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External neck landmark identification and measurement correlation in a normal weight cohort

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Abstract

Background: Airway management, including proper airway devices sizing, is dependent on airway features, which ultimately should correlate with body features: unfortunately such correlation has been inconsistent. The aim of this study was to determine the correlation of normal values of several external neck landmark (airway features) measurements with with age, gender, height and weight (body features) for normal weight adult subjects to establish a consistent correlation.

Methods: After IRB approval, 200 subjects (100 male and 100 female) were enrolled. External neck landmarks were measured using a measuring tape. Measurements were also assessed by digital caliper to compare marginal errors. Only non-obese (BMI≤30 kg/m²) adults presenting for preoperative anesthesia assessment were screened.

Results: A total of 200 subjects completed the study. The difference between female and male hyocricoid distance (6.0±1.3 cm and 6.5±1.4 cm; P<0.01) and thyroid width (4.9±0.8 cm and 5.3±0.7 cm; P<0.001) was statistically significant. Univariate regression analysis demonstrated ENLs measurements were correlated with different physical characteristics except the occipital distance which did not provide any correlation with the airway anatomical variables.

Conclusion: There was a significant correlation between: thyromental, hyoidcricoid and thyroid width distances with height and weight (P≤0.0001); thyroid height and thyrocricoid distances with height (P=0.027 and P=0.008, respectively); hyoidmental with age (P=0.037), and sternomental distance with height and age (P<0.0001). Results from multivariate regression provided interesting insight into the association between each ENL, airway features and physical characteristics. These findings may be useful to determine prediction models of important neck landmarks measurements when actual measurements are not feasible.

Keywords: Airway management, external neck landmark, anatomy, supraglottic airway device

Introduction

The ability to accurately assess the difficulty or size of a patient's airway facilitates clinical choices, such as establishing a particular airway management plan. While correlations have previously been identified between measurements of external neck landmarks (ENL) and internal airway measurements obtained using bronchoscopy or radiologic imaging, and several prediction models have been created on the basis of these relationships [1,2], consistent utilization of such measurements or consistent correlation with certain body features have not been studied or identified yet.

While airway size determination is commonly estimated in children, this is not routine practice for adult patients. In adults, ENLs are most commonly utilized for predicting a difficult

intubation [3-7]. Research and clinical observations have identified weight, height and age as clinically relevant for prediction of the difficult airway [8,9]. Furthermore, radiological studies and ultrasound guided techniques, have also found anatomical features to correlate with neck landmarks and/or airway device outcomes [1,10,11].

There is, however, limited research regarding the measurement of ENLs and their correlation to physical features, such as height, weight and age. Interestingly enough, extraglottic airway devices are also in the midst of such evaluations, since the current manufacturer sizing system are not ideal, and while many are chosen based on weight, others are based on height, and questions remain whether gender should play a role [12].

The hypothesis of the current investigation was to correlate ENLs with other anthropomorphic features, such as height and weight, as well as gender and age of the patient, considering body features to be used in predicting ENLs. For the current investigation, several novel ENLs were also included, which are not commonly part of airway examination, and are based on 3 relevant structures: the thyroid and cricoid cartilages, and the hyoid bone. The authors' hypothesis was that these ENLs form the scaffolding of the upper airway and provide additional useful measurements for proper airway assessment.

The primary aim of this investigation was to establish normal ENL values in non obese adults, to determine 1. Normal values; 2. to correlate these landmark measurements physical features such as gender, age, weight and height; 3. to identify variables based on an univariate analysis and 4. to build prediction models of ENLs based on body and other features, resulted from a multivariate analysis. Indeed, utilizing a the univariate and multivariate analysis, the important ENLs could be useful to create reverse prediction models for such landmarks on the basis of the same easily accessible demographic variables, so that, if the former is impossible to be measured (i.e., trauma) or distorted (i.e., morbid obesity) the latter may be estimated. Such models could also be utilized as potential prediction models and tools to predict the size of features related to airway management and the sizing of extraglottic airway devices (EAD) devices.

