Anatomical Features of the Neck as Predictive Markers of Difficult Laryngoscopy in Men and Women: A Prospective Study

Athul Vijayan[1], H, Baburaj. C[1], Divya Madhu[2]

Associate Professor of Anaesthesia
Assiatant Professor of Anaesthesia

Abstract: ***Background Difficult or failed airway management is the major factor in anesthesia related morbidity and death. Studies of anatomic variables and their implications for difficult airway management have shown that there is low sensitivity, specificity and positive predictive value for any single test, however, correlation is better with a combination of tests. Aim Aim is to evaluate four anatomic features of the neck, namely thyromental distance, sternomental distance, the ratio of height to thyromental distance and neck circumference which can be measured pre-operatively with minimal patient co-operation and to assess their diagnostic value in predicting difficult laryngoscopy Design Prospective observational study Setting Department of Anaesthesiology, Government Medical college, Thiruvananthapuram, Kerala, India, a tertiary care teaching hospital. Patients This study was conducted in 607 adult patients, scheduled for elective surgical procedures under general anesthesia with endotracheal intubation. Main outcome measures The outcome variable studied was difficult laryngoscopy, defined as Cormack-Lehane Grade 3&4 of laryngoscopic view Results The laryngoscopy was assessed as difficult in 109 (18.0%) of the studied patients. The diagnostic value of thyromental distance was found unsatisfactory in the present study. Analysis of data in the present study indicates that sternomental distance is of limited predictive accuracy when used alone. Ratio of height to thyromental distance had relatively good negative predictive value (87.1%) This study found the neck circumference to be the most sensitive and specific test in predicting difficult laryngoscopy among the tests studied. NC had highest sensitivity (72.5%) and specificity (74.1%) with a positive predictive value of 38.0% and negative predictive value of 92.5%. Analysis of data from the present study showed that NC can be used as sole predictor of difficult laryngoscopy in men and women.***

Keywords: Anatomical predictors, difficult airway, difficult laryngoscopy, thyromental distance, sternomental distance, ratio of height to thyromental distance, neck circumference

1. Introduction

Competence in airway management is a critical skill for safely administering anesthesia. Difficult or failed airway management is the major factor in anesthesia related morbidity (dental damage, pulmonary aspiration, airway trauma, unanticipated tracheostomy, anoxic brain injury, cardiopulmonary arrest) and death[1]. Difficult tracheal intubation/ laryngoscopy, defined as successful intubation requiring more than three attempts or taking longer than 10 minutes, occurs in 1.1% to 8.5 % of patients[2, 3, 4, 5]. Failed tracheal intubation occurs at an incidence of 0.01% to 0.03%[2, 3, 6].

Competence in airway management requires 1) knowledge of the anatomy and physiology of the airway 2) ability to assess the patient's airway for the anatomical features that correlate with difficult airway management.3) skill with the many devices for airway management.4) appropriate application of the American Society of Anesthesiologists (ASA) algorithm for difficult airway management.

The difficulty of laryngoscopy and intubation has been strongly linked with the inability to visualize the glotticopening as Grade 3 or 4 of Cormack-Lehane classification of laryngoscopic view[7.] In a meta-analysis of Shiga et al. with 35 studies including a total of 50760 patients without any obvious airway pathology, the incidence of difficult intubation was 5.8% for the overall patient population[4].

Studies of anatomic variables and their implications for difficult airway management have shown that there is low sensitivity, specificity and positive predictive value for any single test[8], however, correlation is better with a combination of tests[4, 5]. This study was designed with the aim to measure four anatomical variables of the neck namely, thyromental distance (TMD), sternomental distance (STMD), the ratio of the height to thyromental distance (RHTMD) and neck circumference (NC)), which can be measured preoperatively with minimal patient co-operation and to assess their diagnostic value in predicting difficult laryngoscopy in our population.

Aim and Objectives

AIM: To evaluate four anatomic features of the neck, namely thyromental distance (TMD), sternomental distance (STMD), the ratio of height to thyromental distance (RHTMD) and neck circumference (NC), which can be measured pre-operatively with minimal patient co-operation and to assess their diagnostic value in predicting difficult laryngoscopy

Objectives:

1) To find the proportion of patients having difficult laryngoscopy
2) To compare anatomical features in patients having easy versus difficult laryngoscopy
3) To develop a predictive model for difficult laryngoscopy based on anatomical features

2. Review of Literature

Review of Anatomy: Anatomy of the Upper Airway

A) Nose

The airway functionally begins at the nares and mouth. Air is warmed and humidified as it passes through the nares during normal breathing. Resistance to airflow through the nasal passage is twice that through the mouth and accounts for approximately two thirds of total airway resistance. In the adult human, the two nasal fossae extend 10 to 14 cm from the nostrils to the nasopharynx divided by a midline quadrilateral septem.

The nasal fossa is bounded laterally by inferior, middle and superior turbinate bones and divide the fossa into inferior, middle and superior meatus[9]. The arterial supply of the nasal cavity is mainly from the ethmoid branches of the ophthalmic artery, sphenopalatine and greater palatine branches of the maxillary artery, and superior labial and lateral nasal branches of the facial artery. Kiesselbach's plexus, formed by the anastomosis of these vessels is situated in Little's area on the antero-inferior portion of the nasal septum. The non olfactory sensory nerve supply to the nasal mucosa is derived from the trigeminal nerve and the parasympathetic autonomic nerves reach the mucosa via facial nerve after relay through sphenopalatine ganglion[10]. The sympathetic fibres are derived from plexus surrounding the internal carotid artery through the vidian nerve.

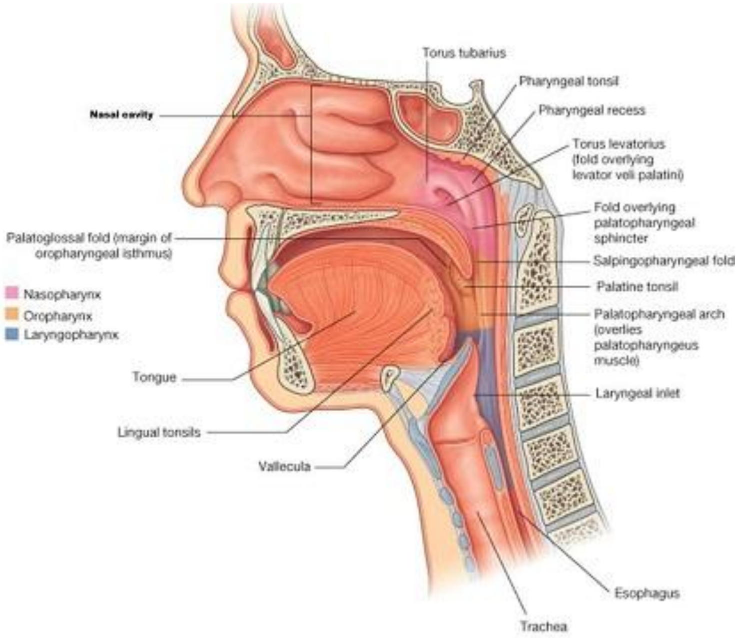

Figure 1: Lateral wall of right nasal cavity

B) PHARYNX

The nasal and oral cavities are connected to the larynx and esophagus by the pharynx. It is a 12 to 15 cm long musculofascial tube extending from the base of the skull to the level of cricoid cartilage anteriorly and the inferior border of sixth cervical vertebra posteriorly. It is widest at the level of the hyoid bone and narrowest at the level of the esophagus. The pharynx is further subdivided into the nasopharynx, oropharynx and hypopharynx[11]. The Eustachian tube opens into the lateral walls of the of the nasopharynx. The tonsilar pillars of the fauces are situated in the lateral walls of the oropharynx. The wall of the pharynx is composed of the external and internal layers of muscles and each layer is composed of three paired muscles, the stylopharyngeus, the salpingopharyngeus and the palatopharyngeus. They elevate the pharynx and shorten the larynx during deglutition. The superior, middle and the inferior constrictors form the external layer and they advance the food from the oropharynx to the esophagus.

The constrictors are innervated by the pharyngeal plexus, formed from the sensory and motor branches of the vagus, the glossopharyngeal and the external branch of the superior laryngeal nerve. The Waldeyer's ring consists of masses of circularly arrayed lymphoid tissue located at the entrance to the respiratory and alimentary tract.

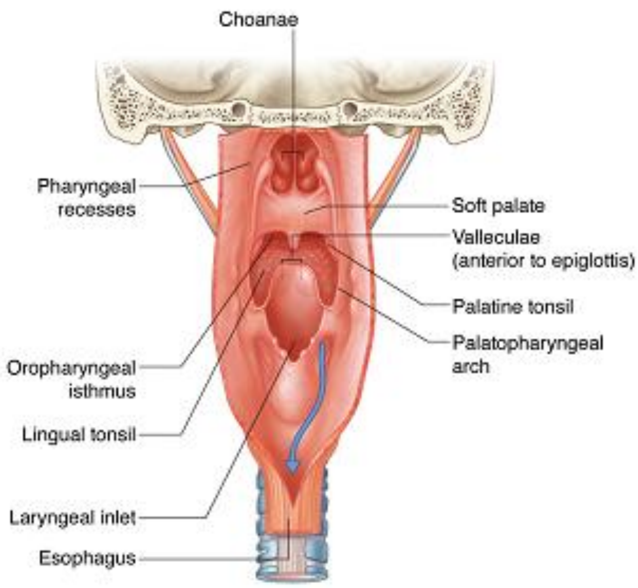

Figure 2: The pharyngeal wall

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C) LARYNX

The adult larynx is between the third and the sixth cervical vertebrae[12]. It is made up of cartilages forming the skeletal framework, ligaments, membranes and muscles. The larynx separates the esophagus from trachea during swallowing. The laryngeal inlet is bounded anteriorly by the upper edge of the epiglottis, posteriorly by a fold of mucous membrane stretched between the two arytenoids cartilages and laterally by the aryepiglottic folds.

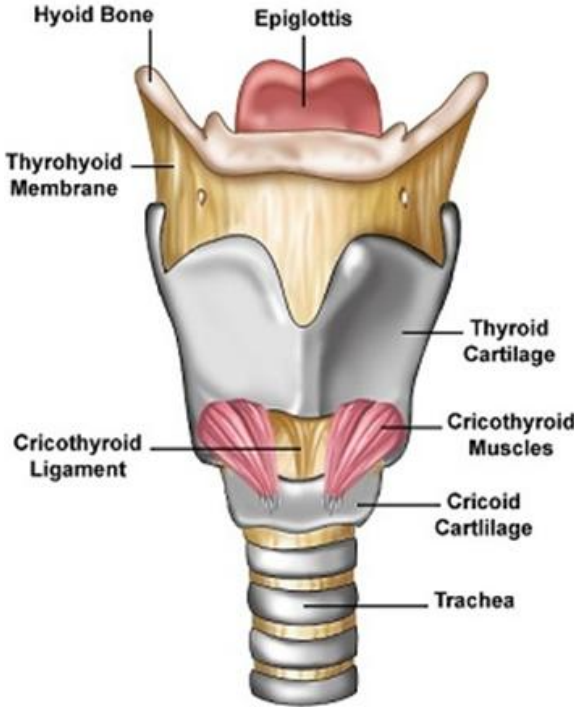

Figure 3: The Larynx

1) Bones of the larynx

The hyoid bone suspends and anchors the larynx during respiratory and phonatory movement. It is U shaped with a body and greater and lesser horns (cornu). It is attached to the styloid process of the temporal bone by the stylohyoid ligament and to the thyroid cartilage by thyrohyoid membrane. The intrinsic tongue muscles originate on the hyoid and the pharyngeal constrictors are attached to it.1[3, 14]

2) Cartilages of the larynx

Nine cartilages provide the framework of the larynx. These are the unpaired thyroid, cricoid and epiglottis and the paired arytenoids, corniculates and cuneiforms. They are connected and supported by membranes, synovial joints and ligaments. The ligaments when covered by mucous membranes are called folds.

