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Original Research Article

Prospective Observational Study to Determine the Accuracy of Ultrasound-Guided Airway Assessment Preoperatively in Predicting Difficult Airway

Ketaki Nirkhi[1], Vijay Patil[2], Anmol Lalwani[3]

[1,3]Associate Professor, Department of Anaesthesiology, Rajiv Gandhi Medical College & Chhatrapati Shivaji Maharaj Hospital, Kalwa, Thane, Maharashtra

[2]HOD, Department of Anaesthesiology, Rajiv Gandhi Medical College & Chhatrapati Shivaji Maharaj Hospital, Kalwa, Thane, Maharashtra

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Corresponding author: Dr. Ketaki Nirkhi

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Abstract

Endotracheal intubation entails the introduction of an endotracheal tube inside the trachea for the purpose of artificial ventilation. Inserting an endotracheal tube using laryngoscope is a skilful activity that requires detailed knowledge of airway anatomy as well as practice of the skill. However even in the best, experienced hands endotracheal intubation can fail due to variety of factors, one of which is unanticipated alteration in airway anatomy. We conducted a study to assess the utility of ultrasonography in predicting difficult intubation, by measuring the thickness of soft tissues in the anterior part of neck at three different levels, namely skin to Hyoid bone, skin to epiglottis at thyrohyoid membrane level and skin to tracheal ring at suprasternal notch level, and compared the difficulty level predicted with the Cormack-Lehane Grading on direct laryngoscopy. We found that ultrasound can be used as a reliable tool to identify difficult airway by measuring the thickness of soft tissues in the anterior part of neck.

Keywords: Difficult Airway, Airway Assessment, Airway Ultrasonography, Difficult Intubation.

Introduction

Airway management is a vital part of anaesthesia practices, intensive care units, and emergency departments, and a proper pre-operative assessment can guide clinicians' plans for securing an airway. Complex airway assessment has recently been at the forefront of anaesthesia research, with a substantial increase in annual publications during the last 20 years [1].

An unusual and unanticipated situation is one of "cannot ventilate and cannot intubate". Closed claims analysis has found that vast majority (85%) of airway related events involve brain damage and one third of mortality was attributable solely to inability to secure airway in spite of the best measures [2]. Many methods have been introduced since then to overcome these problems and identify the patient who will be difficult to intubate.

Right from the beginning, airway assessment was carried out by single factors like Mallampatti's oropharyngeal classification, Thyromental distance, Head and neck movement and Inter incisor gap [3]. But when it was realized that the visualization of larynx during intubation is affected by many factors, the concept of multivariate factor analysis came into existence [4]. In the last few years, Ultrasonography has been gaining popularity and practical applicability in the hands of anaesthesiologist. There have been many studies using Ultrasonography to assess the airway of patients and to predict difficult intubation [5].

Materials and Methods

In this study conducted in the Department of Anaesthesiology, Rajiv Gandhi Medical college and Chhatrapati Shivaji Maharaj Hospital, Kalwa, Thane, we have assessed the utility of ultrasonography in predicting difficult intubation, by measuring the thickness of soft tissues in the anterior part of neck at three different levels, namely skin to Hyoid bone, skin to epiglottis at thyrohyoid membrane level and skin to tracheal ring at suprasternal notch level, and compared the difficulty level predicted with the Cormack-Lehane Grading on direct laryngoscopy.

The study panned over three months during which we conducted a prospective observational single blinded study. 150 patients, who satisfied the inclusion criteria were included in the study.

At the end of the study the patients were classified as GROUP E (Easy intubation group.) and GROUP

D (Difficult intubation group.) based on the Cormack-Lehane classification of laryngoscopic view.

Inclusion Criteria:

1. ASA grade I,II and III
2. Age 18 to 80 years
3. Both Sex
4. Patients undergoing surgery requiring general Anaesthesia with direct laryngoscopy and endotracheal intubation

Exclusion Criteria:

1. The patients with mouth opening less than 3 centimeters,
2. Edentulous patients
3. The patients with head and neck anatomical pathologies that might have unpredictable effect on the ultrasound assessment of the airway.
4. The patients who were not able to extend their neck >30 degree

On the day before the surgery, after obtaining informed written consent, patients were shifted to the ultrasound room in the department of anaesthesiology and the following measurements were made and recorded.