Methods

After obtaining approval from the Committee for the Protection of Human Subjects (6410 Fannin, Suite 1100, Houston, Texas 77030, Phone 713.500.7943, Fax 713.500.7951, Email: cphs@uth.tmc.edu, July 7, 2010, HSC-MS-10-0204), written informed consent was obtained from 100 female and 100 male adult subjects, non-obese (BMI≤30 kg/m^2), aged 18-80 years, ASA I-II and Mallampati I-II, presenting for anesthesia preoperative assessment.

Patient eligibility was determined by screening patient's height; female patients 155-175 cm and male patients 165-185 cm were considered eligible. Demographics, including patient age, gender, height, weight and BMI, were recorded. Measurements of ENLs were performed by a research team member with both a disposable measuring tape and digital caliper, as indicated in **Figure 1** and **Table 1**. Landmarks started to be assessed by a research assistant after a training period, assessing concordance between the anesthesiologist expert in airway management (D.C. and PI) and the team member. The research assistant was also provided with anatomical measurements limits that would help identify potential abnormal values (such values, considered 25-75 percentiles, were based on a preliminary study of 200 subjects) [13].
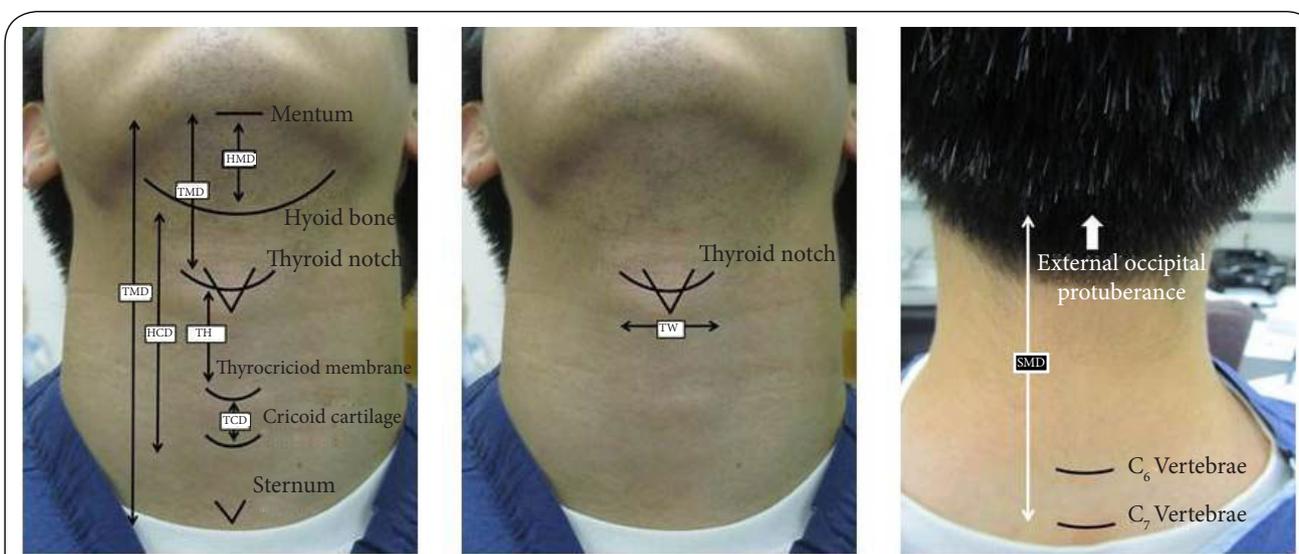
Figure 1. Image of external neck landmarks.
TMD: thyromental distance; HCD: hyoid to cricoid cartilage distance; SMD: sternomental distance; TCD: thyroid cricoid distance; TW: thyroid width; TH thyroid height; HMD: hyoid mental distance; OCD: occipital process to C7 distance.

Table 1. Guidelines for measuring external neck landmarks[*].