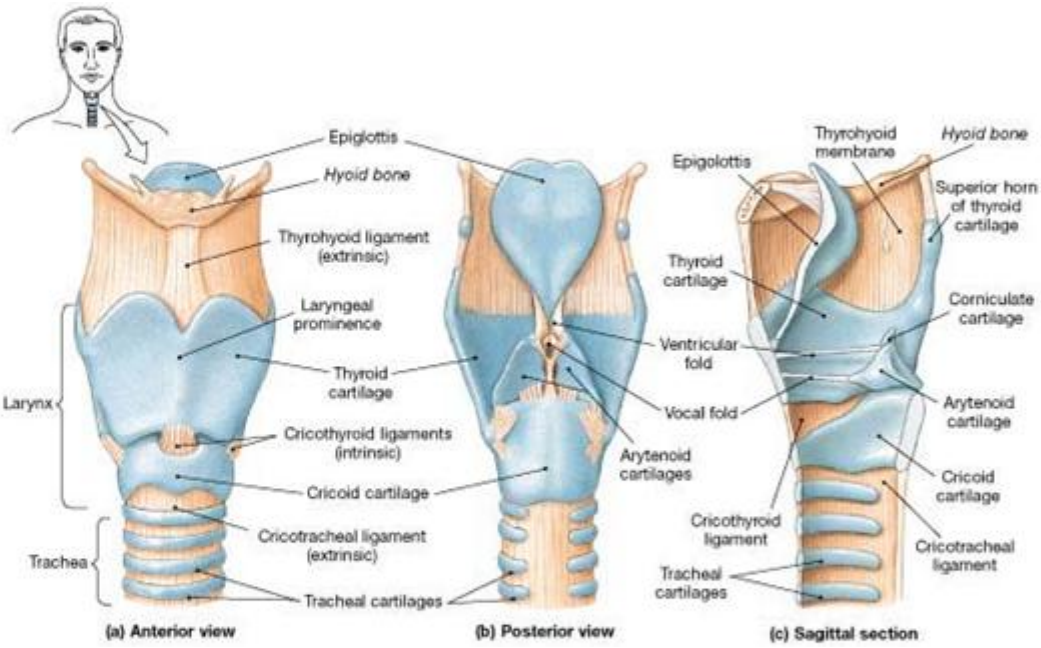

Figure 4: Cartilages of the larynx

a) Thyroid cartilage

It is the longest laryngeal cartilage and largest structure in the larynx. It is shaped shield like and is formed from the embryonic midline fusion of two distinct quadrilateral laminae. The thyroid notch lies in the midline at the top of the fusion site of the two laminae and the vestibular ligaments are attached on the inner side of this fusion line. The greater and lesser cornu of the thyroid are posteriorly directed extension of the edges of the laminae. The lateral thyrohyoid ligament attaches the superior cornu to the hyoid bone and the cricoid cartilage articulate with the inferior cornu at the cricohyoid joint[15]

b) Cricoid cartilage

The cricoid cartilage represents the anatomical lower limit of the larynx and helps support it. It is the only complete cartilaginous ring in the airway. It is signet ring shaped and the bulky portion or laminae are located posteriorly. The cricoid lamina has synovial articulations with arytenoids postero-superiorly and the thyroid cartilage more inferolaterally and anteriorly.1[6] The cricothyroid membrane attaches cricoid to the thyroid cartilage

c) Arytenoids

The two arytenoids cartilages are shaped like three sided pyramids and lie in the posterior aspect of the larynx. The base of the arytenoids articulates with the posterior lamina of the cricoid. This joint is ball and socket type with rotating, gliding and pivoting movements controlling adduction and abduction of the vocal cords. The lateral and posterior cricoarytenoid muscles originate from the arytenoids base. The vocal ligaments and the bases of the true vocal folds extend from the vocal process of the arytenoids to the inner surface of the thyroid lamina

d) Epiglottis

Epiglottis is composed primarily of fibroelastic cartilage. It is shaped like a leaf and is found between the larynx and the base of the tongue. The upper border of the epiglottis is attached to the midline of the thyroid cartilage by thyroepiglottic ligament. The hyoepiglottic ligament connects the epiglottis to the hyoid bone. The mucous membrane covering the anterior aspect of epiglottis sweeps forward as the median glossoepiglottic fold and to the pharynx as the paired lateral epiglottic folds[17]. The pouches like area between the median and lateral folds are the valleculae.

e) Cuneiform and corniculate cartilages

The epiglottis is connected to the arytenoid cartilage by the laterally placed aryepiglottic ligaments and folds. The sesamoid cuneiform cartilage is roughly cylindrical and liesanterosuperior to the corniculate in the fold. The corniculate is a small triangular object visible directly over the arytenoid cartilage.

f) Vocal cords

The vocal cords are formed by the thyroarytenoid ligaments and are the narrowest portion of the adult airway. The antero-posterior dimension of the vocal cord is approximately 23 mm in males and 17 mm in females. The vocal cords run between the vocal process of the arytenoid cartilage and the posterior surface of the thyroid cartilage.

g) Laryngeal cavity

The laryngeal cavity extends from the laryngeal inlet to the lower border of the cricoid cartilage. The area extending from the laryngeal inlet to the vestibular folds is known as the vestibule or supraglottic larynx. The laryngeal space from the free border of the cords to the cricoids cartilage is called the sub glottic larynx.

3) Muscles of the Larynx

They are divided in to extrinsic and intrinsic groups. The extrinsic group connects the larynx with its anatomic neighbours and the intrinsic group facilitates the movements of the laryngeal cartilage.

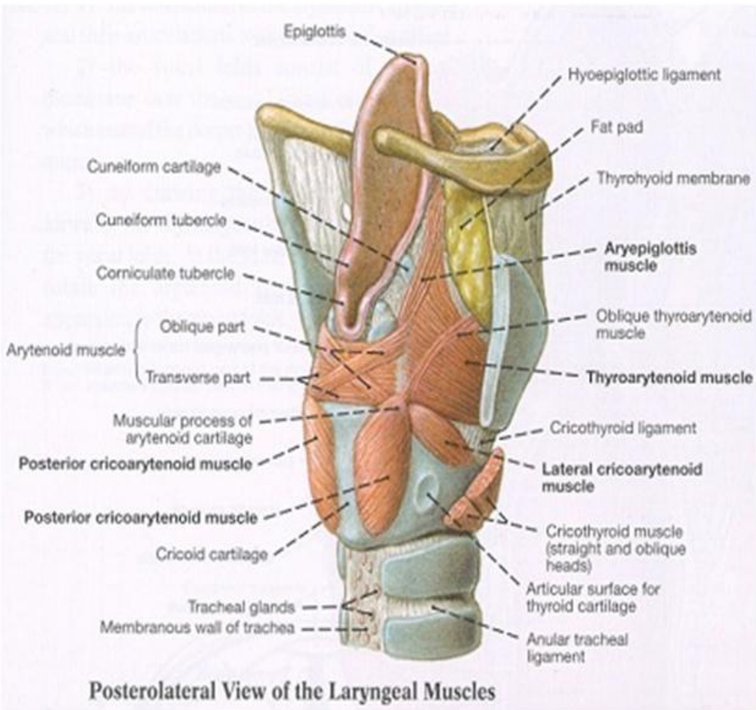

Figure 5: Posterolateral view of laryngeal muscles

Table 1: Extrinsic Muscles of the Larynx

Muscle	Function	Innervation
Sternohyoid	Indirect depressor of the larynx	Cervical plexus Ansahypoglossi C1 C2 C3
Sternothyroid	Depresses the larynx Modifies thyrohyoid and aryepiglottic folds	Cervical plexus Ansahypoglossi C1 C2 C3
Thyrohyoid	Depresses the larynx Modifies thyrohyoid and aryepiglottic folds	Cervical plexes Hpoglossal Nerve C1, C2
Thyroepiglottic	Mucosal inversion of aryepiglottic folds	Recurrent Laryngeal Nerve
Stylopharyngeus	Assists folding of thyroid cartilage	Glossopharyngeal
Inferior Pharyngeal Constrictor	Assists in Swallowing	Vagus Pharyngeal Plexes

Table 2: Intrinsic Musculature of the Larynx

Muscle	Function	Innervation
Posterior cricoarytenoid	Abductor of vocal cords	Recurrent laryngeal
Lateral cricoarytenoid	Adducts arytenoids closing glottis	Recurrent laryngeal
	Adducts arytenoids	Recurrent laryngeal
Oblique arytenoid	Closes glottis	Recurrent laryngeal
Aryepiglottic	Closes glottis	Recurrent laryngeal
Vocalis	Relaxes the cords	Recurrent laryngeal
Thyroarytenooid	Relaxes-tension cords	Recurrent laryngeal
Cricothyroid	Tensor of cords	Superior laryngeal (external branch)

4) Innervation of the Larynx

The main nerves of the larynx are the recurrent laryngeal nerves and the internal and external branches of the superior laryngeal nerves. The external branches of the superior laryngeal nerve supplies motor innervations to the cricothyroid muscle. All other motor supply to the laryngeal musculature is provided by the recurrent laryngeal nerve. Both superior and recurrent laryngeal nerves are derivatives of vagus nerve. The sensory innervations of the larynx are also carried by the superior laryngeal nerve and recurrent laryngeal nerves.