1. **Height** : in centimeters
2. **Weight** : in Kilograms
3. **Modified Mallampatti's classification of airway**: Modified Mallampatti's Test [6] similar to that used by Samsoon and Young [7] was performed in a seated patient who opened his mouth as wide as he could and protruded the tongue as far as possible, while the observer looked from the patient eye level and inspected the pharyngeal structures with a pen torch.

It is important when performing this test that the patient does not phonate. The view was then graded as:

- **Grade I:** Soft palate, fauces, uvula and pillars seen.
- **Grade II:** Soft palate, fauces and uvula seen
- **Grade III:** Soft palate and base of uvula seen.
- **Grade IV:** soft palate not visible.

4) Inter Incisor Gap: Maximum distance between the upper and lower incisors when the patient's mouth is wide open. It was measured in centimeters using an inch tape. The measurements made were recorded.

5) Thyromental Distance: Distance is measured from the thyroid notch to the tip of the mentum. It was measured with the head extended fully, using an inch tape. The measurements made were recorded.

6) Ultrasound measurement of thickness of soft tissue in anterior neck

The thickness of anterior neck soft tissues from the skin, was measured at 3 different levels.

- Level 1: skin to hyoid bone thickness
- Level 2: skin to epiglottis level thickness at the thyrohyoid membrane level
- Level 3: skin to tracheal ring thickness at the suprasternal notch level.

Patient Position: The patient was made to lie down supine with head in neutral position without a pillow under head. Patient was instructed to keep the mouth closed and to take slow breaths during measurements to minimize errors in recordings due to movements during respiration.

Ultrasound machine control settings: The following controls were set in the ultrasound machine for obtaining the airway assessment measurements and images.

- Transducer - Linear High frequency transducer
- Axis/Plane - Short axis/Transverse plane
- Frequency - 11 MHz
- Depth - 3.0 cms - 4.0 cms
- Gain - 20 - 30.

Obtaining Measurements: The measurements of anterior neck soft tissues were made at the above mentioned three levels in short axis view.

a) The hyoid bone was identified as an inverted U-shaped hyperechoic structure in the submandibular region[8]. The image was frozen on screen and measurement from skin to midpoint of hyoid bone was taken using the "measure" option in the ultrasound machine.

b) The Epiglottis was identified in the Thyrohyoid membrane level as a linear hypoechoic structure followed by a hyperechoic shadow [8].

Measurement was taken from skin to epiglottis as mentioned previously.

Recording Data: The collected data were recorded for further analysis. The patients were then taken back to their wards. The next day morning on the day of surgery the patients were shifted to their respective operating rooms and the standard general anaesthesia procedure was performed as per the discretion of the attending anaesthesiologist. The following were kept ready.

- Anaesthesia machine and circuits checked,
- Endotracheal tubes → cuffed portex tubes of appropriate size and one size lower than required.
- Macintosh laryngoscope → with medium and large sized blade
- Airway : oral and Nasopharyngeal airway
- Laryngeal mask airway of appropriate size

- Functioning suction apparatus
- Malleable stylet / Magill's forceps.
- Monitors → ECG Monitor and Pulse oximeter, sphygmomanometer
- Emergency drugs → Atropine, Adrenaline, Dopamine, Lignocaine 2% and 4%.

In case of anticipated difficulty in intubation, fiberoptic equipment was kept ready.

The following standardization measures were taken before obtaining Cormack Lehane grading.

- The attending anaesthesiologist had an experience in the field of anaesthesiology for at least a minimum of 5 years.
- All patients were connected to monitors - ECG, NIBP and PULSE OXIMETER and any additional monitors required as per the type of surgical procedure were kept ready.
- All patients were premedicated, preoxygenated, induced and paralysed using drugs according to the choice of the attending anaesthesiologist before intubation.
- A macintosh blade size 3 was used for laryngoscopy.
- The anaesthesiologists were asked to grade the vocal cord view as per Cormack Lehane grading. The best view obtained at the first attempt by the laryngoscopy without any external manoeuvre were applied was taken as the Cormack Lehane classification.

