Original Article

Evaluation of voice parameters as predictor for difficult airway in adult patients undergoing general endotracheal anaesthesia - A prospective observational study

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Abstract

Background and aims: Voice has emerged as a new potential method for the detection of a difficult airway, building on the fact that voice parameters can reflect the anatomical characteristics of the upper airway. Thus, we hypothesised to evaluate the potential of voice in predicting a difficult airway during general anaesthesia for elective surgeries. The primary objective of the study was to compare the formant frequencies of vowels in patients with normal anthropometric measurements (Group A) and in patients with difficult airway (Group B).

Methods: This prospective observational study was conducted at a tertiary care centre from march 2024 to june 2025. Institute ethics committe approval was obtained (vide approval number: : ETHICS COMM: 72:2023-24 dated 01-02-2024). Written informed consent was obtained for participation in the study. Airway assessment included the modified Mallampati score (MMS), thyromental distance and inter-incisor gap. Preoperatively, patients voice was recorded with digital voice recorder and analysed with Praat software. Sample size was calculated based on a previous study and 46 patients were included in each group. Regarding statistical analysis, collected data was tabulated and organized using MS Excel and was analysed using SPSS version 27.0.

Results: Regarding analysis of voice, only vowel |u| F2 formant is a significant predictor of difficult intubation with AUC = 0.746 & p=0.02. In patients predicted to have difficult airway based on mallampati score, F2 formant frequencies of vowel [u] significantly increased the positive predictive value to 72%.

Conclusion: Evaluation of vowel formants provides valuable information to predict a difficult airway in conjuction with other anthropometric measurements in patients scheduled for general anaesthesia.

Keywords: Airway, Airway management, voice,

Introduction

The goal of airway assessment is to identify patients with potential difficulties and plan airway management as more than 30% of serious anesthesia-related complications are caused by unanticipated difficult airway[1,2]. Difficult airway can be predicted by various methods which include, but not limited to, physical examinations, multivariate scoring system and imaging tests. Physical examination methods such as the modified mallampatti score, thyromental distance and upper lip bite test exhibit high specificity but low sensitivity. Multivariate scoring systems such as LEMON score and wilson's score integrate multiple clinical variables yet their sensitivity remains moderate. Effectiveness of imaging technique is influenced by operator skill, lack of standardised procedures and cut off values. Thus, a synergistic approach combining multiple predictive methods tailored to individual patient profiles offers the most promising result[2,3,4].

In recent years, voice has emerged as a new potential method for the detection of a difficult airway, as voice parameters reflect the anatomical characteristics of the upper airway. Especially size of the base of the tongue which is an important factor determining the degree of difficulty of direct laryngoscopy[5,6]. Prior

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studies by Cao S et al have found that patients with obstructive sleep apnea show significant changes in acoustic parameters compared to healthy controls. Thus, evaluation of the human voice, more specifically sound frequencies has emerged as a possible alternative to predict a difficult airway[7]. However, Marcari et al reported a significant negative relation between the formant frequencies and the length of the mandible and maxilla[8].Thus, we hypothesized to evaluate the potential of voice in predicting a difficult airway during general anaesthesia for elective surgeries. The primary objective of the study was to compare the formant frequencies of vowels in patients with normal anthropometric measurements (Group A) and in patients with predicted difficult airway (Group B). Secondary objectives of the study were to assess predictive value of voice analysis with modified mallampati classification.

Materials and methods

This prospective observational study was conducted at a tertiary care centre from march 2024 to june 2025. Institute ethics committee approval was obtained (vide approval number: :ETHICS COMM: 72:2023-24 dated 01-02-2024). Written informed consent was obtained for participation in the study and use of patient data for research and educational purposes.