Table 3: Motor and Sensory Innervation of the Larynx

Nerve	Sensory	Motor
Superior laryngeal (inferior division)	Epiglottis Base of tongue Supraglottic mucosa Thyroepiglottic joint Cricothyroid joint	None
Superior laryngeal (external division)	Anterior subglottic mucosa	Cricothyroid muscle
Recurrent laryngeal	Subglottic mucosa Muscle spindles	Thyroarytenoid Posterior cricoarytenoid Lateral cricoarytenoid Oblique arytenoids Aryepiglottic Vocalis

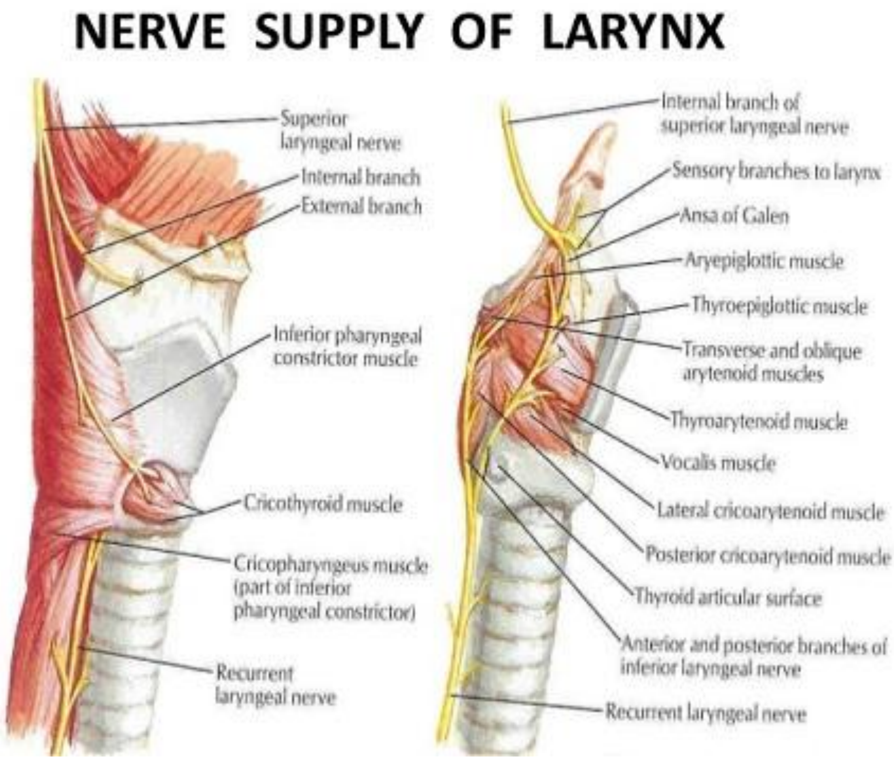

Figure 6: Nerve supply of larynx

5) Blood supply of the larynx

Blood supply to the larynx derived from the external carotid and subclavian arteries. The external carotid give rise to the superior thyroid artery, which bifurcates forming the superior thyroid artery, whichagain bifurcates forming the superior laryngeal artery and supply the supraglottic region. The inferior thyroid artery, derived from the thyrocervical trunk terminates as inferior laryngeal artery and supply the infraglottic larynx.

Physiology and Pathophysiology of the Upper Airway

Upper Airway Obstruction

In an awake patient, airway patency is maintained by muscle tone in the head and neck, particularly the pharynx and tongue. As consciousness is lost and muscle tone decreased, the soft palate, epiglottis and tongue fall backward under the influence of gravity in a supine patient and obstruct the airway. Head extension and jaw thrust can be applied to relieve airway obstruction to a variable extent. The lateral position alternatively or in addition to head extension and jaw thrust may be used to allow the obstructing tissue to move downward to relieve obstruction[18]. The dynamic collapse of pharynx between the intervening nasopharynx and larynx, make the airflow through the collapsible segment depend on the intraluminal pressure gradient and leads to an additional dynamic component of upper airway obstruction[19].

Laryngospasm

Laryngospasm is defined as the reflex closure of the true vocal cords alone or with the false cords because of stimulation of the intrinsic laryngeal muscles. Laryngospasm can result from a combination of reflex hyperactivity at an intermediate depth of anesthesia and noxious distant surgical and local stimulus.

Difficult Laryngoscopy and Cormack-Lehane Grading

The ease or difficulty of tracheal intubation is made according to the four grades of laryngoscopic view[7] of laryngeal aperture

Table 5: Cormack-Lehane Grades of Laryngoscopic view

Cormack-Lehane Grade	Visualized oral anatomy	Potential intubation implications
1	Entire glottis opening from anterior to posterior commissure	Should facilitate an easy intubation
2	Just the posterior portion of glottis	Normally not difficult to pass a styleted tracheal tube through the laryngeal aperture
3a	Epiglottis only (epiglottis can be lifted using a laryngoscopic blade)	Intubation is difficult, but possible using an EschmannBougie introducer or flexible fiberoptic scope
3b	Epiglottis only (but epiglottis cannot be lifted from the posterior pharynx using a laryngoscopic blade)	Intubation can be difficult, because insertion of an EschmannBougie introducer may be impeded. Successful intubation can be accomplished with optical stylet or a flexible fiberoptic scope
4	Only soft tissue with no identifiable airway anatomy	Difficult intubation, requiring advanced techniques to intubate the trachea

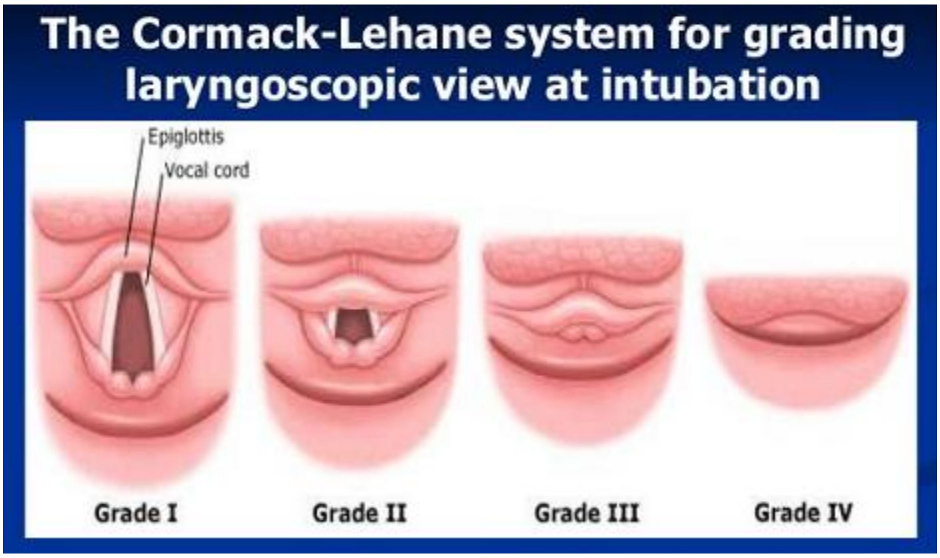

Figure 7: Comack-Lehanelaryngoscopic view

Difficult Intubation

Difficult intubation is defined as successful tracheal intubation requiring more than three attempts or taking longer than 10 minutes by a conventionally trained anesthesiologist [1, 2].

Difficult Mask Ventilation

Difficult mask ventilation is defined as the inability of an unassisted anesthesiologist to maintain the measured oxygen saturation as measured by pulse oximetry> 92% or to prevent or reverse signs of inadequate ventilation during positive-pressure mask ventilation under general anesthesia[20.]

Airway Assessment

The purpose of airway assessment is to identify possible difficulty with direct laryngoscopy and tracheal intubation, mask ventilation or creation of surgical (percutaneous) airway.

A) History

Assessment of difficult airway begins with a comprehensive history and physical examination to determine whether there are any medical, surgical, or anesthetic factors that have implications for airway management. Patients who have had a previous problem with airway management should have been informed of the problem, the apparent reason for the difficulty, how tracheal intubation was accomplished and the implication for future anesthetics. The previous anesthetic record should contain a description of the airway difficulties, what airway management techniques were used and whether they were successful[1.] A history of previous airway difficulty has a higher positive predictive value and lower negative predictive value than any tests[21]. However, a history of previous easy laryngoscopy does not guarantee straight forward easy intubation as increased age or pathology may result in increased difficulty. Patients with a history of difficult airway management can be registered with Medic-Alert system, which allows a 24 hour access to the pertinent information. Various congenital and acquired disease states have a correlation with difficult airway management (Table 4).

Table 4: Congenital and acquired disease states associated with difficult airway

Congenital syndromes associated with Difficult Endotracheal Intubation	
Syndrome	Description
Trisomy 21	Large tongue, small mouth make laryngoscopy difficult Small subglottic diameter possible Laryngospasm is common
Goldenhar (oculoauriculovertebral anomalies)	Mandibular hypoplasia and cervical spine abnormality make laryngoscopy difficult
Klippel – Feil	Neck rigidity because of cervical vertebral fusion
Pierre Robin	Small mouth, Large tongue, mandibular anomaly
Treacher Collins (mandibular dysostosis)	Laryngoscopy is difficult
Turner	High likelihood of difficult tracheal intubation

Pathologic states that influence airway management	
Pathologic state	Difficulty
Epiglottitis (infectious)	Laryngoscopy may worsen obstruction
Abscess (submandibular, retropharyngeal, Ludwig's angina)	Distortion of the airway renders facemask ventilation or tracheal intubation extremely difficult
Croup, bronchitis, pneumonia	Airway irritability with a tendency for cough, laryngospasm, bronchospasm
Papillomatosis	Airway obstruction
Tetanus	Trismus renders oral tracheal intubation impossible
Traumatic foreign body	Airway obstruction

Cervical spine injury	Neck manipulation may traumatize the spinal cord
Basilar skull fracture	Nasotracheal intubation attempts may result in intracranial tube placement
Maxillary or mandibular injury	Airway way obstruction, difficult facemask ventilation and tracheal intubation. Cricothyroidotomy may be necessary with combined injuries
Laryngeal fracture	Airway obstruction may worsen during instrumentation. Endotracheal tube may be misplaced outside the larynx and worsen the injury
Laryngeal edema (after intubation)	Irritable airway. Narrowed laryngeal inlet
Soft tissue neck injury (edema, bleeding, subcutaneous emphysema)	Anatomic distortion of upper airway Airway obstruction
Neoplastic upper airway tumors (pharynx, larynx)	Inspiratory obstruction with spontaneous ventilation
Lower airway tumors (trachea, bronchi, mediastinum)	Airway obstruction may not be relieved by tracheal intubation. Lower airway is distorted
Radiation therapy	Fibrosis may distort the airway or make manipulation difficult
Inflammatory rheumatoid arthritis	Mandibular hypoplasia, temporomandibular joint arthritis, immobile cervical vertebrae, laryngeal rotation and cricoarytenoid arthritis make tracheal intubation difficult
Ankylosing spondylitis	Fusion of the cervical spine may render direct laryngoscopy impossible
Temporomandibular joint syndrome	Severe impairment of mouth opening
Scleroderma	Tight skin and temporomandibular joint involvement make mouth opening difficult
Sarcoidosis	Airway obstruction (lymphoid tissue)
Angioedema	Obstructive swelling renders ventilation and tracheal intubation difficult
Endocrine or metabolic acromegaly	Large tongue, bony overgrowth
Diabetes mellitus	May have decreased mobility of the atlanto-occipital jonit
Hypothyroidism	Large tongue and abnormal soft tissue (mixedema) make ventilation tracheal intubation difficult
Thyromegaly	Goiter may produce extrinsic airway compression or deviation
Obesity	Upper airway obstruction with loss of consciousness. tissue mass makes successful facemask ventilation difficult

B) Tests of Airway Difficulty

Airway tests to detect difficulty with direct laryngoscopy are based on anatomical features and values have been selected as probable indicators of difficulty. Studies of anatomical variables and their implications for difficult airway management have shown that there is low sensitivity, specificity and positive predictive value for any single test, however, correlation is better with a combination of tests. These tests are based on examination of the oropharyngeal space, neck mobility, submandibular space and submandibular compliance.

1) Mouth Opening

Mouth opening is measured as the interincisor distance and a value of less than 3 to 4.5 cm correlates with difficulty achieving a line of view on direct laryngoscopy[5, 21, 22]and an interincisor gap of less than one finger breadth or 1.5 cm will impair insertion of an LMA and laryngoscope. The interincisor distance (IID) by itself is not a reliable predictor of difficult tracheal intubation[24].

Figure 8: Interincisor distance

2) Jaw Protrusion or Mandibular Protrusion Test

The ability to slide lower incisors in front of the upper ones may be classified as A, B and C.