The surgery was carried out and after surgery was over the patients were reversed and extubated. They were observed for half an hour post operatively for full recovery and then the patients were shifted to the postoperative wards for further management.

Based on the Cormack Lehane (CL) class noted, patients were grouped into two groups.

- **Group 1:** Easy laryngoscopy group (CL 1 and CL 2)
- **Group 2:** Difficult laryngoscopy group (CL 3 and CL4)

To allow for comparisons between the difficult airway and easy airway groups, a two-sided Student's t-test was employed as appropriate. For sub group analysis, the measurements obtained by ultrasonography at each level were divided into three subgroups and analyzed according to the percentage of cases falling into the Easy intubation group and difficult intubation group.

ROC curve analysis was made for all three levels for obtaining cut off points that delineates the Group E from Group D, and to assess for the sensitivity and specificity for each measured level.

Spearman's rank correlation co-efficient was used to analyze for any correlation between clinical screening tests and sonographic measurements.

Association between demographic variables and occurrence of difficult intubation was assessed using Pearson's chi square test. $p < 0.05$ was considered significant and $p > 0.05$ was not significant

Observations and Results

Primary outcome: Correlation between Cormack-Lehane classification and sonographic measurements of thickness of soft tissues in the anterior neck at three levels namely

a) Hyoid bone
b) Thyro-hyoid membrane (Epiglottis)
c) Suprasternal notch.

Secondary outcome: Correlation between sonographic measurements at the three levels and clinical airway screening. Of the 150 patients, 139 patients were classified into Group E and the rest 11 patients were classified in Group D. The observations and results were as follows.

There was no statistically significant difference in age, sex and height distribution.

Table 1: Weight Distribution

	N	Mean	Standard Deviation
Group E	139	59.15	7.019
Group D	11	72.82	6.306

Independent t test, P =0.000

Table 2: Thickness of Anterior Neck Soft Tissue from Skin to Hyoid Bone

	N	Mean	Standard Deviation
Group E	139	0.74	0.1233
Group D	11	0.88	0.1465

Independent t test P = 0.000

Table 3: Thickness of Anterior Neck Soft Tissue from Skin to Epiglottis at Thyrohyoid Membrane Level

	N	Mean	Standard Deviation
Group E	139	1.72	0.260
Group D	11	2.54	0.098

Independent t test, P = 0.000

Table 4: Thickness of Anterior Neck Soft Tissue from Skin to Tracheal Ring at Suprasternal Notch Level

	N	Mean	Standard Deviation
Group E	139	0.74	0.113
Group D	11	0.88	0.117

Independent t test, P = 0.000

The comparison of above mentioned characteristics showed statistically significant difference.

Sub Group Analysis

Table 5: Anterior Neck Soft Tissue Thickness from Skin to Hyoid Bone

	Group E		Group D	
	N	%	N	%
0.40-0.65 cms	34	24.5 %	0	0
0.66-0.90 cms	94	67.6%	6	54.5%
0.91-1.20 cms	11	7.9%	5	45.5%
Total	139		11	

Table 5: Thickness of Anterior Neck Soft Tissue from Skin to Epiglottis at Thyrohyoid Membrane Level

	Group E		Group D	
	N	%	N	%
1.30-1.80 cm	89	64.02	0	0
1.81-2.30 cm	50	35.97	0	0
2.31-2.70 cm	0	0	11	100
Total	139		11	

Table 6: Thickness of Anterior Neck Soft Tissue from Skin to Tracheal Ring at Suprasternal Notch Level

	Group E		Group D	
	N	%	N	%
0.40-0.65 cm	32	23%	0	0
0.66-0.90cm	103	74.1%	5	45.45%
0.91-1.20cm	4	2.9%	6	54.55%
Total	139		11	

1) Mallampatti's Classification Vs Ultrasound Assessment Using Chi Square Test:

Table 7: Hyoid Bone Level

		Mallampatti's No Of Cases		Total
		Easy	Difficult	
Hyoid Level No Of Cases	Easy	90	9	99
	Difficult	49	2	51
Total		139	11	150

Chi square test, P = 0.25

Table 8: Epiglottis Level

		Mallampatti's No Of Cases		Total
		Easy	Difficult	
Epiglottis Level No Of Cases	Easy	129	10	139
	Difficult	10	1	11
Total		139	11	150

