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Normal Tracheal Measurements in the Saudi Population Using Computed Tomography

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Abstract: ***Objective**: The aim of this study is to set up the normal tracheal measurements in the Saudi population and to correlate such measures with those published internationally in order either to reinforce confidence in following the traditional tube sizes or further studies needed to determine which sizes would be more suitable. **Methods**: Saudi patients aged 14-80 who underwent CT neck at our hospital during the period (January 2012-June 2014) were included. Patients with conditions that might affect the normal tracheal diameters were excluded so as the studies that didn't include the carina in the field of view. Studies were viewed using both soft tissue and lung windows. The tracheal and laryngeal lengths were obtained. The maximum anteroposterior (AP), transverse (TRANS) and cross-sectional areas (CS) were taken at three levels; at the cricoid cartilage, junction of the proximal and middle trachea and thejunction of the middle and distal trachea. The analysis was done using SPSS version 16.0. The mean AP, TRANS and CS were generated at each level then a uniform mean AP, TRANS and CS were calculated. **Result**: The study included 68 patients 33 male (48.5%) and 35 female (51.5%).The mean anteroposterior diameter, mean transverse diameter and mean cross-sectional area of an adult male is as follows 21.70 mm, 16.97mm and 298.76 mm^2. The mean Anteroposterior diameter, mean transverse diameter and mean cross-sectional area of an adult female is as follows 16.85mm, 14.22mm and 191.89mm^2. The mean laryngeal length was 47.26mm in males and 36.29 mm in females while themean tracheal length was 120.29 mm and 107.23 mm.Marked sexual dimorphism was notedNo significant correlation between tracheal anteroposterior and transverse diameter and the subject's height or weight. However positive correlation between the subject's height and the laryngeal length was found, where 1 unit height (1 meter) predicts almost 0.7 cm extra length in thelarynx. **Conclusion**: We conclude that the tracheal dimensions in the Saudi population appear to be smaller than the New Zealanders and possibly the Americans and closer in parameters to the Iranian or Japanese population. Prospective studies using a larger sample size would be beneficial in an attempt to strengthen our conclusion***

Keywords: Computed tomography, tracheal, stenosis, intubation, Aaudi Arabia

1. Introduction

Appropriate selection of the endotracheal tube (ETT) size during intubation is of practical importance, to ensure proper placement and to avoid complications. For instance, using a larger than necessary endotracheal tube size was found to be a significant risk factor for posterior glottic stenosis (1). ETT size selection has been based on guidelines that were generated from studying the normal tracheal measurements of Western population. Accordingly, the typical ETT size used for an adult female is 7-8 mm and for the adult male is 8-8.5 mm(2,3). Inappropriate ETT sizing may lead to technical difficulties or undesired complications, such as subglottic/laryngeal edema, ischemia, ulceration, and subsequent stenosis (4)

Several methods have been used to aid in determining the appropriate ETT size. One method entails using radiographs to measure the tracheal width (5). However, the radiographic measurements accuracy was questioned due to inherent methodological issues such as variable magnification, rotation, inspiration, beam penetration, and intrinsic two dimensional nature(6) On the other hand, computed tomography (CT) proved to be a useful, fast and noninvasive method for obtaining tracheal measurements, with results comparable to the gold standard of bronchoscopy (7,8). The focus in the majority of the previously published studies was on measuring the growing trachea of the pediatric population (9, 10). Only a few studies addressed tracheal morphometry using CT in adult subjects (6, 11, 12, 13, 14,15).Other methods include MRI or ultrasonography. However, the latter is operator dependant (7). ETT cuff-leak test is a non-radiological method that has been proposed as a means for selecting the appropriate ETT size, yet reproducibility of this test has not been validated (16).

The currently available data on CT tracheal dimensions in the Middle Eastern cohort are sparse (14); let alone data on the Saudi population. To our knowledge, only one study has addressed such an issue (14). An attempt to create a national reference for tracheal dimensions would be of use, especially that the Western tracheal measurements are used as a model when placing ETTs in the Saudi population. Such reference can be then compared to the international data, where any discrepancies can be addressed. Thus, the aim of this study is to generate standard measurements of the normal trachea in the Saudi population using CT and to compare such measurements with those published internationally.