A total of 96 patients aged between18 to 65 years, belonging to ASA physical status I and II scheduled for elective surgery under general endotracheal anaesthesia were enrolled into study. Patients who were excluded from the study were those unable to pronounce vowels, patients with hearing or perception abnormalities and mental or central nervous system abnormalities. During preoperative evaluation demographic variables such as age, sex, weight, height and body mass index (BMI) were noted. Based on the World Health Organisation (WHO)'s The AsiaPacific perspective: redefining obesity and its treatment (2000), patients with a bodymass index (BMI) ≥25.0 kg/m2 were defined as obese[9].

Airway assessment included the modified Mallampati score(MMS), distance and inter-incisor gap. MMS was determined with the patient seated and the examiner's eyes at the level of the patient's mouth. The patient opened his/her mouth as widely as possible without phonation and the view was graded from class I to IV[10].Inter-incisor gap was measured using a millimetre ruler, with the patient in sitting position. Patients were dichotomised into two groups less than 3.5 cms and more than 3.5 cms[11].The thyromental distance was measured using a millimetre ruler from the lower border of the thyroid notch to the mentum, with the head extended and the mouth closed. The resulting measurement was then dichotomised as more than 6 cms or less than 6 cms[12].The patients were also dichotomised with respect to body mass index (BMI) into obese (BMI more than 25) or non-obese (BMI less than 25). Thus, patients with MMS of I and II, inter-incisor gap more than 3.5 cms, thyromental distance more than 6 cms and BMI less than 25 were included in Group A. Patients with MMS of III and IV, inter-incisor gap less than 3.5 cms, thyromental distance less than 6 cms and BMI more than 25 were included in Group B[13,14].

In relation to the evaluation of voice, samples were recorded using a digital handheld voice recorder (Sony, ICD-PX470). The recorder was placed at a distance of 5 cm from the border of the lip, measured using a millimetre ruler. They were instructed to sustain the phonation of the vowels /a/, /i/, /u/, /e/, and /o/ at their habitual pitch and a comfortable loudness level. These samples were transferred to Praat software (version 5.3.23), which is an open-source software tool used for speech signal editing and labeling. All the voice samples were analyzed by a specialist in speech language pathology where the first three formant frequencies (F1, F2, F3) were extracted. The more intense frequencies within the spectrum of voice frequencies are called voice formants, The frequency of each voice formant is determined by the area of a specific segment of the vocal tract. The first formant (F1) is related to the opening of mouth and vertical displacement of tongue; formant 2 (F2) is associated with horizontal displacement of tongue; formant 3 (F3) has a connection with anterior oral and pharyngeal cavities[15,16].The pre-anaesthetic evaluation and recording of voice samples were performed by an anaesthesiologist who was not involved in induction of anaesthesia or laryngoscopy.

The patients were wheeled into operation theatre, intravenous access and routine monitors namely Electrocardiogram, pulse oximetry and non-invasive blood pressure connected. General anaesthesia administered as per institution protocol by one of the 10 attending anaesthetists (each of whom had> 3 years' experience).

The primary objective of the study was to compare the formant frequencies of vowels in patients with normal anthropometric measurements (Group A) and in patients with difficult airway (Group B). Secondary objectives of the study were to assess predictive value of voice analysis with modified mallampati classification.

The sample size was calculated assuming the expected mean and standard deviation of the predictor of difficult airway in the easy laryngoscopy as, $\sigma 1$ (4.4,0.69) and in the difficult laryngoscopy as, $\sigma 0$ (3.82,1.22), as per the previous study by Şükrü Mert BAŞPINAR et al.[17] The other parameters considered for sample size calculation included were ddd power of study and ddd two sided alpha error. The required sample size was calculated using the following formula as proposed by Kirkwood BR et al.

Formula used for sample size calculation:

N = Sample size

$\mu 1$, $\mu 0$ =Difference between the means ($\mu 1=4.4$ and $\mu 0=3.82$)

$\sigma 1$, $\sigma 0$ =Standard deviations ($\sigma 1=0.69$ and $\sigma 0 =1.22$)

u = two-sided percentage point of the normal distribution corresponding to 100 % - the power = ddd, u = 0.84

v = Percentage point of the normal distribution corresponding to the (two sided) significance level for significance level = ddd, v = 1.960

The required sample size as per the above-mentioned calculation was 46 in each group. To account for a nonparticipation rate/ loss to follow up rate of a about 5%, another 2 subjects will be added to the sample size. Hence, the final required sample size was 48 subjects in each group.