Chi square test, P = 0.87

Table 9: Suprasternal Notch Level

		Mallampatti's No Of Cases		Total
		Easy	Difficult	
Suprasternal Notch Level No Of Cases	Easy	88	9	97
	Difficult	51	2	53
Total		139	11	150

Chi square test, P = 0.21

2) Interincisor Gap and Thyromental Distance Vs Ultrasound Assessment Using Spearman's Rank Correlation Coefficient:

Table 10: Spearman's Rank Correlation Coefficient

		Hyoid Level	Thyro Hyoid Membrane Level	Suprasternal Notch Level
Inter Incisor Gap	Correlation Coefficient	-0.202	-0.504	-0.254
	Significance	0.13	0.06	0.24
Thyro Mental Distance	Correlation Coefficient	-0.213	-0.263	-0.226
	Significance	0.09	0.07	0.06

Correlation is considered to be present if significance value is < 0.05

Discussion

Airway management remains one of the most important responsibilities of an anaesthetist. An anaesthesiologist is expected to maintain a person's airway patency in the setting of an emergency situation and also while providing anaesthesia in elective surgical situation. A patent airway means maintaining the ability of the person's lungs to provide oxygen to the tissues thereby preventing hypoxia and hypoxia related adverse effects [9].

Difficult airway is a situation in which gas exchange cannot be maintained through any one of the methods such as bag and mask ventilation, supraglottic airway devices or endotracheal intubation, thereby leading to respiratory related injuries. Difficult tracheal intubation accounts for 17% of the respiratory related injuries and results in significant morbidity and mortality [10]. The airway assessment begins with a through history regarding previous surgeries, intubations and trauma to head and neck regions that might indicate any chance of occurrence of difficulty in intubation. A through general physical examination and examination of airway reveals information that might help in predicting occurrence of difficult intubations.

In an attempt to avoid facing the situation of unanticipated difficult airway the anaesthetists developed the method of preoperative airway assessment. The assessment technique was first started in the year 1980s when Vijayalakshmi Patil MD [11] suggested that the measure of anatomical structures present in head and neck has a role in occurrence of difficult airway. Around the same period Seshagiri Rao Mallampatti MD [12] developed a hypothesis to predict difficult airway based on the structures that are visible in the oropharynx while the patient's mouth is wide open and tongue ids protruded out.

The next step in preoperative airway assessment was the development of grouped indices like Wilson's score, Lemon assessment, Arne's simplified score, etc. This was followed by radiographic predictors like X-ray neck in the lateral view to measure the C1 spine to occiput distance, length of the mandible and depth of mandibular space. During the past few years the field of anaesthesia has been gaining eyesight, with the aid of Ultrasonography [13]. Ultrasonography is a safe, non-invasive and a real time imaging tool, the utility of which is being studied in recent years by anaesthesiologists in various aspects. Some of the uses of ultrasonography in the field of anaesthesiology are ultrasound guided peripheral nerve blocks, vascular cannulations, regional anaesthesia techniques, airway assessment, identification of lung and plural pathologies, etc.

In this study the usefulness of ultrasonography in predicting difficult airway is analyzed. The main problem that was encountered in the past using ultrasonography for airway assessment was the difficulty in visualizing the airway structures. The reason for this was that these structures were situated superficially and were filled with air that produced a high acoustic impedance and hence resulted in production of poor image quality.

The modern ultrasound machines are made such that they have a multiarray and variable frequency transducer with cross beam imaging facility and improved lateral and spatial resolutions, so that the images obtained are high quality [14].

Prasad et al [15] has studied the reliability of using ultrasonography for airway assessment. They have compared the airway measurements in supra hyoid region and infra hyoid region taken by Ultrasonography and Computed tomography. They concluded that the ultrasound measurements were comparable with those obtained from CT scan.

Vishwanath et al [16] conducted a prospective study with the aim of determining the usefulness of ultrasonography in assessment of difficult airway preoperatively to compare and correlate airway assessment done clinically and airway viewed ultrasonographically with Cormack–Lehane classification of the direct laryngoscopy. They concluded that by measuring the thickness of soft tissues in the anterior part of neck with ultrasound difficult airway can be predicted, thus ultrasound can be used for assessing difficult airway preoperatively. In our study, the mean and standard deviation of weight showed a significant difference among both the groups. This result is comparable with the study conducted by W.H.Kim [17] et al, a prospective observational study. It was concluded that obese patients had a difficult intubation.