Class A: Lower incisors can be protruded anterior to the upper incisors

Class B: Lower incisors can be brought edge to edge with the upper incisors

Class C: Lower incisors cannot be brought edge to edge with the upper incisors

Based on the classification class C protrusion is associated with difficult laryngoscopy and difficult mask ventilation, whereas class A protrusion rarely produces any difficulty[23, 25].

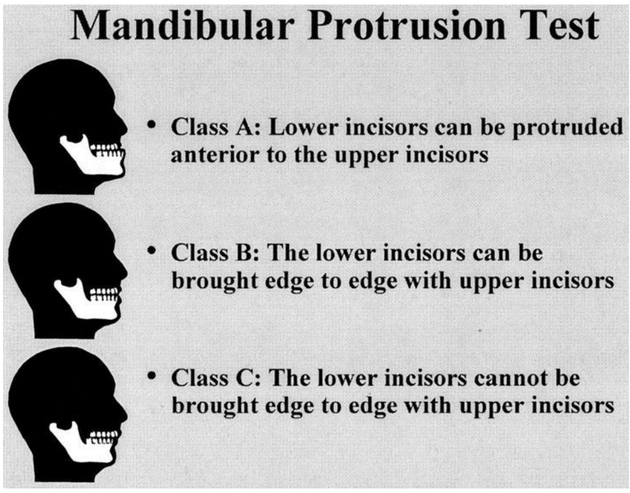

Figure 9: Mandibular protrusion test

3) Upper Lip Bite Test (ULBT)

The upper lip bite test assesses the degree to which the lower incisors can advance over the upper lip and includes three classes (figure)

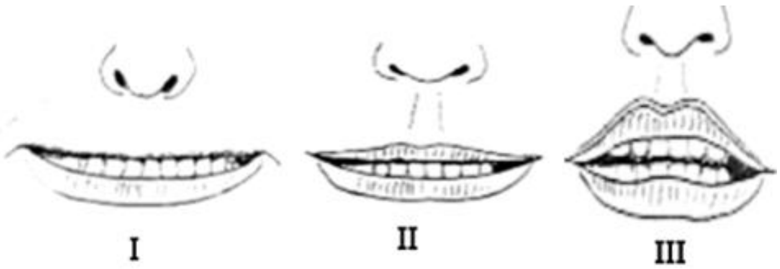

Figure 10: Upper lip bite test

Class A: The lower incisors can bite upper lip above vermilion line
Class B: Lower incisors can bite upper lip below vermilion line
Class C: Lower incisors cannot bite upper lip

The upper lip bite test has the ability to assess jaw protrusion movement and protruding incisors simultaneously. Use of upper lip bite test in conjunction with other tests predict ease of laryngoscopy and tracheal intubation[5].

4) MODIFIED MALLAMPATI TEST

Mallampati hypothesized that when the base of the tongue is disproportionately large in relation to oropharyngealcavity, the enlarged base of the tongue can obscure the visibility of the tosillar pillars and uvula resulting in difficult laryngoscopy and intubation[26]. Originally Mallampati described three classes; Samsoon and Young later modified the classification and added a fourth class [27]. Classification is assigned according to the extent the base of the tongue is able to mask the visibility of pharyngeal structures as

Class 1: Soft palate, uvula, fauces, and tonsillar pillars are visualized
Class 2: Soft palate, uvula and fauces seen-tonsillar pillars not visualized
Class 3: Only base of uvula visualized
Class 4: Uvula not visualized, no structures seen-only soft tissues

Figure 11: Modified Mallampati Test

The test is performed with patient in the sitting position, head in neutral position, the mouth wide open, and the tongue protruding to its maximum. Patient should not be encouraged to phonate as it can cause contraction of the soft palate leading to false positive results. To avoid false positive or false negative, the test should be repeated twice.

4) Atlanto-Occipital (AO) Joint Extension

The sniffing or Magill position is considered the optimal 'classical' position of the head and neck for facilitating tracheal intubation. The patient is asked to hold the head erect, face directly to the front, is asked to extend the head maximally, and examiner estimates the angle traversed by the occlusal surface of the upper teeth. Measurement can be simple visual estimate ormore accurately with a goniometer. The extension of the AO joint on the upper cervical spine allows the alignment of the three axes (oral, pharyngeal and laryngeal) into a straight line during laryngoscopy, enhancing the ease of laryngoscopy and tracheal intubation[28].

Any reduction in extension is expressed in grades

Grade 1: >35 degrees
Grade 2: 22 to 34 degrees
Grade 3: 12 to 21 degrees
Grade 4: <12 degrees

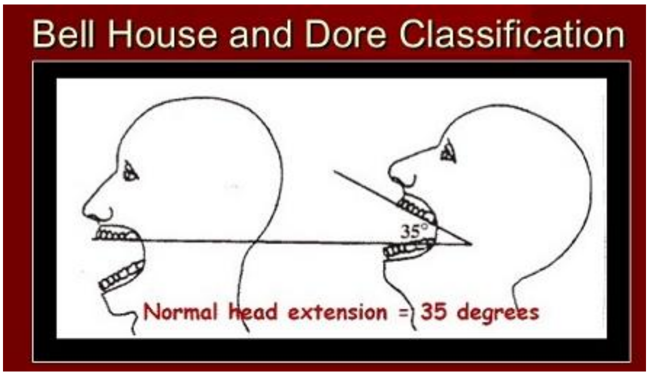

Figure 12: AO joint extension

6) Thyromental Distance (TMD) (Patil's test)

Thyromental distance is defined as the distance from the chin (mentum) to the top of the notch of the thyroid cartilage with the head fully extended and can be measured with a ruler for accuracy. The thyromental distance gives an estimate of the mandibular space and helps in determining how readily the laryngeal axis will align with the pharyngeal axis when atlanto-occipital joint is extended[29].

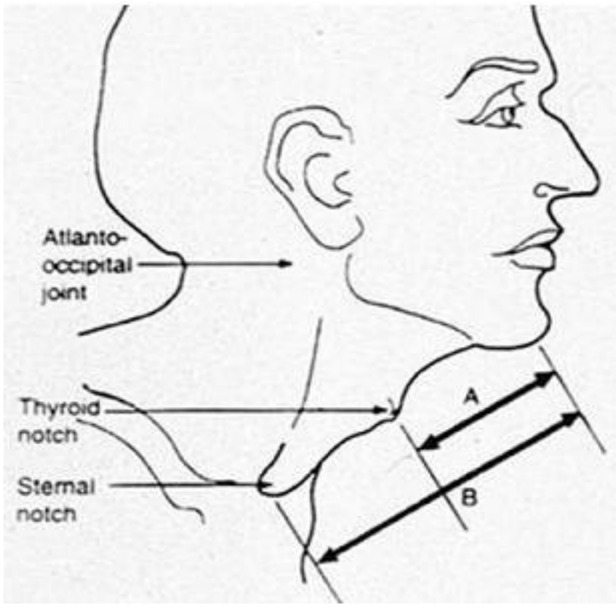

Figure 13: Thyromental Distance Measurement

TMD measurement of >6.5 cm: With no other abnormalities, indicates the like hood of easy intubation

TMD measurement of 6 to 6.5 cm: This indicates that the alignment of the pharyngeal and laryngeal axes isdifficult, thus resulting in difficulty with laryngoscopy and intubation. However intubation is possible with the use of adjuncts to intubation such as gum elastic bougie or optical stylet.

TMD measurement of <6cm: This indicates that laryngoscopy and specifically tracheal intubation may be impossible[30]. Typically seen in patients with receding mandible or short neck.

7) Sternomental Distance (STMD):

Sternomental distance is measured from the sternum to the tip of the mandible with the head fully extended and mouth closed. The normal STMD measurement is 13.5 cm[24, 31].

Figure 14: Sternomental Distance

8) Mandibulo-Hyoid Distance

Measurement of the mandibular length from the chin (mentum) to hyoid should be at least 4 cm or 3 finger breadth[32.] if the vertical distance between the mandible and hyoid bone is increased, it might pose a problem with difficult laryngoscopy.

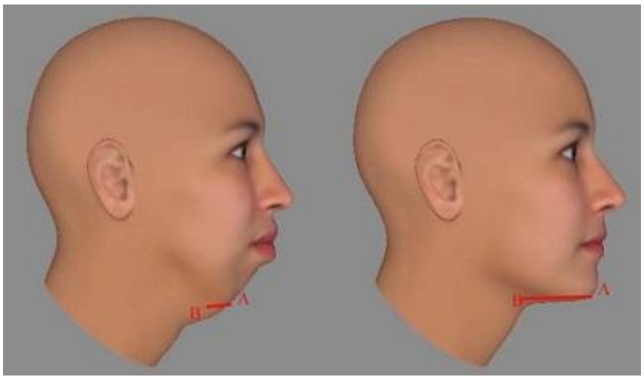

Figure 15: Mandibulohyoid distance

9) Neck Circumference (NC)

The neck circumference measured at the level of thyroid cartilage with the head in neutral position[33] (Fig: 16). Neck circumference over 43 cm independently correlate with difficult laryngoscopy and intubation[34].

Figure 16: Measurement of neck circumference

3. Review of Previous Studies

Tracheal intubation is difficult in 1-4% of patients with seemingly normal airway[35]. Numerous investigators have attempted to predict the difficult airway by using simple bedside physical examination and there are many publications using univariate or multivariate predictors of difficult laryngoscopy and intubation. Yentis describes the problem with many studies[36] in achieving a high positive predictive value because of the rarity of difficult intubation.

In an observational study of 22, 660 attempts at mask ventilation by Kheterpal S *et al.* the criteria that correlated with difficult mask ventilation and difficult intubation included independent risk factors such as limited mandibular protrusion, a history of sleep apnea, a history of snoring and a BMI of 30Kg/m^2 or greater[37.] This study supported and was able to demonstrate the value of mandibular protrusion test in predicting difficult mask ventilation and DI as suggested by Takenaka*et al.2*[3]

Savva *et al.* found that the Interincisor distance was not a useful independent test in identifying difficult tracheal intubation[24]. In the Australian Critical Incident Monitoring study, the four variables associated with difficult intubation were limited mouth opening, obesity, limited neck extension and lack of a trained assistant[38].

Limited mouth opening along with limited jaw protrusion often ranks high in composite scores such as the Wilson Risk Sum[39] (weight, head and neck movement, interincisor gap, mandibular jaw protrusion, receding mandible, buck teeth) and the Arne Risk Index Scores[40] (history of DI, pathologies associated with DI, clinical symptoms, TMD < 6 cm, restricted head and neck movement, Mallampati scores 2 to 4, IID < 5 cm, jaw protrusion class B or C) to predict the ease or difficulty of tracheal intubation. The jaw protrusion test in obstetric patients, along with Wilson Risk Sum and Mallampati score showed high sensitivity, specificity and positive predictive value[41.]

Khan Z H *et al.* showed that Class 3 ULBT along with IID <4.5 cm, TMD < 6.5 cm and STMD < 13 cm were defined as predictors of difficult intubation[5.] Specificity and accuracy of the ULBT were significantly higher than TMD, STMD or IID individually. The combination of ULBT with STMD tests provided the highest sensitivity and the recommendation was to use ULBT in conjunction with other tests to more reliably predict ease of laryngoscopy or tracheal intubation.