Results

Atotal of 96 participants were enrolled into the study, out of which 4 were excluded from the analysis due to inability to pronounce the vowels.

Demographic variables such as gender, weight and BMI were comparable between the two groups as shown in table 1. Regarding age and height, there was statistically significant difference between group A and group B.

Table 1: Demographic characteristics between the two groups

Characteristics	Group A	Group B	Significance
Age (yrs)	41.32 ± 15.8	52.03 ± 18.2	0.0027*
Height (cms)	152.18 ± 9.1	156.23 ± 9.2	0.033*
Weight (kg)	58.25 ± 20.9	63.16 ± 24.0	0.288
BMI			
< 25	43 (89.6%)	40 (83.3%)	0.373
≥ 25	5 (10.4%)	8 (16.7%)	
Sex			
Female	16 (33.3%)	23 (47.9%)	0.147
Male	32 (66.7%)	25 (52.1%)	

Age, Height and Weight expressed as mean ± SD, BMI and gender expressed as ratio.

Regarding analysis of voice, the first 3 formant frequencies F1, F2, and F3 of vowels were extracted and compared between the two groups. Analysis is represented in the table 2 as shown below.

Table 2: Mean formant frequencies between group A and Group B

Formant frequencies		Intubation	Mean ± SD (Hz)	Unpaired 't	p-value
|a|	F1	Group A	772 ± 147.56	0.813	0.42
		Group B	799.6 ± 105.59		
	F2	Group A	1357.3 ± 119.63	0.643	0.523
		Group B	1336.3 ± 128.82		
	F3	Group A	2798.07 ± 295.41	0.104	0.917
		Group B	2806.15 ± 293.88		
|i|	F1	Group A	419.55 ± 135.27	1.677	0.099
		Group B	476.67 ± 130.69		
	F2	Group A	2120.73 ± 375.22	0.918	0.363
		Group B	2046.23 ± 246.39		
	F3	Group A	3112.72 ± 261.98	2.845	0.006*
		Group B	2940.96 ± 212.28		
|u|	F1	Group A	467.13 ± 70.28	1.326	0.191
		Group B	493.95 ± 77.78		
	F2	Group A	1107.67 ± 324.09	2.888	0.006*
		Group B	1407.12 ± 433.41		
	F3	Group A	2680.57 ± 373.95	0.575	0.568
		Group B	2727.70 ± 211.64		
|e|	F1	Group A	466.82 ± 42.03	1.484	0.145
		Group B	501.05 ± 98.55		
	F2	Group A	2142.13 ± 199.82	2.042	0.048*
		Group B	1949.05 ± 427.7		
	F3	Group A	2847.86 ± 168.65	1.263	0.213
		Group B	2776.52 ± 209.64		
|o|	F1	Group A	484.88 ± 34.95	2.518	0.017*
		Group B	532.45 ± 86.8		
	F2	Group A	1080.31 ± 309.71	1.118	0.269
		Group B	1178.85 ± 294.11		
	F3	Group A	2754.88 ± 275.9	1.126	0.268

*Significant difference, SD: Standard deviation

It is evident from the table that, formant frequencies vary between Group A and Group B and the difference being statistically significant in formant F3 of vowel [i], formant F1 of vowel [o], formant F2 of vowel [u] and vowel [e]

Table 3: Predictive capacity of various vowel formants in predicting difficult intubation