Landmark	
Thyromental distance (TMD)	Lower midline border of mandible in jaw occlusion and neck extended to thyroid notch
Hyoid to cricoid cartilage distance (HCD)	Hyoid bone to upper border of cricoid cartilage
Sternomental distance (SMD)	Mentum as per TMD to sternal notch
Thyroid cricoid distance (TCD)	Thyroid notch to lower border of cricoid cartilage
Thyroid width (TW)	Lateral borders of upper thyroid cartilage
Thyroid height (TH)	Thyroid notch to lower border of thyroid cartilage
Hyoid mental distance (HMD)	Mentum as per TMD extended to hyoid bone
Occipital process to C7 distance (OCD)	Lowest point of occipital process to upper border of C7

[*]All measurements, with the exception of OCD, are taken with the head and neck in an extended position. The OCD is taken with the neck in neutral position.

As per protocol, any subject that was identified with values beyond such limits would be re-measured by the faculty anesthesiologist with airway expertise. Every measurement was performed in proper position: i.e., patient sitting, neck midline in both extended and neutral position. For the tape measurement, structures were followed by skin contact, while with caliper, linear approximation could occur. Sternomental distance (SMD) measurements were limited by length of caliper (16 cm).

Due to the limited number of patients and measurement techniques, race was not included in the analysis to allow proper stratification. For the same reason ENLs were not measured in different neck positions (neutral-flexed, sniffing, extended) but only in one optimal position for the measurements.

Means and standard deviations were summarized for patient demographics and all external neck measurements. A paired t-test was performed to compare the differences between the measuring tape and digital caliper ENL measurements. Two sample t-test was conducted to compare the ENL measurements between female and male patients. Univariate regression was applied to assess the relationship between ENL measurements, and physical characteristics (age, height and weight). Multivariate regression model was also applied to assess the relationship between ENL measurements, and physical characteristics and ascertain the results of the univariate analysis. A backward selection procedure was applied to identify the important factors. All variables with p-value <0.20 as well as gender are included in the final model. All statistical analyses were performed using SAS 9.3 (SAS Institute. Inc., Cary, NC) and a p-value <0.05 was considered significant.

Results

A total of 200 adults (100 females and 100 males) were screened, selected and enrolled in the study. Statistically significant differences were determined between measuring tape and digital caliper measurements respectively for thyromental distance (TMD) (6.8±1.1 cm, 6.6±1.1 cm; P<0.001), hyoid to cricoid cartilage distance (HCD) (6.2±1.4 cm, 6.1±1.3 cm; P=0.015), sternomental distance (SMD) (16.0±2.0 cm, 15.3±2.1 cm; P<0.001), thyroid width (TW) (5.1±0.8 cm, 5.0±0.7 cm; P<0.001), and occipital process to C7 distance (OCD) (7.7±1.6 cm; 7.3±1.5 cm; P<0.001) (**Table 2**).

Table 2. Comparison of measuring tape and digital caliper measurements.

Landmark	Measuring Tape (n=200)	Digital caliper (n=200)	P Value
Thyromental Distance (TMD, cm)	6.8±1.1	6.6±1.1	<0.001
Hyoid to Cricoid Cartilage Distance (HCD, cm)	6.2±1.4	6.1±1.3	0.015
Sternomental Distance (SMD, cm)	16.0±2.0	15.3±2.1	<0.001
Thyroid Cricoid Distance (TCD, cm)	5.0±0.8	5.0±1.0	0.82
Thyroid Width (TW, cm)	5.1±0.8	5.0±0.7	<0.001
Thyroid Height (TH, cm)	3.5±0.8	3.5±0.7	0.21
Hyoid mental Distance (HMD, cm)	3.9±0.9	3.8±0.9	0.070
Occipital process to C7 Distance (OCD, cm)	7.7±1.6	7.3±1.5	<0.001

Demographics and ENLs of the study population, calculated from the tape measurements, are presented in **Table 3**. Statistically significant differences between females and males was shown in HCD (females, 6.0±1.3 cm; males, 6.5±1.4 cm; P<0.01), TCD (females, 4.9±0.8 cm; males, 5.2±0.8 cm; P=0.046), thyroid width (females, 4.9±0.8 cm; males, 5.3±0.7 cm; P<0.001) and OCD (7.4±1.6 cm, 7.9±1.7; P=0.023). Though not significant, males tended to have larger thyrocricoid distances and OCDs than females (P=0.051).