2. Materials and Methods

CT Scans Selection

Our institutional ethical committee approved this study, waiving the consent form. The picture archiving and communication system (PACS, Sectra, version 14.3,Attieh Medico Ltd.,Jeddah,Saudi Arabia) was retrospectively searched for CT neck examination performed at our hospital from January 2012 to June 2014. The patients' clinical information was collected from the electronic health record system (Phoenix Hospital Information System, version 1.0.0.1, Al-Anaiah International Company) and hardcopy documents.

Only neck CT examinations of Saudi nationals aged 14-80 years old were included in the study. Excluded CT examinations were those of non-Saudis, with diseases or conditions that may compromise the airway or where the carinawas not included in the field of view.

CT Scans Technique and Analysis

CT scans were acquired using one of the following CT scanners: 128-detector row Somatom Definition AS (Siemens Healthcare, Jeddah, Saudi Arabia), 128-detector row Definition Flash dual source scanner (Siemens Healthcare, Jeddah, Saudi Arabia) and 64-detector row Somatom Definition (Siemens Healthcare, Jeddah, Saudi Arabia). Using a standard protocol of: end inspiratory acquisition in the craniocaudal direction, in the supine position , 120 kV, automatically calculated mAs utilizing care dose 4D software, 5 mm slice thickness, Pitch of 0.8,acquisition of either 128x0.6mm (when using either of the first two machines) or 64 x 0.6mm (when utilizing the third scanner),using B20 smooth kernel and larynx window (for the 128-detector row scanners)or the B31 medium smooth kernel and larynx window (for the 64-detector row scanner).

CT studies were analyzed viewed using soft tissue and lung windows. The cricoid cartilage and carina levels were identified on axial images and cross-referenced with the midline sagittal image. The laryngeal length was measured from the cricoid cartilage to the tip of the epiglottis on the midline sagittal plane. The distance between the cricoid cartilage and carina was then measured on the midline sagittal plane, constituting the tracheal length. The tracheal length was then divided into equal proximal, middle and distal thirds. Then, the junction between each third was marked on the midline sagittal image. The maximum anteroposterior (AP), transverse (trans) and the cross-sectional area (CS) measurements of the luminal air column were obtained at the following levels: cricoid cartilage, proximal-mid tracheal third and mid-distal tracheal third (Fig.1). All the measurements were taken by consensus agreement of two senior radiology residents.

Statistical Analysis:

Analysis was performed using Statistical Package for Social Sciences version 16.0 for Windows (SPSS Inc., Chicago, IL, USA). Descriptive statistics was used to obtain frequencies and percentages for categorical variables and used to obtain means and standard deviations for continuous variables. Independent t-test was used to compare means of age and anatomical measurements across genders. Linear regression, in addition to Pearson correlation, was used to analyze age, height, weight, and body mass index (BMI) as predictors for tracheal and laryngeal measurements. A two-tailed p-value < 0.05 was considered statistically significant.

3. Results

The study included 68 neck CT scan examinations, constituted of 33 males and 35 females. The population's age range was 14-80 years old (mean age 36 years +/- 16). Subjects' characteristics and demographics are shown in table 1.

Of the studies done during the allocated period a large number was excluded (n=1026) due to various reasons which includedscans not reaching the carina (n=355), non-Saudi Patient (n=262), previous Surgery or Intubation (n=93), mass compressing or deviating the trachea (n=82), file insufficiency(n=76), head and neck surgery(n=59), pediatric age group (n=24), known tracheal abnormality(n=21) tracheostomy or intubation at the time of the CT scan (n=8)and patient already included in the study (n=4).

Tracheal and laryngeal measurements along with a comparison between adult males and females are summarized in table 2 and are illustrated in Figures 2 and 3. All measurements were significantly higher in males. Figure 4 demonstrate the three cross-sectional levels, at each level, AP, TRANS and CS were measured. Table 3 clarifies the detailed measurements at those levels. For each subject, a mean AP, mean TRANS and mean CS were calculated. Those were used in the comparison between males and females and in the comparison of our study to the published data that we had come across.