Area Under the Curve					
Study parameters		AUC (95% C.I)	SE	p-value	Cut-off (Hz)
|a|	F1	0.688 (0.493 - 0.882)	0.10	0.075	744.10
	F2	0.529 (0.313 - 0.745)	0.11	0.782	1333.44
	F3	0.404 (0.196 - 0.612)	0.11	0.363	2724.98
|i|	F1	0.629 (0.423 - 0.836)	0.11	0.220	408.78
	F2	0.471 (0.253 - 0.688)	0.11	0.782	1953.51
	F3	0.321 (0.129 - 0.513)	0.10	0.089	3083.92
|u|	F1	0.638 (0.439 - 0.836)	0.10	0.192	446.26
	F2	0.746 (0.571 - 0.92)	0.09	0.020*	1145.99
	F3	0.596 (0.385 - .807)	0.11	0.363	2547.03
|e|	F1	0.642 (0.435 - 0.848)	0.11	0.179	492.69
	F2	0.338 (0.145 - 0.530)	0.10	0.123	2095.38
	F3	0.475 (0.265 - 0.685)	0.11	0.813	2809.34
|o|	F1	0.617 (0.403 - 0.83))	0.11	0.268	534.09
	F2	0.633 (0.424 - 0.843)	0.11	0.206	1105.62
	F3	0.388 (0.180 - 0595)	0.11	0.286	2634.32

*Significant Predictor, SE – Standard error

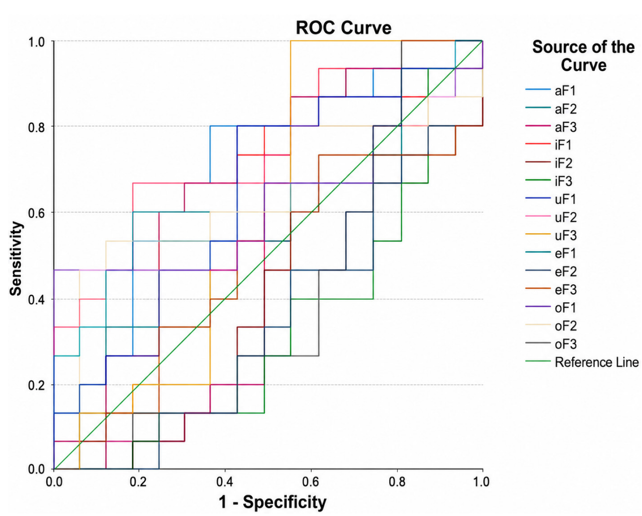

Figure 1: Receiver Operating Characteristic (ROC) curve showing predictive capacity of various vowel formants

Interpretation of ROC is only vowel |u| F2 formant is a significant predictor of difficult intubation with AUC = 0.746 & p=0.02

Table 4: Predictive accuracy of vowel |u| F2 formant in predicting difficult intubation

		Intubation according to Mallampati Scoring system		
		Difficult	Easy	Total
Intubation as predicted by vowel |u| F2 formant at cut-off 1145.99 Hz	Difficult	18	7	25
	Easy	10	19	29
	Total	28	26	54

Sensitivity = 64.3%

Specificity = 73.1%

Positive predictive value (PPV) = 72%

Negative predictive value (NPV) = 65.5%

Accuracy = 68.5%

ROC analysis interpretation: Vowel |u| F2 formant can be considered as significant predictor (p=0.02) of difficult intubation with a fair discriminating power (AUC = 0.746). Optimal cut-off (for clinical utility): 1145.99 Hz ie; patients with vowel |u| F2 formant >1145.99 Hz can be predicted to have difficult intubation. Sensitivity = 64.3% ie; Vowel |u| F2 formant can correctly identify 64.3% of the actual difficult intubation cases. Specificity = 73.1% ie; Vowel |u| F2 formant can correctly identify 73.1% of the actual easy intubation cases. PPV = 72% ie; among the patients as predicted to have difficult intubation by Vowel |u| F2 formant, 72% of them truly had difficult intubation. NPV = 65.5% ie; among those patients predicted to be of undergoing easy intubation by Vowel |u| F2 formant, only 65.5% of them truly had an easy intubation. Accuracy = 68.5% - predictive capacity of Vowel |u| F2 formant in correctly classifying easy & difficult intubation cases.