The Mallampati classification has been used either as a single univariate predictor or as a part of multivariate analysis to predict difficult tracheal intubation. El-Ganzouri and colleagues [22] studied 10507cosecutive patients with respect to mouth opening, TMD, Mallampati classification, neck movement, ability to prognath, body weight and history of difficult tracheal intubation and concluded that improved risk sratification for difficult laryngoscopy can be obtained by use of a multivariate airway risk index with better accuracy compared to Mallampati classification alone. M Adamus *et al.*, in an observational study[42] including 1518 patients concluded that, the modified Mallampati test is of limited value in predicting difficult intubation when used alone and cannot be relied on.

A meta-analysis of bedside screening test performance conducted by Shiga *et al.* found the combination of Mallampati classification and TMD as the most useful bedside test for predicting difficult laryngoscopy and intubation[4]. Rocke*et al.* Used multivariate analysis to predict difficult intubation in obstetric patients and showed that a patient with Mallampati class 3 or 4 plus protruding incisors, short neck and receding mandible, the probability of difficult laryngoscopy was greater than 90%[43]. Calder *et al.*, hypothesized in an observational study in 20 volunteers[44], that cranio-cervical extension occurs during normal mouth opening. They demonstrated that patients with restricted cranio-cervical movement may have reduced mouth opening and contribute to difficulties with airway management.

Frerk C M, assessed modified Mallampati test and measurement of TMD in 244 patients and concluded that a patient with Mallampati class 3 or 4 and TMD < 7 cm is likely to prove difficult to intubate[30]. Savva*et al. e*valuated 355 consecutive patients using TMD, STMD, protrusion of mandible and IID[24]. The result of this study showed that STMD had a sensitivity of 82.4% and specificity of 88.6% and was the best predictor for difficult tracheal intubation amongst all other tests. Shiga *et al.* Suggested STMD as the best single test for ruling out difficult intubation[4].

Chou H C and Wu TL studied radiographically 11 patients in whom direct laryngoscopy proved difficult and 100 control subjects and found that the mandibulohyoid distance was substantially longer in patients whose trachea was difficult to intubate. They suggested that a relatively short mandibular ramus or a relatively caudal larynx may be unfavourable anatomic factors in difficult laryngoscopy[32].

Gonzalez *et al. s*tudied patients with a BMI below and above 30 Kg/m^2 and found that a neck circumference over 43 cm independently correlated with difficult intubation in both populations[34]. Brodsky *et al.* Studied patients with a BMI > 40 kg/m^2 and found that NC was a significant predictor of difficult intubation[33]. Liaskou Chara *et al. a*ssessed the predictive value of NC in a prospective open cohort study and found NC to be a relatively poor predictor of difficult laryngoscopy[45]. They postulated that gender specific cut off points should be used for NC to improve diagnostic accuracy.

4. Materials and Methods

Study Design: Prospective observational study
Study Setting: Department of Anaesthesiology, Govt. Medical college, Thiruvananthapuram

Study Population: All patients satisfying the inclusion and exclusion criteria, who give written informed consent to take part in the proposed study.

Inclusion Criteria: Patients above the age of 18 years belonging to ASA PS 1 and 2, scheduled for surgical procedures under general anaesthesia with tracheal intubation.

Exclusion Criteria: Patients with obvious airway malformations, patients who need rapid sequence induction/intubation under cricoid pressure like obstetric patients, patients who need awake intubation, cervical spine pathology requiring specific manipulations and patients with severe obesity (Body mass index (BMI) more than 35 Kg/m^2).

Data Collection Methods: Interview and observation
Statistical Tools: Semi structured questionnaire
Sample Size: Calculated from an earlier study[45] using the formula
$N=4pq \div L^2$
Where p = the proportion of patients having Cormack-Lehane Grade 3 / Grade 4
q = 1-p
L= permissible error in the estimation of p (taken as 20% of p)
From literature p= 0.13, q= 0.87, L = 20 × 0.13 ÷ 100 = 0.026, L^{2}= 0.000676
So, N= 4 × 0.13 × 0.8 ÷ 0.0007
= 0.4524 ÷ 0.0007
=607

Operational Definitions:
Difficult Laryngoscopy: Cormack-Lehanelaryngoscopic Grade3 or 4

Thyromental Distance (TMD):
The straight line distance in centimeters from the lower border of the thyroid notch to the bony point of the mentum with the head extended and mouth closed

Sternomental Distance (STMD):
The straight line distance in centimeters from the bony point of the mentum to the upper border of the manubrium sterni with the head extended and the mouth closed

The Ratio of the Height to Thyromental Distance (RHTMD):

Neck Circumference: The circumference of the neck at the level of the thyroid cartilage with the head in neutral position

Procedure
Institutional approval and ethical clearance were obtained and 607 patients scheduled for surgery under general anesthesia were enrolled prospectively. The population of patients belonged to Thiruvananthapuram and nearby areas of same ethnicity. Inclusion and exclusion criteria were satisfied in determining patient selection. Informed consent was obtained from each patient. Pre anesthetic evaluation and pre-operative preparation was done as per the institutional protocol. Demographic data including age, gender, height, TMD, STMD, RHTMD and NC were recorded. In the operating room standard monitoring was applied to every patient (electrocardiograph, pulse oximeter, non invasive blood pressure measurement and capnograph) and a vein catheter for fluid and drug administration. After pre-oxygenation with 100% oxygen for 3 minutes anaesthesia was induced with propofol 2.5 mg/Kg and Fentanyl 2µg /Kg followed by succinyl choline 2mg/Kg to fascilitate tracheal intubation (after 90 seconds) with the patient's head in "sniffing position". Direct laryngoscopy performed with a Macintosh blade by senior anaesthesiologists with not less than 7 years experience, not apprised of the pre-operative measurements. In the present study, in order to eliminate any bias from inter‑observer variability, a single investigator performed all the pre‑operative measurements. The size of the laryngoscopic blade was chosen according to the patient size (size 3 for medium and size 4 for large sized adults) and the anaesthelogist's clinical judgement. Larygoscopic view was classified according to the Cormack-Lehane grade. Difficult laryngoscopy is defined as the inadequate exposure of the glottis (Cormack-Lehane Grade 3 or 4) under direct laryngoscopy with a blade of appropriate length without any external pressure or other manoeuvre applied.

5. Observations and Results

This study was conducted in 607 adult patients, scheduled for elective surgical procedures under general anesthesia

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with endotracheal intubation. Descriptive statistical analysis was carried out for each study variable.

Demographic Data
The distribution of sample according to age and gender were as shown in Table: 6 and Fig: 17

Table 6: Distribution of sample according to age

Age	Frequency	Percent
21-30	139	22.9
31-40	143	23.6
41-50	158	26.0
51-60	110	18.1
61-70	57	9.4
Total	607	100.0

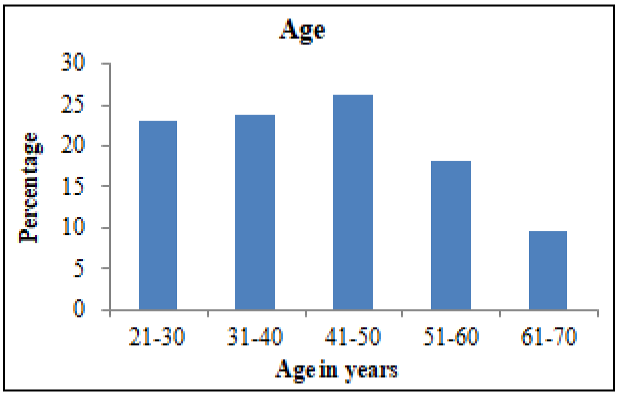

Figure 17: Histogram showing distribution of age in the whole population

Out of the 607 patients studied 48.4% were males and 51.6% females

Table 7: Distribution of sample according to age and gender

Age in years	Gender				Total	
	Male		Female			
	N	%	N	%	N	%
21-30	67	22.8	72	23.0	139	22.9
31-40	64	21.8	79	25.2	143	23.6
41-50	87	29.6	71	22.7	158	26.0
51-60	54	18.4	56	17.9	110	18.1
61-70	22	7.5	35	11.2	57	9.4
Total	294	100.0	313	100.0	607	100.0

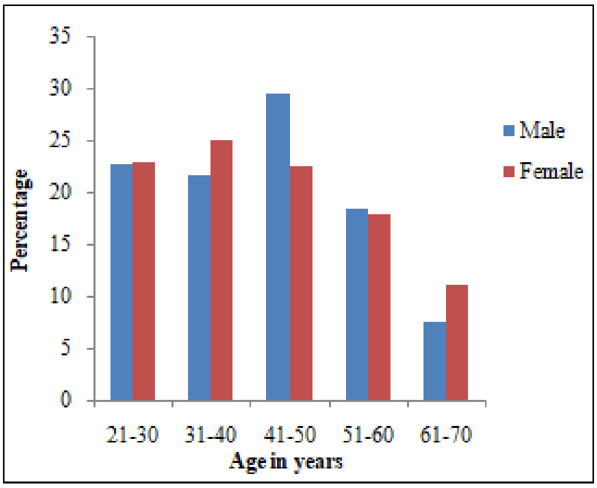

Figure 18: Histogram showing distribution of age in males and females

Study Variables:

Thyromental Distance (TMD)
The mean TMD of the population was 6.84 cm with a SD of 0.61. The maximum and minimum values of TMD were 8.25 and 5.50 respectively (table: 8)

Sternomental Distance (STMD)
The mean STMD of the population was 14.38 with a SD of 1.37 with maximum and minimum values 18.50 and 12.25 respectively (table: 8)

Ratio of Height to Thyromental Distance (RHTMD)
The mean RHTMD of the population was 23.69 and with a SD of 1.35 with maximum and minimum values of 28.18 and 20.26 (table: 8)

Neck Circumference (NC)
The mean NC of the population was found to be 40.26 with a SD of 2.27. the maximum value of NC was 47 cm and the minimum value 35 cm (table: 8)

Table 8: Descriptive statistics for the whole sample

	N	Mean	Median	SD	Minimum	Maximum
TMD	607	6.84	6.75	.61	5.50	8.25
STMD	607	14.38	14.00	1.37	12.25	18.50
RHTMD	607	23.69	23.45	1.35	20.26	28.18
NC	607	40.26	40.00	2.27	35.00	47.00

Outcome Variable
The outcome variable studied was difficult laryngoscopy, defined as Cormack-Lehane Grade 3&4 of laryngoscopic view, and was found in 18% of the total population under study

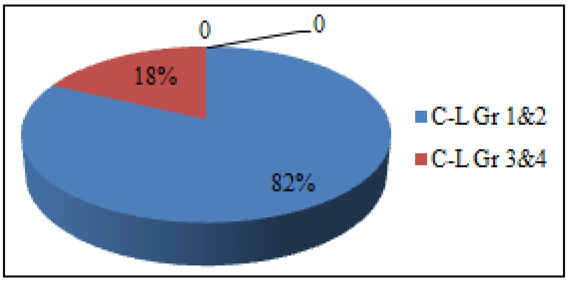

Figure 19: Pie chart representing the percentage of difficult laryngoscopy

Analysis of Association

The sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of each studied variable were calculated and Receiver Operating Characteristic (ROC) curves were used to identify the optimal cut-off point of each variable. The Area Under the Curve (AUC) was calculated to assess the prognostic accuracy of each variable in the whole sample as well as in men and women. Multivariate analysis with logistic regression, incorporating TMD, STMD, RHTMD and NC was used to create a model predicting difficult laryngoscopy