There was no significant correlation between anteroposterior and transverse tracheal diameters and the height or weight and thus the BMI of the subjects. On the other hand, there is a positive correlation between height and laryngeal length, where 1 unit change in height (1 meter) predicts almost 0.7 cm of extra length in the larynx.

4. Discussion

Patients may occasionally suffer from hoarseness of voice or sore-throat after endotracheal intubation, and a small percentage may develop laryngeal injuries of variable severity (1). Due diligence in selecting the appropriate tube size is mandated, in an effort to decrease the chance of encountering such complications. Traditionally, an endotracheal tube size of 7-7.5mm is used in females and 8.5mm is used in males. These sizes have been adoptedfrom Western anesthesia textbooks (2,3). However, since anthropometric measurements generally vary between ethnicities (14), our study aims to observe the normal range of tracheal diameters in the Saudi population and to compare our results with those published internationally. To our knowledge, this current study is the first study to measure tracheal diameters in the Saudi population.

Earlier studies have used radiographs as a method for obtaining tracheal measurements. Breatnach et al. measured the AP and transverse diameter of the trachea on posteroanterior and lateral x-rays of 808 adult subjects at a point 2 cm above the aortic arch. They found that in adult males of all ages, the AP diameter is consistently larger than the transverse diameter. That observation was not as strong in females, and the difference was significant only from the third decade onward. As in our study they didn't find any correlation between the tracheal measurements and the subject's height or weight (5).

In the current study, we have used CT scan as the method for tracheal measurement as it is non-invasive, well tolerated by patients, reproducible, and found to be comparable to bronchoscopy; which is the gold standard for tracheal measurements; by koletsis et al(8). The decision to use CT scan rather than radiographs was also influenced by a retrospective study by Sakuraba et al (7), which has compared tracheal diameter obtained from chest x-rays and those using CT scans utilizing data of patients who underwent cervical vertebral laminectomy in 146 patients who received both conventional chest radiographs and CT scans. The study found that measurements using x-rays didn't correlate with those using CTs and concluded that radiographs are not useful to select the appropriate size of ETT.

We have opted to use CT scans of the neck that reached the carina so that the whole length of the trachea would be included in all subjects. That is in contrary to a study done by Gamsu and Webb et al. (11), which studied normal and abnormal trachea using CT scan. It included normal 50 adult patients, only 10 patients in whom the trachea was visualized throughout its entire length. The rest of the normal patients, it was either the extra or intrathoracic trachea that was analysed. However, the focus of their study was the morphology of trachea and adjacent structures with a comparison of the normal to the abnormal rather than the measurements per say.

Only a few studies have addressed nation-specific CT measurements of the trachea. A study conducted in New Zealand assessed tracheal morphometry in vivo using chest CT scans of 60 adult patients supplemented by measurements of 10 cadaver tracheas (6). Their measurements of maximum transverse and anteroposterior diameters were done just above the carina. Their results showed a mean anteroposterior diameter of 21.4± 3.2, mean transverse was 25.7 ±3.7.That study in addition to the comparison by in vitro data has also differed from ours by the additional measurement of tracheal volume, position of the carina in relation to midline and the subcarinal angle.

An Iranian prospective study by Zahedi-Nejad N et al. included 200 adult patients (14). Anteroposterior and transverse diameter were obtained at two levels: right below sternal notch and right below the lower aspect of the aorticarch. They yielded a mean AP of 19.6 mm in males and 14.8 mm in females. The corresponding mean transverse diameter values were as follows, 18 mm in males and 14.9 in females. They compared their result withradiology textbooks (17).They have concluded that Persian people tracheal measurements are close to those of the European people and attributed the apparent difference to the different measurement techniques.