Statistical analysis: Collected data was tabulated and organized using MS Excel and was analysed using SPSS version 27.0 All continuous variables are represented as mean ± Sd and the comparisons between the groups are made using 'Unpaired t' test. The diagnostic performance of the formant frequencies was evaluated using ROC curve in terms of area under curve (AUC) with 95% C.I, sensitivity, specificity, PPV, NPV and accuracy. A p-value ≤ 0.05 was considered to be statistically significant.

Discussion

Risk factors for difficult airway being multifactorial, no single anthropometric measurement or a clinical test can predict a difficult airway in all patients[18]. Thus, voice analysis can be used as an innovative predictor of difficult airway in conjunction with other anthropometric measurements. As shown by the results of our study, formant frequencies differ between patients with normal anthropometric measurements and patients predicted to have a difficult airway. These differences can be explained based on the fact that formant frequencies are the distinguishing frequency components of human articulation that are dependent on the shape and length of the vocal tract in addition to the movement of the articulators[7].

In 1985, Mallampati et al, presented the bedside test for prediction of difficult airways which was modified by Samson and young in 1987[6,10].In patients predicted to have difficult airway based on mallampati score, F2 formant frequencies of vowel [u] significantly increased the positive predictive value to 72%. Thus, vowel [u] F2 formant can be considered a significant predictor whereas study conducted by Carvalho et al concluded that the model containing mallampati and F1, F2 formants of vowel [i] showed a probability of 91.8% with AUC =0.918 in correctly classifying a randomly selected patient [16].

Rodiera C et al, studied acoustic parameters of the voice together with the demographic data of the patient. They suggested that neither voice analysis nor demographics alone are sufficient for reliable classification. However, combining voice parameters with demographics enhances classification accuracy for a difficult airway[5]. Machine learning algorithms were used for classification whereas in our study Praat software was used for voice analysis.

Cao S et al, evaluated both vowels and consonants (chinese phonetic alphabet) for predicting difficult mask ventilation and found that the formants of [o], [e], [i], [u],[en] and [ci] presented a correlation with difficult mask ventilation[7].However, in our study, only vowels were analysed. Among the demographic data between two groups, age and height were higher in the difficult airway group which was statistically significant, both being difficult airway predictors[19].

Conclusion

Evaluation of vowel formants provides valuable information to predict a difficult airway in conjuction with other anthropometric measurements in patients scheduled for general anaesthesia. Voice parameter-based methods for airway evaluation are promising as they are non-intrusive and may also promote the development of telematic airway evaluation.

Recommendations

In our study, voice was recorded with the patient in sitting position, whereas anaesthesia will be given in supine position. So, changes in voice with change in patient position can be evaluated especially in obese patients.

Voice recording is done when the patient is awake; however, after induction of anaesthesia and administration of neuromuscular blockade, the shape of airway changes considerably due to upper airway collapse. Also, in our study only vowels were evaluated. Future studies can include evaluation of both vowels and consonants in indian population.

Acknowledgements

I acknowledge with deep gratitude the assistance of Theaja Kuriakose, Associate Professor in Speech Language Pathology, JSSISH, Dharwad for guiding in collection of voice samples and extracting the formant frequencies.