Thyromental Distance:
The mean TMD of the whole sample was 6.84 cm with a SD of 0.6 and statistical analysis using Chi-square test showed

no significant association with laryngoscopic grade (*p* value 0.26 table: 9)

Table 9: Descriptive statistics for TMD

C-L	N	TMD		F	p
		Mean	sd		
Grade 1	284	6.86	.60	1.343	.260
Grade 2	214	6.87	.63		
Grade 3	103	6.74	.59		
Grad 4	6	6.67	.70		
Total	607	6.84	.61		

The ROC curve of TMD drawn for the whole sample, in male gender and in female gender showed the optimal cut-off point to be <6.375, <7.125 and < 6.375 respectively (Fig: 20, 21, 22). The sensitivity, specificity, PPV and NPV of TMD in the whole sample for predicting difficult laryngoscopy were 37.6%, 73.7%, 23.8% and 84.4% respectively (table: 10). The sensitivity and specificity in men and women were 58.2%, 50.0% and 60.7%, 65.6% respectively. The PPV and NPV in men and women were 25.4%, 23.3% and 86.3%, 86.3% respectively. The Area Under the Curve in the whole sample and in men and women were 0.582, 0.584 and 0.613 (table: 11) showing no significant association in predicting difficult laryngoscopy

Table 10: Test result of each variable in the whole sample

	Cut off value	Sensitivity	Specifiicity	Positive predictive value	Negative predictive value
RHTMD	>23.54	62.4	55.8	23.6	87.1
NC	>41.5	72.5	74.1	38.0	92.5
TMD	<6.375	37.6	73.7	23.8	84.4
STMD	<13.375	34.9	76.7	24.7	84.3

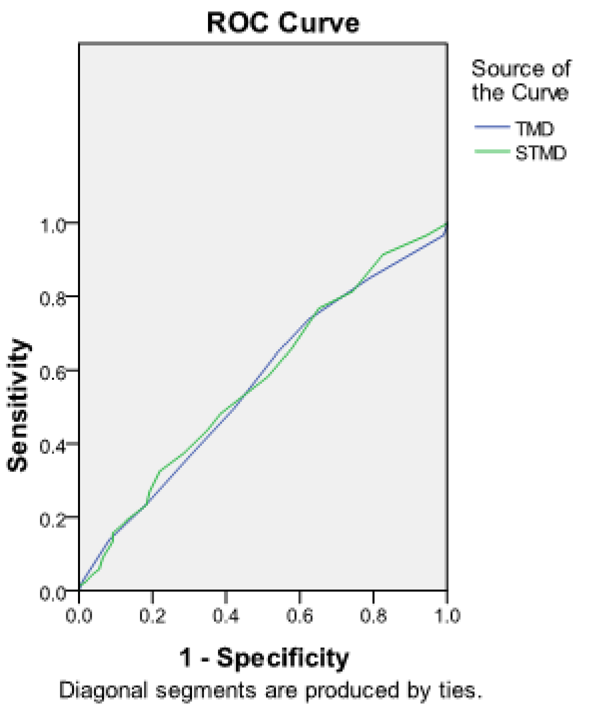

Figure 20: ROC curve of TMD and STMD of whole sample

Table 11: AUC for each variable in the whole sample

Test Result Variables	Area	se	p	Asymptotic 95% Confidence Interval	
				Lower Bound	Upper Bound
RHTMD	.582	.030	.007	.524	.640
NC	.790	.024	.000	.743	.838
TMD	.561	.030	.046	.502	.620
STMD	.570	.031	.022	.510	.630

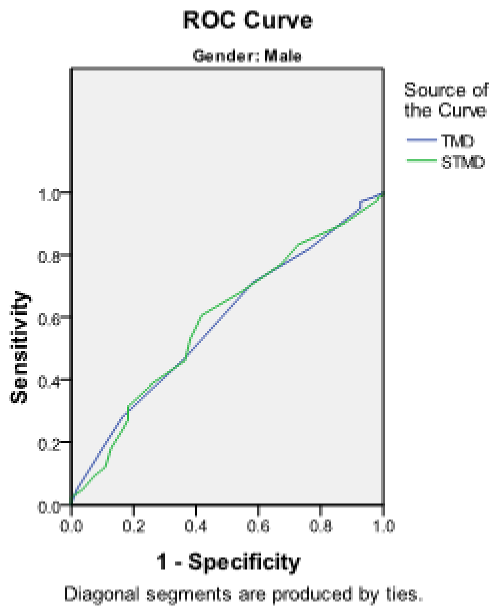

Figure 21: ROC curve of TMD and STMD in males

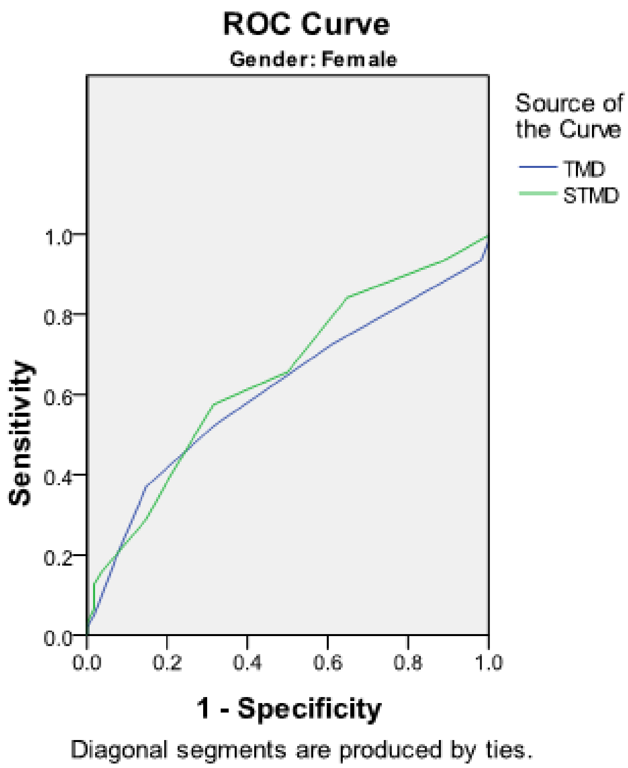

Figure 22: ROC curve of TMD and STMD in females

Table 12: AUC for each variable in men and women

Gender	Test Result Variable (s)	Area	Std. Error[a]	p	Asymptotic 95% Confidence Interval	
					Lower Bound	Upper Bound
Male	TMD	0.584	0.042	0.053	0.502	0.665
	STMD	0.588	0.043	0.041	0.505	0.672
	RHTMB	0.576	0.044	0.078	0.491	0.662
	NC	0.762	0.036	0	0.692	0.833
Female	TMD	0.613	0.038	0.009	0.539	0.687
	STMD	0.647	0.04	0.001	0.569	0.725
	RHTMB	0.595	0.038	0.028	0.52	0.67
	NC	0.817	0.033	0	0.752	0.881

Table 13: Test characteristic of each variable in men and women

		Cut off value	Sensitivity	Specificity	Positive predictive value	Negative predictive value
RHTMD	Male	>23.11	60.0	52.7	22.6	85.1
RHTMD	Female	>24.14	68.5	51.4	22.7	88.7
NC	Male	>41.5	72.7	72.0	37.4	92.0
NC	Female	>41.5	72.2	76.1	38.6	92.9
TMD	Male	<7.125	41.8	71.1	25.0	84.2
TMD	Female	<6.375	68.5	52.1	23.0	88.8
STMD	Male	<14.87	58.2	60.7	25.4	86.3
STMD	Female	<13.125	50.0	65.6	23.3	86.3

Sternomental Distance

The mean STMD of the whole population studied was 14.38 cm with a SD of 1.37 and statistical analysis using Chi-square test showed no significant association with laryngoscopic grade (*p* value 0.177 see Table: 14)

Table 14: Descriptive statistics for STMD

C-L	N	STMD		F	p
		Mean	sd		
Grade 1	284	14.46	1.34	1.65	0.177
Grade 2	214	14.41	1.43		
Grade 3	103	14.11	1.3		
Grad 4	6	14.38	1.73		
Total	607	14.38	1.37		

The ROC curve of STMD drawn for the whole sample, and in men and women (Fig: 20, 21, 22), showed the optimal cut-off point to be <13.375, < 14.87 and <13.125 respectively (table 10 & 13). The sensitivity, specificity, PPV and NPV in the whole sample were 34.9%, 76.7%, 24.7% and 84.3% respectively. The sensitivity and specificity in men and women were 58.2%, 50.0% and 60.7%, 65.6% respectively when studied separately. STMD had high PPV (86.3%) in both men and women. The AUC in the whole sample and in men and women were 0.570, 0.588 and 0.647 respectively showing no significant association in predicting difficult laryngoscopy (table: 11&12)

Ratio of Height to Thyromental Distance (RHTMD):

The mean RHTMD of the whole population studied was 23.69, with a SD of 1.35 and statistical analysis using Chi-square test showed no significant association with laryngoscopic grade (*p* value 0.099 see table: 15)

Table 15: Descriptive statistics for RHTMD

C-L	N	RHTMD		F	p
		Mean	sd		
Grade 1	284	23.61	1.33	2.104	0.099
Grade 2	214	23.64	1.41		
Grade 3	103	23.96	1.28		
Grad 4	6	24.19	1.47		
Total	607	23.69	1.35		

The ROC curve of RHTMD drawn for total population and in men and women (Fig: 23, 24, 25) showed the optimal cut-off point to be >23.5, >23.11 and >24.14 respectively. The sesitivity, specificity, PPV and NPV for RHTMD were 62.4%, 55.8%, 23.6% and 87.1% respectively (see table: 10). The sensitivity and specificity in men and women, when studied separately were 60%, 68.5% and 52.7%, 51.4% respectively. The PPV and NPV in men and women were 22.6%, 22.7% and 85.1%, 88.7% respectively (table: 13). The AUC in the whole sample and in men and women were 0.582, 0.576 and 0.595 respectively showing no significant association in predicting difficult laryngoscopy (table 11 & 12).