Kumar and Ravikumar have produced similar work studying the internal diameters of the subglottic region and the trachea in the Indian population (12). It was a cross-sectional observational study including 48 subjects who undergone neck and chest CT scans for reasons other than airway compromise. Their methodology differed in that they measured anteroposterior, transverse and circumference at various levels from 5 to 70 mm below the level of the glottis in the subglottic and upper trachea. The mean transverse diameter was 16.5 in males and 17.34 in females. The mean sagittal was 12.55 in males and 13.05 in females. They have concluded that dimensions of the subglottic region and trachea are less than that stated in the western literature and have raised the question of whether they are using larger than needed endotracheal tube sizes.

Boiselle et al. studied tracheal collapsibility in healthy volunteers during forced expiration using CT scans. In his paper, he had compared tracheal diameters during inspiration and expiration. The diameters were obtainedat two anatomic levels: 1 cm above the aortic arch and 1 cm above the carina. The study included 51 healthy adult subjects. We used the measurements obtained in inspiration in a comparison with our study even though Boiselle et al. did address the ethnicity of the studied population (15).

We have observed that the tracheal dimensions in females are comparatively smaller with statistically significant difference compared to males. The marked gender dimorphism was also noted by other studies(6,12,14).

In comparison between our study and the previously mentioned studies, we found that the most pronounced difference was between our study and the study by Kamel et al.(6). We found that the mean anteroposterior diameter was 19.20± 3.2 in the Saudi subjects versus 21.4± 3.2 in New Zealanders, the difference between means was 2.2 . ; mean transverse diameter was 15.55±2.2 in the Saudi subjects versus 25.7 ±3.7 in New Zealanders, the difference between means was 10.15. That difference is too large tobe attributed to different measurement techniques.

The limitation of our study included its retrospective nature; the reality that all subjects were patients who performed CT scans of the neck for one reason or another. In the sake of reducing the limiting effect of the latter, we have excluded all subjects with factors possibly affecting the tracheal morphometry. The small sample size was also a limitation that was in part due to the fact the study targeted Saudi population while most of the CTs done during the allocated study period were for non-Saudis. In comparing our results with other studies, the fact that each of those studies has chosen a different measurement level was also a limiting factor.

5. Conclusion

We conclude that the tracheal dimensions in the Saudi population appear to be smaller than the New Zealanders and possibly the Americans and closer in parameters to the Iranian or Japanese population. This prompts the question of whether we have been using larger than necessary endotracheal tube sizes. Prospective studies using a larger sample size would be beneficial in an attempt to strengthen our conclusion. Studies in collaboration with anesthesiologists and surgeons should be made to determine the rate of post-intubation complication and correlate with tube size used. If we could validate our conclusion, this might change the practice of endotracheal intubation in our country. A secondary benefit of generating the range of the normal tracheal dimensions is to know what is obviously abnormal, and this might help the radiologists and in turn the treating physicians in cases of undiagnosed tracheal stenosis (resulting from a tracheostomy, prolonged intubation or previous neck trauma), saber-sheath trachea, tracheomegaly or tracheomalacia.