Primary outcome measures that were assessed were the ability of the ultrasonography to identify the occurrence of difficult intubation. Ultrasound

measurements of anterior neck soft tissues were taken at three levels namely, Hyoid level, thyrohyoid membrane level and suprasternal notch level.

Our study results show that the intubation was difficult with increase in thickness of the anterior neck soft tissue at the three levels namely, skin to hyoid bone thickness, skin to epiglottis at the level of thyrohyoid membrane and skin to tracheal ring at the suprasternal notch level.

This result is comparable to the study by Srikar adikari et al [18]. In their study conducted in 50 patients, increased thickness of anterior neck soft tissue at the hyoid bone level and at the epiglottis at thyrohyoid membrane level was associated with increased difficulty in intubation.

The result also correlates with the study by Deepak [19] et al, where he used ultrasonography and obtained the depth of pre epiglottic space and found that there was a strong positive correlation between the Depth of Pre-epiglottic space and Cormack Lehane classification.

In the hyoid group level where anterior neck soft tissue thickness was measured from skin to hyoid bone, the observations suggest that this range has a significantly high percentage of detecting difficult intubation cases.

Similarly in the anterior neck soft tissue thickness from skin to epiglottis at thyrohyoid membrane level, the group was divided into three subgroups and the result showed that, the thickness range of 2.31 cms to 2.70 cms was able to identify all the 11 cases of difficult intubation. That is, it was able to detect 100% of the difficult intubation cases.

In the third group, that is, the anterior neck soft tissue thickness from skin to tracheal ring at the suprasternal notch level, the group was divided into three subgroups and the thickness range of 0.91cms to 1.20 cms was able to detect 2.9% of cases in Group E and 54.5% of cases in Group D. So in this level, this range can be taken as a cut off range for detecting difficult intubation.

So based on primary outcome analysis it was found that ultrasonography can be used as a safe, simple and a non-invasive tool in predicting difficult intubation pre-operatively by measuring the thickness of anterior neck soft tissues. Increased thickness of the soft tissues were associated with increased difficulty in intubation.

Based on the subgroup analysis it was found that even though ultrasonography measurements at all three levels as mentioned above were able to detect occurrence of difficult laryngoscopy, the percentage of casesdetected at the specified cut off range were not high at two of the levels (45.5% for hyoid bone level and 54.5% for suprasternal notch level). Whereas in the thyrohyoid membrane level, the specified range of 2.31 cms to 2.70 cms was able to detect all 100% of the cases. This suggests that the ability of the ultrasonographic measurement of anterior neck soft tissue thickness in predicting occurrence of difficult intubation was more accurate in the thyrohyoid membrane level.

Analysis of the secondary outcome for correlation between Clinical airway assessments (Mallampatti's test) by the Chi square test showed no significant correlation between ultrasonographic airway assessment made at the 3 levels and clinical airway assessment.

Analysis of the secondary outcome for correlation between Clinical airway assessment (Interincisor gap and Thyromental distance) by the Spearman's rank correlation coefficient showed no significant correlation between ultrasonographic airway assessment made at the 3 levels and clinical airway assessment.

Ezri et al [20] quantified the soft tissue of the neck from the skin to the anterior aspect of the trachea at the vocal cords using ultrasound in morbidly obese patients. They concluded that an abundance of pretracheal soft tissue at the level of the vocal cords is a good predictor of difficult laryngoscopy in obese patients.

From this it can be concluded that Ultrasonography can be used as an independent tool for assessing airway, which will be helpful in cases of emergency intubations and cases of cervical spine injuries requiring emergency intubation.

Conclusion

The prospective observational study conducted to assess the utility of ultrasonography in predicting difficult airway preoperatively concluded that Ultrasonography can be used to predict difficult airway preoperatively by measuring anterior neck soft tissue thickness. Increase in the anterior neck soft tissue thickness correlates with the increasing difficulty of intubation. There was no significant correlation between clinical airway assessment and ultrasound airway assessment.

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