References

1. *Karimbanakkal F, Rajesh MC, Bau SH. Comparison between El-Ganzouri risk index and sonologically measured skin-to-epiglottis distance for predicting difficult laryngoscopy: A prospective observational study. Indian J Anaesth. 2025 Apr;69(4):380-385.*
2. *Wang Z, Jin Y, Zheng Y, Chen H, Feng J, Sun J. Evaluation of preoperative difficult airway prediction methods for adult patients without obvious airway abnormalities: a systematic review and meta-analysis. BMC Anesthesiol. 2024 Jul 17;24(1):242.*
3. *Apfelbaum JL, Hagberg CA, Connis RT, Abdelmalak BB, Agarkar M, Dutton RP et al. 2022 American Society of Anesthesiologists Practice Guidelines for Management of the Difficult Airway. Anesthesiology. 2022 Jan 1;136(1):31-81.*
4. *K VZ, Kumar MS, J CJ. Airway assessment: Predictors for difficult intubation – A prospective observational study. Indian J Clin Anaesth. 2023;10(1):11-20.*
5. *Rodiera C, Fortuny H, Valls A, Borras R, Ramírez C, Ros B. Voice Analysis as a Method for Preoperatively Predicting a Difficult Airway Based on Machine Learning Algorithms: Original Research Report. Health Sci Rep. 2024;7(12):e70246.*
6. *Mallampati SR, Gatt SP, Gugino LD. A clinical sign to predict difficult tracheal intubation: a prospective study. Canadian Anaesthetists' Society Journal 1985; 32: 429–34*
7. *Shuang Cao, Ming Xia, Ren Zhou, Jie Wang, Chen-Yu Jin, Bei Pei et al. Voice parameters for difficult mask ventilation evaluation: an observational study. Ann Transl Med 2021;9(23):1740*
8. *Macari AT, Karam IA, Tabri D. Formants frequency and dispersion in relation to the length and projection of the upper and lower jaws. J Voice 2015;29:83-90.*
9. *Inoue S, Zimmet P, Caterson I, Chunming C, Ikeda Y, Khalid AK, et al. Asia Pacific Perspective: Redefining obesity and its treatment. World Health Organization, Western Pacific Region; 2000.*
10. *Samsoon GL, Young JR. Difficult tracheal intubation: a retrospective study. Anaesthesia 1987; 42: 487–90.*
11. *Narkhede HH, Patel RD, Narkhede HR. A prospective observational study of predictors of difficult intubation in Indian patients. J Anaesthesiol Clin Pharmacol. 2019 Jan-Mar;35(1):119-123.*
12. *Pradeep S, Bhar Kundu S, Nivetha C. Evaluation of neck-circumference-thyromental-distance ratio as a predictor of difficult intubation: A prospective, observational study. Indian J Anaesth 2023;67:445-51.*
13. *Healy DW, LaHart EJ, Peoples EE, Jewell ES, Bettendorf RJ Jr, Ramachandran SK. A Comparison of the Mallampati evaluation in neutral*

or extended cervical spine positions: a retrospective observational study of >80 000 patients. Br J Anaesth. 2016 May;116(5):690-8.

14. *Ezri T, Warters RD, Szmuk P. The incidence of class "zero" airway and the impact of Mallampati score, age, sex, and body mass index on prediction of laryngoscopy grade. Anesthesia and Analgesia 2001; 93: 1073–5.*
15. *de Carvalho CC, da Silva DM, de Carvalho AD, Jr. Evaluation of the association between voice formants and difficult facemask ventilation. Eur J Anaesthesiol 2019;36:972-3.*
16. *de Carvalho CC, da Silva DM, de Carvalho Junior AD, Santos Neto JM, Rio BR, Neto CN et al. Pre-operative voice evaluation as a hypothetical predictor of difficult laryngoscopy. Anaesthesia. 2019 Sep;74(9):1147-1152.*
17. *Başpınar ŞM, Günüşen İ, Sergin D, Sargın A, Balcıoğlu ST. Evaluation of anthropometric measurements and clinical tests in the diagnosis of difficult airway in patients undergoing head and neck surgery. Turk J Med Sci. 2022 Jun;52(3):730-740*
18. *Trambadia DN, Yadav P, A S. Preoperative Assessment to Predict Difficult Airway Using Multiple Screening Tests. Cureus. 2023 Oct 11;15(10):e46868.*
19. *Sharma V, Yadav HP, Prakash A, Yadav N, Kumar M, Abbas H. Assessment of Different Indices as Predictors of Difficult Airway in Obese Patients. Cureus. 2024 Feb 26;16(2):e55005.*

Conflict of interest: Nil
Source of funding: Nil

Date received: Mar 26, 2026
Date accepted: May 20, 2026