References

[1] Hillel A, Karatayli-Ozgursoy S, Samad I, Best S, Pandian V, Giraldez L et al. Predictors of Posterior Glottic Stenosis: A Multi-Institutional Case-Control Study. Annals of Otology, Rhinology & Laryngology. 2015;.
[2] Scott Moses M. Endotracheal Intubation Preparation [Internet]. Fpnotebook.com. 2015 [cited 31 October 2015]. Available from:http://www.fpnotebook.com/lung/Procedure/EndtrchlIntbtnPrprtn.htm
[3] Miller R, Pardo M, Stoelting R. Basics of anesthesia. Philadelphia, PA: Elsevier/Saunders; 2011.
[4] Coordes A, Rademacher G, Knopke S, Todt I, Ernst A, Estel B, et al. Selection and placement of oral ventilation tubes based on tracheal morphometry. Laryngoscope. 2011;121(6):1225-30.
[5] Breatnach E, Abbott GC, Fraser RG. Dimensions of the normal human trachea. AJR Am J Roentgenol. 1984;142(5):903-6.
[6] Kamel KS, Lau G, Stringer MD. In vivo and in vitromorphometry of the human trachea. Clin Anat. 2009;22(5):571-9
[7] Sakuraba S, Serita R, Kuribayashi J, Kosugi S, Arisaka H, Yoshida K, et al. Comparison of tracheal diameter measured by chest x-ray and by computed tomography. Anesthesiol Res Pract. 2010;2010.
[8] Koletsis EN, Kalogeropoulou C, Prodromaki E, Kagadis GC, Katsanos K, Spiropoulos K, et al. Tumoral and non-tumoraltracheastenoses: evaluation with three-dimensional CT and virtual bronchoscopy. J Cardiothorac Surg. 2007;2:18.
[9] Takita K, Morimoto Y, Okamura A, Kemmotsu O. Do age-based formulae predict the appropriate endotracheal tube sizes in Japanese children? J Anesth. 2001;15(3):145-8.
[10] Wang TK, Wu RS, Chen C, Chang TC, Hseih FS, Tan PP. Endotracheal tube size selection guidelines for Chinese children: prospective study of 533 cases. J Formos Med Assoc. 1997;96(5):325-9.
[11] Gamsu G, Webb WR. Computed tomography of the trachea: normal and abnormal. AJR Am J Roentgenol. 1982;139(2):321-6.
[12] Prasanna Kumar S, Ravikumar A. Biometric study of the internal dimensions of subglottis and upper trachea in adult Indian population. Indian J Otolaryngol Head Neck Surg. 2014;66(Suppl 1):261-6.
[13] Stern EJ, Graham CM, Webb WR, Gamsu G. Normal trachea during forced expiration: dynamic CT measurements. Radiology. 1993;187(1):27-31.
[14] Zahedi-Nejad N, Bakhshayesh-Karam M, Kahkoei S, Abbasi-Dezfoully A, Masjedi MR. Normal dimensions of trachea and two main bronchi in the Iranian population. Pol J Radiol. 2011;76(4):28-31.
[15] Boiselle PM, O'Donnell CR, Bankier AA, Ernst A, Millet ME, Potemkin A, et al. Tracheal collapsibility in healthy volunteers during forced expiration: assessment with multidetector CT. Radiology. 2009;252(1):255-62.
[16] Schwartz R, Stayer S, Pasquariello C. Tracheal tube leak test — is there inter-observer agreement?. Can J Anaesth. 1993;40(11):1049-1052.
[17] Padle S, MacDonald S LS: The central airways. In: Adam: Grainger & Allison's ed. diagnostic radiology, 5th ed. China; Churchill Livingstone, electronic ed. An Imprint of Elsevier, 2008; 12