Based on the data collected, univariate regression analysis was conducted to determine the relationships between the ENLs and patient demographic variables (**Table 4**). There was a significant correlation between: thyromental, hyoid-cricoid and thyroid width distances with height and weight (P≤0.0001); thyroid height and thyrocricoid distances with height (P=0.027 and P=0.008, respectively); hyoidmental with age (P=0.037), and sternomental distance with height and age (P<0.0001). No significant correlation was observed between the occipital distance and any of the anatomical variables. Results from multivariate regression provides further insight into the association between

Table 3. Demographics and ENLs of study population by gender.

	All Subjects (n=200)	Females (n=100)	Males (n=100)	P-Value
Age (yr)	48.1±17.4	45.9±17.1	50.4±17.4	0.070
Height (cm)	169.4±7.7	164.0±5.5	174.9±5.5	<0.0001
Weight (kg)	71.0±11.8	64.4±9.6	77.6±9.9	<0.0001
Thyromental Distance(TMD, cm)	6.8±1.1	6.7±1.2	7.0±1.1	0.051
Hyoid to Cricoid Cartilage Distance (HCD, cm)	6.2±1.4	6.0±1.3	6.5±1.4	<0.01
Sternomental Distance (SMD, cm)	16.0±2.0	15.8±1.8	16.1±2.1	0.20
Thyroid Cricoid Distance (TCD, cm)	5.0±0.8	4.9±0.8	5.2±0.8	0.046
Thyroid Width (TW, cm)	5.1±0.8	4.9±0.8	5.3±0.7	<0.0001
Thyroid Height (TH, cm)	3.5±0.8	3.4±0.8	3.6±0.7	0.12
Hyoid mental Distance (HMD, cm)	3.9±0.9	3.9±1.0	3.9±0.9	0.71
Occipital process to C7 Distance (OCD, cm)	7.7±1.6	7.4±1.6	7.9±1.7	0.023

*P-values are obtained by two sample t-test by comparing demographics and ENLs between females and males.

Table 4. Univariate analysis to assess the association between each landmark and physical characteristics.

ENL	Age (years)		Height (cm)		Weight (kg)	
	Coefficient Estimate±SE	P-value	Coefficient Estimate±SE	P-value	Coefficient Estimate±SE	P-value
Thyromental Distance (TMD)*	0.006±0.005	0.208	0.040±0.010	<0.0001	0.022±0.007	0.001
Hyoid to Cricoid Cartilage Distance (HCD)	0.004±0.005	0.464	0.042±0.012	0.001	0.032±0.008	<0.0001
Sternomental distance (SMD)	-0.031±0.008	<0.0001	0.083±0.017	<0.0001	0.016±0.012	0.169
Thyroid Cricoid Distance (TCD)	-0.006±0.003	0.086	0.020±0.007	0.008	0.005±0.005	0.315
Thyroid Width (TW)	0.001±0.003	0.817	0.027±0.007	0.0001	0.020±0.005	<0.0001
Thyroid Height (TH)	0.000±0.003	0.897	0.015±0.007	0.027	0.008±0.004	0.079
Occipital process to C7 Distance (OCD)	-0.010±0.007	0.135	0.027±0.015	0.071	0.010±0.010	0.290
Hyoid mental Distance (HMD)	-0.008±0.004	0.037	0.013±0.009	0.143	-0.002±0.006	0.705

each ENL and physical characteristics (**Table 5**). Taking TMD as an example, height is significant correlated with TMD. We expect one unit increase of height will increase 0.043 unit of TMD after holding other variables at constant (i.e., in the same gender group with the same weight).

Discussion

In this study, a combination of several novel measurements, including hyoid to cricoid cartilage distance, thyrocricoid distance, thyroid width, thyroid height and hyomental distance of the larynx were measured and correlations were established between such measurements and other anatomical variables.

Currently available screening tests for predicting difficult intubation, including TMD and modified Mallampati, have demonstrated variable discriminative power when used alone.