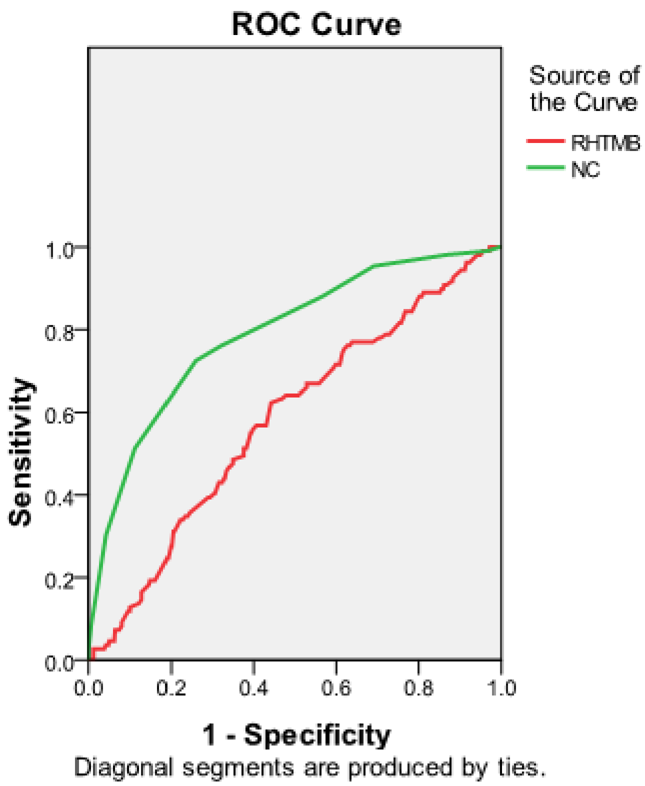

Figure 23: ROC curve of RHTMD and NC of whole sample

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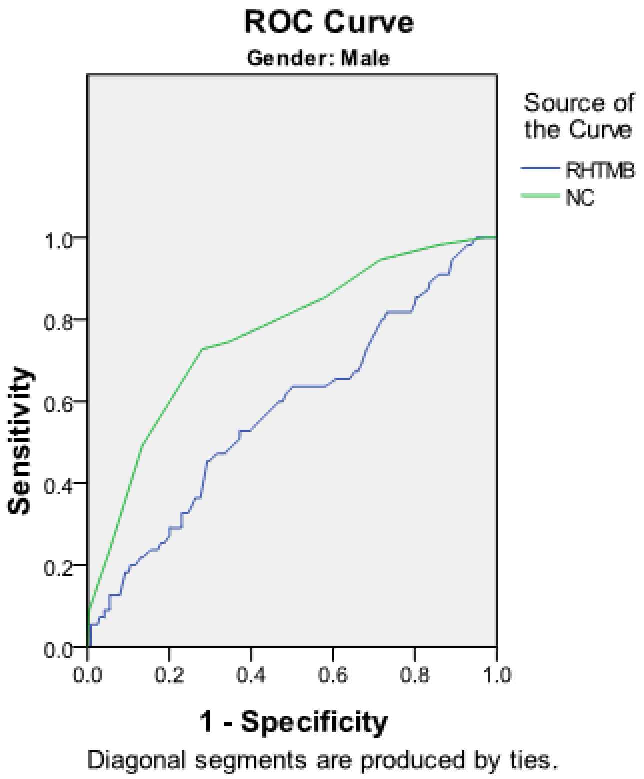

Figure 24: ROC curve of RHTMD and NC in males

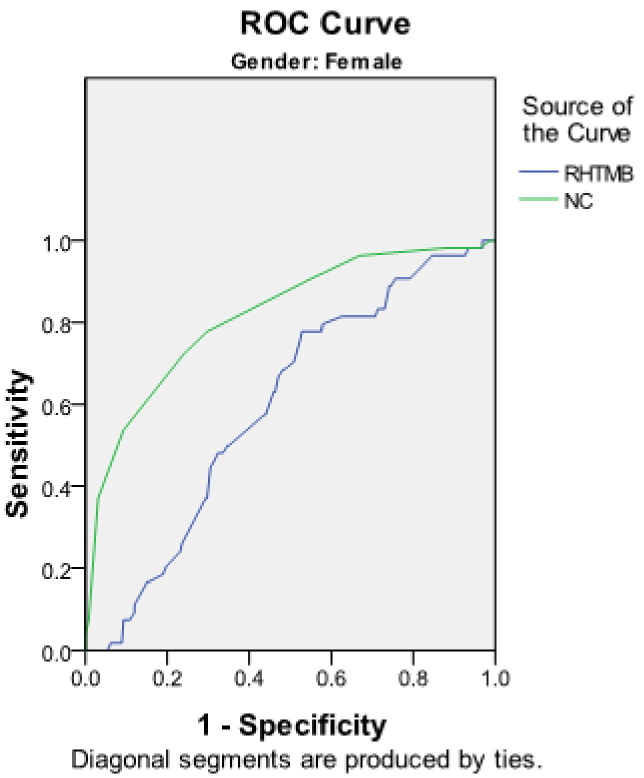

Figure 25: ROC curve of RHTMD and NC in females

Neck Circumference (NC)

The mean NC of the whole population studied was 40.26 cm with a SD of 2.27 and statistical analysis using Chi-sqare test showed significant association between NC and Cormack-Lehanelaryngoscopic view (*p*value<o. oo1 see table: 16)

Table 16: Descriptive statistics for NC

C-L	N	NC Mean	NC sd	F	p
Grade 1	284	39.72	1.99	40.877	<0.001
Grade 2	214	39.96	2.18		
Grade 3	103	42.21	2.12		
Grad 4	6	42.67	1.37		
Total	607	40.26	2.27		

The ROC curve of NC drawn for total population and in men and women showed the optimal cut-off point to be >41.5 cm in all the groups (Fig: 23, 24, 25). The sensitivity, specificity, PPV and NPV of NC in the whole population were 72.5%, 74.1%, 38.0% and 92.5% respectively (table: 10). The sensitivity and specificity in men and women were 72.7%, 72.2% and 72.0%, 76.1% respectively. The PPV and NPV in men and women were 37.4%, 38.6% and 92.0%, 92.9% respectively (table: 13). The AUC in the whole population and and in men and women were 0.790, 0.762 and 0.817, showing significant correlation with NC in predicting Cormack-Lehane grade of laryngoscopic view (table 11&12)

Multivariate Analysis

Logistic regression model was created incorporating TMD, STMD, RHTMD and NC and the optimal cut-off point from the ROC curve. The Hosmer-Leme show test was done and indicated a good logistic regression model fit (x^2 = 5.117, df= 5, *p*= 0.402>0.05). (table: 17)

Binary logistic regression analysis incorporating the variables TMD, STMDm RHTMD and NC

Table 17: Hosmer and Lemeshow test

χ^2	df	p
5.117	5	0.402

Classification table

Observed		Predicted CL: Grade 3 & 4	Predicted CL: Grade 1 & 2	Percentage Correct
CL	Grade 3 & 4	1	108	0.9
	Grade 1 & 2	3	495	99.4
Overall Percentage				81.7

Variables in the Equation

	B	S. E.	p	OR	95% C. I. for OR Lower	95% C. I. for OR Upper
RHTMD	0.821	0.302	0.007	2.272	1.257	4.106
NC	2.022	0.241	0	7.554	4.708	12.121
TMD	-0.335	0.369	0.365	0.715	0.347	1.476
STMD	0.267	0.328	0.416	1.306	0.686	2.486
Constant	-2.63	0.573	0	0.072		

The inclusion of TMD. STMD, RHTMD and NC improved the prognostic value of the model. RHTMD and NC (*p* value <0.05) were significant independent prognostic factors whereas TMD and STMD were not significant prognostic factors (*p* value>0.05). Table 18

Table 18: Logistic regression analysis with *p* value of each variable

	B	S. E.	p	OR	95% C. I. for OR	
					Lower	Upper
RHTMD	0.821	0.302	0.007	2.272	1.257	4.106
NC	2.022	0.241	0	7.554	4.708	12.121
TMD	-0.335	0.369	0.365	0.715	0.347	1.476
STMD	0.267	0.328	0.416	1.306	0.686	2.486
Constant	-2.63	0.573	0	0.072		

Variables in the Equation

The ROC curve of the risk model (Fig: 26) describes the screening characteristics of the model. The Area Under the Curve was found to be 0.774 (CI 0.724-0.823) denoting that the model had a significant diagnostic accuracy higher than that of each test alone (table: 19).

Figure 26**:** Receiver operating characteristic curve of the logistic regression model incorporating the thyromental distance (TMD), sternomental distance (STMD), ratio of height to thyromental distance (RHTMD) and neck circumference (NC) in the whole sample.

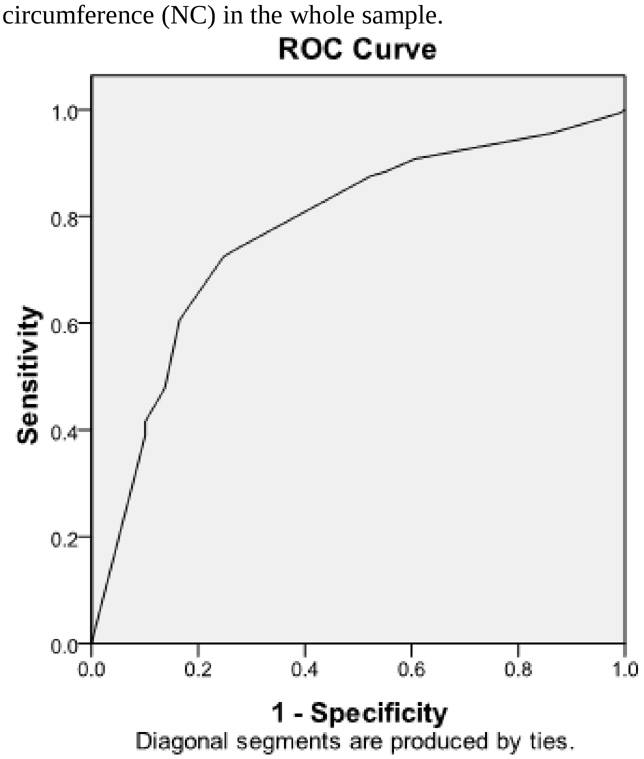

Table 19: Area under the curve of logistic regression model

Area	Std. Error[a]	p	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
.774	.025	.000	.724	.823

6. Discussion

Unanticipated difficult / failed intubation is a significant source of morbidity and mortality in surgical patients despite the availability of supraglottic devices for securing the airway or equipment based on sophilisticated technologies (fiberoptic bronchoscopy). If we are able to predict potential difficult intubation during the pre-anesthetic visit, an alternate approach to the airway may be used from the very beginning of anesthesia, so that the risk of hypoxemia associated with difficult intubation is reduced.

The ease of tracheal intubation is determined by many factors, with the Cormack-Lehane grade of laryngoscopic view being the most important one. This study assessed the value of thyromental distance (TMD), Sternomental Distance (STMD), The ratio of height to thyromental distance (RHTMD) and Neck circumference (NC) as anatomical features of neck in predicting difficult laryngoscopy in men and women

This study was designed with the aim to measure four anatomical variables of the neck namely, thyromental distance (TMD), sternomental distance (STMD), the ratio of the height to thyromental distance (RHTMD) and neck circumference (NC)), which can be measured preoperatively with minimal patient co-operation and to assess their diagnostic value in predicting difficult laryngoscopy in our population. In clinical practice, these study findings may be applicable in patients whocannot cooperate adequately or are unable to perform other tests such as the Mallampati and upper lip bite tests, due to mental or physical inability. The predictive tests used in the present study are measurements performed with the patient's head in a neutral or extension position, which may be achieved even passively in incapable patients.

The laryngoscopy was assessed as difficult (Cormack–Lehane grades 3 and 4) in 109 (18.0%) of the studied patients. The diagnostic value of TMD was found unsatisfactory in the present study. The optimal cut-off point for TMD in the whole sample was <6.375 cm with poor sensitivity in the whole population as well as in men and women (sensitivity was 37.6%, 41.8%, and 68.5% respectively). The cut-off point was similar to the cut-off point in the meta-analysis of Shiga et *al.* and in the prospective study by Khan. Z. H et *al (*TMD ≤6CM and ≤6.5cm respectively). The test showed relatively high negative predictive value (NPV) of 84.4% in the whole population reflecting the proportion of easy intubation correctly proved to be easy. The TMD was found to be gender dependent in the present study, yet different cut-off points in men and women (<7.15cm and 6.375 cm) did not improve the predictive accuracy of the test in either gender. This study found TMD to be a poor predictor of difficult larnygoscopy and is not accurate enough to be used as a sole predictor of difficult laryngoscopy as suggested by other investigators[4, 5].