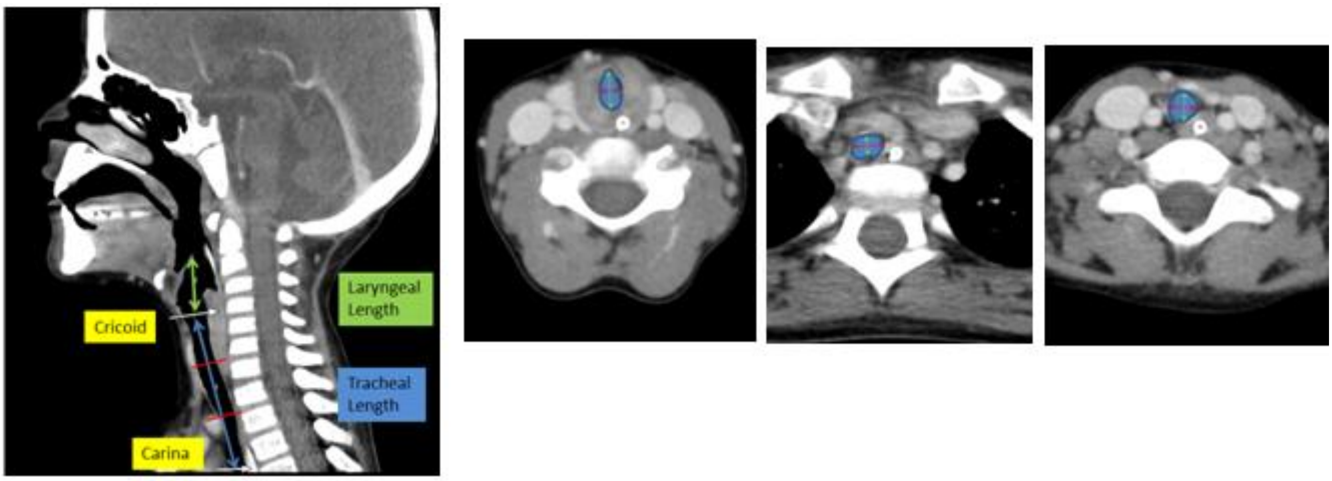

Figure 1: Midsagittal CT scan image, Position of the cricoid and carina identified (in yellow), Laryngeal length (in green), Tracheal length (in blue). Corresponding axial images at the level of cricoid, junction of proximal and middle third (top red line and junction of middle and distal thirds(bottom red line). AP(green arrow),TRANS (red arrow),CS(blue circle)

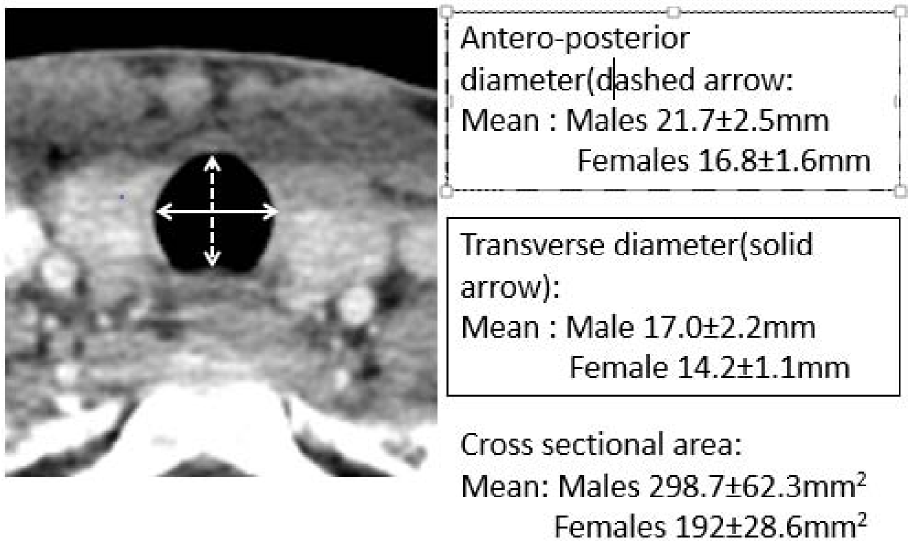

Figure 2: Normal tracheal cross-sectional measurements in Saudi males and females