Combining multiple indicators does not add incremental diagnostic value in comparison to the value of each test alone in a consistent way. One of the frequent ques tions was whether or not any of these measurements could be correlated to physical features. For instance Frerk et al., [3] identified TMD as a valuable predictor, yet TMD value per se has been quest-ioned over other practical correlations, such as TMD to height ratio [8].

On a methodological standpoint, while some of the differences between the distances obtained with the measuring tape and caliper were statistically significant, they are indeed clinically insignificant making on a daily-based the measuring tape a sufficient and efficient option, particularly considering the limitation of the digital caliper for the TMD measurement.

Few limitations need to be recognized; race was not

Table 5. Results from multivariate regression to assess the association between each ENL and physical characteristics.

ENL	Coefficient Estimates±SE	p-value
TMD		
Male vs Female	-0.310±0.222	0.165
Height (cm)	0.043±0.015	0.005
Weight (kg)	0.011±0.009	0.192
HCD		
Male vs Female	0.187±0.223	0.404
Weight (kg)	0.027±0.010	0.005
SMD		
Male vs Female	-0.923±0.354	0.010
Age (years)	-0.032±0.007	<0.0001
Height (cm)	0.130±0.023	<0.0001
TCD		
Male vs Female	0.065±0.161	0.687
Age (years)	-0.007±0.003	0.048
Height (cm)	0.018±0.010	0.088
TW		
Male vs Female	0.252±0.127	0.049
Weight (kg)	0.014±0.005	0.012
TH		
Male vs Female	-0.003±0.148	0.983
Height (cm)	0.015±0.010	0.114
OCD		
Male vs Female	0.578±0.229	0.013
Age (years)	-0.012±0.007	0.069
HMD		
Male vs Female	-0.335±0.184	0.071
Age (years)	-0.008±0.004	0.043
Height (cm)	0.029±0.012	0.015

considered in the current study stratification and no movement or changes in neck position were addressed that could have affected the results, because the number of patient would have not been enough to balance groups, or because the measurements can only be taken in certain neck positions. Of note, many of the gender differences noted are not surprising, as eventually larynx morphology is under the control of numerous growth factors and hormones, in particular sex hormones [14]. These results may be useful to understand gender differences in laryngeal structure and for designing laryngeal models, but future investigations may have to take into account race differences. There is speculation from the present investigation that potentially could result in the correlation of these novel ENLs and individual patient demographic factors.

Laryngeal morphology is complex with many variables which should be taken into consideration in order to accurately predict such laryngeal structure and airway size, as well as appropriate sizing of EADs [15-17], and further studies are currently under investigation, with some given preliminary results [18-19].

Indeed EAD sizing which is still not optimal [12] and anatomical prediction models as the one presented in the cur-

rent investigation, may develop as novel aspect in airway management.

Competing interests
The authors declare that they have no competing interests.

Authors' contributions

Authors' contributions	DC	JW	RC	CC	TT	TCV	CAH
Research concept and design	✓	--	--	--	--	--	✓
Collection and/or assembly of data	--	--	✓	--	--	--	--
Data analysis and interpretation	✓	✓	✓	✓	✓	✓	✓
Writing the article	✓	--	✓	✓	✓	--	--
Critical revision of the article	✓	✓	--	--	--	✓	✓
Final approval of article	✓	✓	✓	✓	✓	✓	✓
Statistical analysis	--	--	--	✓	--	--	--

References

1. Cherng CH, Wong CS, Hsu CH and Ho ST. **Airway length in adults: estimation of the optimal endotracheal tube length for orotracheal intubation**. *J Clin Anesth.* 2002; **14**:271-4. | Article | PubMed

2. Naguib M, Malabarey T, AlSatli RA, Al Damegh S and Samarkandi AH. **Predictive models for difficult laryngoscopy and intubation. A clinical, radiologic and three-dimensional computer imaging study**. *Can J Anaesth.* 1999; **46**:748-59. | Article | PubMed