The optimal cut-off point of STMD was <13.375 cm in the present study and was similar to those reported by Ramadhaniet *al*[31]. Savva *et al.* used a lower cut-off point (<12.5 cm) to predict difficult laryngoscopy and found STMD to be a useful bedside screening test for predicting difficult intubation. But the present study showed poor sensitivity (34.9%) and moderate specificity (76.7%) in predicting difficult laryngoscopy and genderwise cut-off points and classification did not improve the diagnostic accuracy of STMD in men and women. Analysis of data in the present study indicate that STMD is of limited predictive accuracy when used alone as reported by Khan. Z. H et*al*[5] and other investigators. However, this test showed relatively high NPV (84.4%) in the present study.

The optimal cut-off point for RHTMD calculated in this study (>23.5cm) was higher than those analysed by Liaskou Chara *et al*[45] (>18.4cm) probably reflecting the racial difference in height and neck measurements among the two population studied. Similar to TMD and STMD, the AUC of ROC curve of RHTMD was <0.5 indicating its poor predictive value in predicting difficult laryngoscopy when used as a single test. RHTMD had relatively good NPV (87.1%)

This study found the neck circumference (NC) to be the most sensitive and specific test in predicting difficult laryngoscopy among the tests studied. NC had highest sensitivity (72.5%) and specificity (74.1%) with a PPV of 38.0% and NPV of 92.5%. The optimal cut-off point (>41.5 cm) was similar in both men and women and the AUC was higher in women (0.817) than in men (0.762) indicating a higher like hood for difficult laryngoscopy in women with increased neck circumference than in men with increased neck circumference. Analysis of data from the present study showed that NC can be used as sole predictor of difficult laryngoscopy in men and women

Multivariate analysis with logistic regression model incorporating TMD, STMD, RHTMD and NC increased the predictive accuracy of the model with RHTMD and NC as significant independent prognostic factors. The study found that the other three anatomical predictors of difficult laryngoscopy studied namely, TMD, STMD and RHTMD carry low sensitivity rate when used alone, but improves the predictive accuracy when used in combination as suggested by many previous investigators[4, 5].

7. Conclusion

Neck circumference may be used as an independent test in predicting difficult laryngoscopy and intubation in both men and women. Other anatomical predictors of difficult laryngoscopy studied, namely the thryomental distance, sternomental distance and the ratio of height to thyromental distance carry low sensitivity rate when used alone, but improves the predictive accuracy when used in combination as suggested by many previous investigators.

References

[1] Caplan RA, Benumof JL, Berry FA, Blitt GD, Bode RH, Cheney FW, Connis RT, Guidry OF, Ovassapian A, Practice Guidelines by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway: An Update Report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway. Anesthesiology 98: 1269-1277; 2003.

[2] Crosby ET, Cooper RM, Douglas MJ et al: The unanticipated difficult airway with recommendation for management. Can J Anaesth 45: 757, 1998.

[3] Hawthorne L., Wilson R., Lyons G., et al: Failed intubation revisited: 17-year experience in a teaching maternity unit. *Br J Anaesth* 1996; 76: 680-684.

[4] Shiga T, Wajima Z, Inoue T, Sakamoto A. Predicting difficult intubation in apparently normal patients: a meta-analysis of bedside screening test performance. Anesthesiology.2005; 103 (2): 429-37.

[5] Khan ZH, Mohammadi M, Rasouli MR, Farrokhnia F, Khan RH. The diagnostic value of the upper lip bite test combined with sternomental distance, thyromental distance, and interincisor distance for prediction of easy laryngoscopy and intubation: a prospective study. AnesthAnalg.2009; 109 (3): 822-4.

[6] Jonathan L, Benumof JL. Management of the difficult adult airway. Anaesthesiology.1991; 75: 1087-110.

[7] Cormack RS, Lehane J. Difficult tracheal intubation in obstetrics. Anaesthesia 1984; 39: 1105-11.

[8] Stackhouse R A, Bainton C R; Difficult airway management, In Hughes SC, Levinson G, Rosen M A editors; Shnider and Levinson's anesthesia for obstetrics, Philadelphia, 2001, Lippincott Williams and Wilkins, pp 375-389.

[9] Reznik G K, Comparative anatomy, Physiology and function of the upper respiratory tract, Environ health prospect1990*;* 85: 171

[10] Williams P, Warwick R, Dyson M, et al: Gray's anatomy, 37th ed. New York; Churchill Livingstone; 1989: 365

[11] Beasley P: *Anatomy of the pharynx and oesophagus*. In: Kerr AG, ed. *Scott Brown's Otolaryngology*, Oxford: Butterworth-Heinemann; 1997: 8.

[12] Issacs R S, Sykes J M; Anatomy and physiology of the upper airway, AnesthesiolClin North Am, 20: 733-745, 2002

[13] Bannister LH, Berry MM, Collins P, et al: *Gray's Anatomy*, 38th ed. . New York: Churchill Livingstone; 1995: 1637.

[14] Roberts J: Functional anatomy of the larynx. *IntAnesthesiolClin* 1990; 28: 101.

[15] Tucker HM: *Physiology of the larynx*. In: Tucker HM, ed. *The Larynx*, 2nd ed. . New York: Thieme Medical; 1993: 23.

[16] Hanafee WN, Ward PH: *Anatomy and physiology*. In: Hanafee WN, Ward PH, ed. *The Larynx: Radiology, Surgery, Pathology*, New York: Thieme Medical; 1990: 3.

[17] Kolman J, Morris I: Cricoarytenoid arthritis: A cause of acute upper airway obstruction in rheumatoid arthritis. *Can J Anesth* 2002; 49: 729.

[18] Arai YC, Fukunaga K, Hirota S, Fujimoto S. The effects of chinlift and jaw thrust while in the lateral position on stridor scorein anesthetized children with adenotonsillarhypertrophy. AnesthAnalg 2004; 99: 1638 – 41

[19] Hillman DR, Platt PR, Eastwood PR. The upper airway during anaesthesia. Br J Anaesth.2003 Jul; 91 (1): 31–39.

[20] Langeron O, Masso E, Huraux C, Guggiari M, Bianchi A, Coriat P, RiouB: Prediction of difficult mask ventilation. ANESTHESIOLOGY 2000; 92: 1229–36,

[21] Harmer M. Difficult and failed intubation in obstetrics IJOA (1997) 6: 25-31

[22] el-Ganzouri, AR, McCarthy RJ, Tuman KJ, Tanck EN, Ivankovich AD: Preoperative airway assessment: predictive value of a multivariate risk index. AnesthAnalg 1996; 82: 1197–204

[23] Takenaka I, Aoyama K, Kadoya T: Mandibular protrusion test for predictionof difficult mask

ventilation. ANESTHESIOLOGY 2001; 94: 935, author reply 937
[24] Savva D. Prediction of difficult tracheal intubation. Br J Anaesth1994; 73: 149-53.
[25] Calder I, Calder J, Crockard H A; difficult direct laryngoscopy in patients with cervical spine disease, Anesthesia 1995; 50: 756-63
[26] Mallampati SR, Gatt SP, Gugino LD, Desai SP, WaraksaB, Freiberger D, *et al*. A clinical sign to predict difficult intubation: A prospective study. Can AnaesthSoc J 1985; 32: 429-34.
[27] Samsoon GL, Young JR. Difficult tracheal intubation: A retrospective study. Anaesthesia 1987; 42: 487-90.
[28] Bellhouse CP, Dore C. Criteria for estimating likelihood of difficulty of endotracheal intubation with Macintosh laryngoscope. AnaesthIntensive Care 1988; 16: 329-37.
[29] Patil, Vijayalakshmi U., Linda C. Stehling, and Howard L. Zauder.1983. *Fiberoptic endoscopy in anesthesia*. Chicago: Year Book Medical Publishers. rcade O. The importance of increased neck circumferenceto intubation difficulties in obese patients. AnesthAnalg2008; 106: 1132-6.33) Gonzalez H, Minville V, Delanoue K, Mazerolles M, ConcinaD, Fourcade O. The importance of increased neck circumferenceto intubation difficulties in obese patients. AnesthAnalg2008; 106: 1132-6.
[30] Frerk CM: Predicting difficult intubation. Anaesthesia 1991; 46: 1005–8
[31] Al Ramadhani S, Mohamed LA, Rocke DA, et al. Sternomental distance as the sole predictor of difficult laryngoscopy in obstetric anaesthesia. Br J Anaesth.1996 Sep; 77 (3): 312–6
[32] Chou HC, Wu TL. Mandibulohyoid distance in difficult laryngoscopy. Br J Anaesth 1993; 71: 335-9.
[33] Brodsky JB, Lemmens HJ, Brock-Utne JG, VierraM, Saidman LJ. Morbid obesity and tracheal intubation. AnesthAnalg2002; 94: 732-6.
[34] Gonzalez H, Minville V, Delanoue K, Mazerolles M, ConcinaD, Fou
[35] A survey of anaesthetic practice in predicting difficult intubation in the United Kingdom and Europe. McPherson, Vaughan RS, Wilkes AR, Mapleson WW, Hodzovic I. Submitted to the European Journal ofAnasesthesiology.
[36] Yentis SM. Predicting difficult intubation-worthwhile exercise or pointless ritual? *Anaesthesia*2002; **57**: 105-109.
[37] Kheterpal S, Han R, Tremper KK, et al. Incidence andpredictors of difficult and impossible mask ventilation. Anesthesiology 2006; 105: 885–91
[38] Williamson JA, Webb RK, Szekely S, Gillies ER, Dreosti AV. The Australian IncidentMonitoring Study. Difficult intubation: an analysis of 2000 incident reports. AnaesthIntensiveCare 1993; 21 (5): 602-7.
[39] Wilson ME, Spiegelhalter D, Robertson JA et al. Predicting difficultintubation. Br J Anaesth 1988; 61: 211-16.
[40] Arne J, Descoins P, Fusciardi J, et al. Preoperative assessment fordifficult intubation in general and ENT surgery: predictive valueof a clinical multivariate risk index. Br J Anaesth1998; 80: 140–6.
[41] Gupta S, Pareek S, Dulara SC: Comparison of two methods for predictingdifficult intubation in obstetric patients. Middle East J Anesthesiol 2003; 17: 275–85
[42] M. Adamus, S. Fritscherova, L. Hrabalek, T. Gabrhelik, J. Zapletalova and V. Janout, "Mallampati Test as a PredictorofLaryngoscopic View, " Biomedical Papers of theMedical Faculty of the University Palacký, Vol.154, No.4, 2010, pp.339-344.
[43] Rocke DA, Murray WB, Rout CC, Gouws E. Relative risk analysis of factorsassociated with difficult intubationin obstetric anesthesia. Anesthesiology1992; 77: 67–73
[44] Calder I, Picard J, Chapman M, O'Sullivan, C, Crockard HA: Mouth opening: A new angle. ANESTHESIOLOGY 2003; 99: 799–801
[45] LiaskouChara, VouzounerakisEleftherios, Moirasgenti Maria, Trikoupi Anastasia, and StaikouChryssoulaIndian J Anaesth.2014 Mar-Apr; 58 (2): 176–182.