue at the epiglottis (AUC 0.616). Neck circumference showed no useful discrimination (AUC 0.459).

Table 4. Receiver operating characteristic area under the curve (AUC) of predictors for difficult laryngoscopy

Predictor	AUC
Composite ultrasound airway score	0.692
Anterior soft tissue at hyoid	0.666
Anterior soft tissue at epiglottis	0.616
Neck circumference	0.459

Discussion

In this cross-sectional study of 180 adult patients undergoing elective surgery under general anaesthesia at a tertiary care teaching hospital in South India, difficult laryngoscopy occurred in 32.2% of patients, and ultrasonographic measures of anterior neck soft-tissue thickness were significantly associated with a difficult laryngoscopic view. Patients with Cormack-Lehane grade III–IV laryngoscopy had significantly greater anterior soft-tissue thickness at both the hyoid and the epiglottis and a higher composite ultrasound airway score than those with an easier view. Among conventional tests, shorter thyromental and hyomental distances were also predictive of difficulty, whereas neck circumference and BMI were not. On ROC analysis, the composite ultrasound airway score provided the best discrimination, although its AUC of 0.692 indicates only moderate, rather than excellent, predictive accuracy.

These findings are consistent with the central hypothesis underlying airway ultrasonography, namely that increased depth of anterior neck soft tissue mechanically impedes the tissue compression and axis alignment required for an unobstructed glottic view during direct laryngoscopy [12]. Our results accord with pilot work by Adhikari and colleagues, who reported that point-of-care ultrasound measurement of anterior neck soft tissue at the level of the hyoid bone and the thyrohyoid membrane was greater in patients with difficult laryngoscopy [13]. Similarly, Hui and Tsui demonstrated the feasibility of a sublingual ultrasonographic approach for predicting difficult intubation, reinforcing the concept that sonographically quantified soft-tissue and tongue dimensions carry predictive information not available from surface inspection alone [14]. Broader reviews of airway ultrasonography by Kundra et al. and Suzuki et al. have emphasised its non-invasive, bedside, and repeatable character and its expanding role across the spectrum of airway management, from prediction to confirmation of tube placement. The significant association we observed between the composite ultrasound airway score and difficult laryngoscopy supports the view that combining soft-tissue measurements into a single index may capture more of the relevant anatomy than any single sonographic measurement.

The performance of conventional bedside tests in our cohort is also in keeping with the existing literature. Shorter thyromental and hyomental distances were

significantly associated with difficult laryngoscopy, mirroring the long-recognised relationship between a reduced mandibular space and an anterior larynx. Thyromental distance and ratio-based derivatives such as the ratio of height to thyromental distance have repeatedly featured among the more useful individual bedside predictors, although none has demonstrated consistently high sensitivity and specificity [10,11]. The modified Mallampati classification, while widely used, has well-documented limitations in isolation, which has motivated the development of composite scores such as the MTAO combination and the Simplified Predictive Intubation Difficulty Score that aggregate several variables to improve prediction [8,13]. The observation that neck circumference and BMI did not differ significantly between our groups is notable; although obesity and a large neck have been linked to airway difficulty in some populations, the relationship is inconsistent, and our data suggest that, in this South Indian cohort, regional soft-tissue thickness measured sonographically discriminated better than gross anthropometric surrogates. This is concordant with reports that the causes and predictors of difficult intubation vary by patient subgroup and clinical context [9,12], and that body habitus measures alone are imperfect markers of the local anatomy that ultimately determines the laryngoscopic view.

From a clinical standpoint, our findings suggest that airway ultrasonography may serve as a valuable, objective adjunct to conventional bedside assessment rather than a replacement for it. Because the examination is rapid, radiation-free, portable, and repeatable, it can be readily incorporated into the routine preoperative airway evaluation, particularly in patients in whom conventional tests are equivocal or in whom soft-tissue pathology is suspected [3,4,14]. The composite ultrasound airway score, by integrating measurements at more than one level, offers a pragmatic single summary measure that performed at least as well as, and numerically better than, individual measurements in our analysis. Nonetheless, the moderate AUC of 0.692 warrants a measured interpretation. A discriminatory value in this range indicates that the composite score improves prediction above chance but cannot, on its own, reliably separate patients who will have a difficult laryngoscopy from those who will not. This level of performance is broadly comparable to that of many established bedside predictors, which similarly achieve only modest standalone accuracy [6,9,10]. The most rational application is therefore likely to be within a multimodal assessment strategy in which sonographic soft-tissue measurements are combined with thyromental and hyomental distances, the modified Mallampati class, and clinical judgement to refine pre-test probability and guide airway planning. Future research in South Indian and other under-represented populations should focus on deriving and validating population-specific thresholds, on multivariable models that combine ultrasonographic and conventional variables, and on prospective evaluation of whether ultrasound-informed planning improves clinical outcomes.

Conclusion

In adult patients undergoing elective surgery under general anaesthesia at a tertiary care teaching hospital in South India, greater anterior neck soft-tissue thickness at the hyoid and epiglottis and a higher composite ultrasound airway score were significantly associated with difficult laryngoscopy, as were shorter thyromental and hyomental distances. The composite ultrasound airway score showed the best, though still moderate, discrimination (AUC 0.692). Airway ultrasonography is a promising, non-invasive, bedside adjunct that may complement conventional airway assessment, but given its moderate predictive accuracy it should be integrated into a multimodal evaluation rather than used in isolation.

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