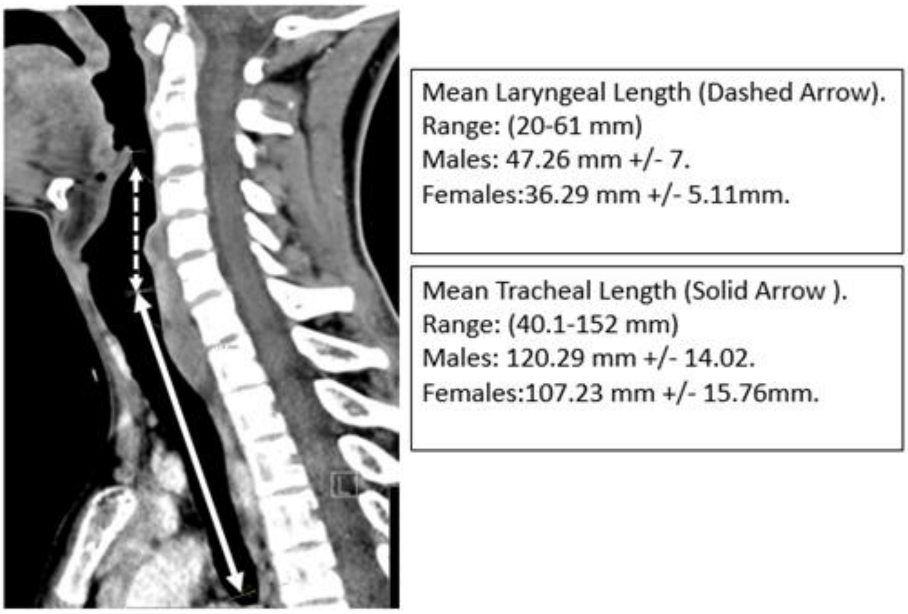

Figure 3.Mid-sagital CT scan of the neck showing tracheal length and laryngeal length

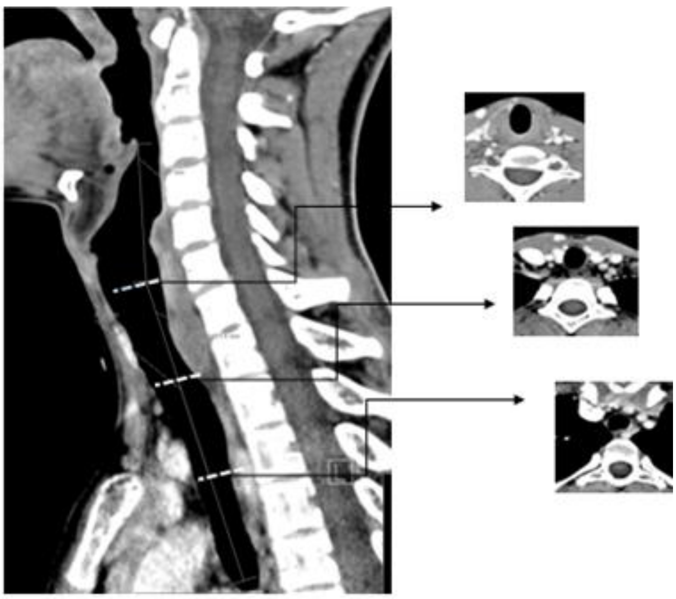

Figure 4: Mid-sagital CT scan of the neck showing the three levels at which AP,TRANS & CS were obtained.

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Table 1: Subject's Demographics

Variable	Total	Male		Female		p-value
		Mean	SD	Mean	SD	
Age (years)	36[16]	38	17	34	15	.292
Height (m)	1.6 [.079]	1.7	.061	1.6	.059	<.001
Weight (kg)	71 [22]	74	30	64	16	.250
BMI (kg/m²)	27 [7]	27	11	26	6	.877

Table 2: Anatomical Measurements in the Saudi population and Gender Differences

Variable	Total		Male		Female		p-value
	Mean	SD	Mean	SD	Mean	SD	
Laryngeal Length	41.61	8.20	47.26	7.00	36.29	5.11	<.001*
Tracheal Length	113.57	16.22	120.29	14.02	107.23	15.76	.001*
Mean AP*	19.21	3.20	21.70	2.48	16.85	1.63	<.001*
Mean TRANS*	15.55	2.21	16.97	2.24	14.22	1.05	<.001*
Mean CS*	243.75	71.87	298.76	62.32	191.89	28.59	<.001*