3. Frerk CM. **Predicting difficult intubation**. *Anaesthesia.* 1991; **46**:1005-8. | Article | PubMed

4. Prakash S, Kumar A, Bhandari S, Mullick P, Singh R and Gogia AR. **Difficult laryngoscopy and intubation in the Indian population: An assessment of anatomical and clinical risk factors**. *Indian J Anaesth.* 2013; **57**:569-75. | Article | PubMed Abstract | PubMed Full Text

5. Butler PJ and Dhara SS. **Prediction of difficult laryngoscopy: an assessment of the thyromental distance and Mallampati predictive tests**. *Anaesth Intensive Care.* 1992; **20**:139-42. | Article | PubMed

6. Chou HC and Wu TL. **Thyromental distance--shouldn't we redefine its role in the prediction of difficult laryngoscopy?** *Acta Anaesthesiol Scand.* 1998; **42**:136-7. | PubMed

7. Lee A, Fan LT, Gin T, Karmakar MK and Ngan Kee WD. **A systematic review (meta-analysis) of the accuracy of the Mallampati tests to predict the difficult airway**. *Anesth Analg.* 2006; **102**:1867-78. | Article | PubMed

8. Krobbuaban B, Diregpoke S, Kumkeaw S and Tanomsat M. **The predictive value of the height ratio and thyromental distance: four predictive tests for difficult laryngoscopy**. *Anesth Analg.* 2005; **101**:1542-5. | Article | PubMed

9. Schmitt HJ, Kirmse M and Radespiel-Troger M. **Ratio of patient's height to thyromental distance improves prediction of difficult laryngoscopy**. *Anaesth Intensive Care.* 2002; **30**:763-5. | Article | PubMed

10. Elliott DS, Baker PA, Scott MR, Birch CW and Thompson JM. **Accuracy of surface landmark identification for cannula cricothyroidotomy**. *Anaesthesia.* 2010; **65**:889-94. | Article | PubMed

11. Frerk CM, Till CB and Bradley AJ. **Difficult intubation: thyromental distance and the atlanto-occipital gap**. *Anaesthesia.* 1996; **51**:738-40. | Article | PubMed

12. Van Zundert TC, Hagberg CA and Cattano D. **Standardization of extraglottic airway devices, is it time yet?** *Anesth Analg.* 2013; **117**:750-2. | Article | PubMed

13. Cattano D, Wojtczak J, Seitan C, Shamam S, Aijazi H, Vale H, Altamirano A and Hagberg CA. **External Neck Measurements, Laryngeal Anatomy and Gender/Height Controlled Variability in Adult Patients.** *Anesthesiology.* 2012; **A314**. | Article

14. Beckford NS, Rood SR, Schaid D and Schanbacher B. **Androgen stimulation and laryngeal development**. *Ann Otol Rhinol Laryngol.* 1985; **94**:634-40. | PubMed

15. Goudsouzian NG, Denman W, Cleveland R and Shorten G. **Radiologic localization of the laryngeal mask airway in children**. *Anesthesiology.* 1992; **77**:1085-9. | Article | PubMed

16. Russo SG, Cremer S, Galli T, Eich C, Brauer A, Crozier TA, Bauer M and Strack M. **Randomized comparison of the i-gel, the LMA Supreme, and the Laryngeal Tube Suction-D using clinical and fibreoptic assessments in elective patients**. *BMC Anesthesiol.* 2012; **12**:18. | Article | PubMed Abstract | PubMed Full Text

17. Levitan RM and Kinkle WC. **Initial anatomic investigations of the I-gel airway: a novel supraglottic airway without inflatable cuff**. *Anaesthesia.* 2005; **60**:1022-6. | Article | PubMed

18. Cattano D, Wojtczak J, Seitan C, Aijazi H, Vale H, Altamirano A and Hagberg CA. **Models for predicting laryngeal anatomy and a standardized sizing system for the supraglottic airway devices.** *Anesthesiology*. 2012; A784.

19. Cattano D, Wojtczak J, Callender R and Hagberg CA. **Models for determining external neck landmark dimensions and predicting internal airway size.** *Anesthesiology.* 2013; A4142.