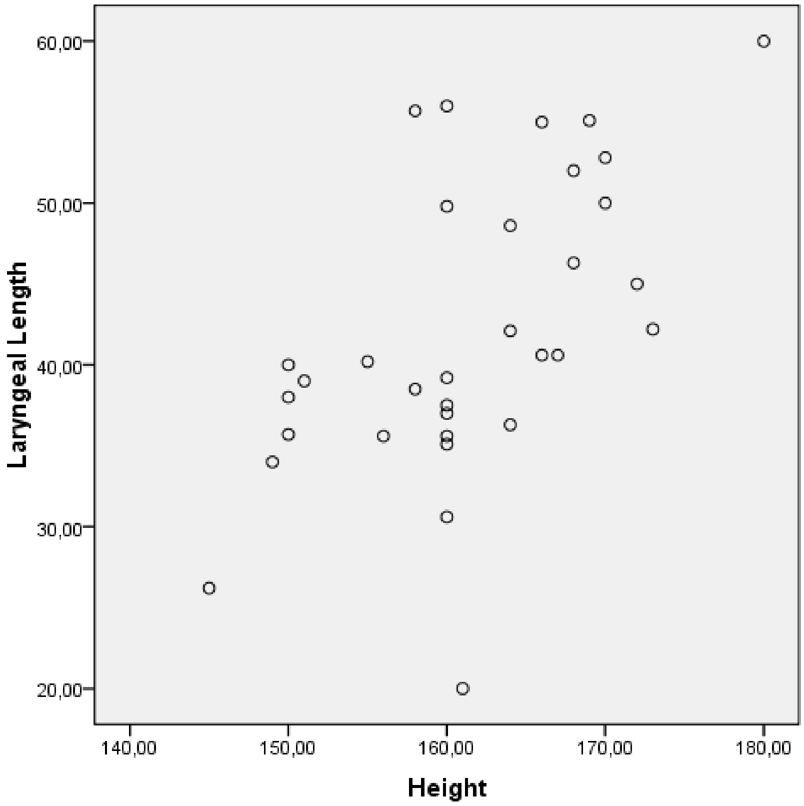
Table 3: Detailed measurements of the tracheal section, at three levels

Measurement		**Total**	**Males**	**Females**	**p-value****
		Mean [SD]	Mean [SD]	Mean [SD]	
Proximal (Cricoid)	AP	20.00 [3.71]	22.58 [2.68]	17.58 [2.87]	<.001*
	TRANS	13.06 [2.54]	14.19 [2.47]	11.99 [2.13]	<.001*
	CS	206.32 [64.47]	252.04 [60.11]	163.20 [29.10]	<.001*
(Medial)	AP	20.27 [3.92]	23.04 [3.63]	17.67 [1.90]	<.001*
	TRANS	16.44 [2.70]	18.12 [2.84]	14.86 [1.24]	<.001*
	CS	277.20 [93.45]	345.74 [85.90]	212.58 [37.49]	<.001*
Distal	AP	17.33 [3.42]	19.49 [3.23]	15.29 [2.13]	<.001*
	TRANS	17.15 [2.56]	18.60 [2.61]	15.8 [1.60]	<.001*
	CS	24.73 [77.32]	298.76 [71.98]	199.87 [45.25]	<.001*

Measurement		**Total**	**Males**	**Females**	**p-value****
		Mean [SD]	Mean [SD]	Mean [SD]	
Proximal (Cricoid)	AP	20.00 [3.71]	22.58 [2.68]	17.58 [2.87]	<.001*
	TRANS	13.06 [2.54]	14.19 [2.47]	11.99 [2.13]	<.001*
	CS	206.32 [64.47]	252.04 [60.11]	163.20 [29.10]	<.001*
(Medial)	AP	20.27 [3.92]	23.04 [3.63]	17.67 [1.90]	<.001*
	TRANS	16.44 [2.70]	18.12 [2.84]	14.86 [1.24]	<.001*
	CS	277.20 [93.45]	345.74 [85.90]	212.58 [37.49]	<.001*
Distal	AP	17.33 [3.42]	19.49 [3.23]	15.29 [2.13]	<.001*
	TRANS	17.15 [2.56]	18.60 [2.61]	15.8 [1.60]	<.001*
	CS	24.73 [77.32]	298.76 [71.98]	199.87 [45.25]	<.001*

Table 4: Anatomical Correlations (linear regressions)

Measurement (dependent variable)	**Predictors**									
	Age		**Height**		**Weight**		**BMI**		**Tracheal Length**	
	Coef.	**P-value**	**Coef.**	**P-value**	**Coef.**	**P-value**	**Coef.**	**P-value**	**Coef.**	**P-value**
Laryngeal Length	.018	.783	.669	.000*	.125	.060	.205	.298	.098	.113
Tracheal Length	0.121	.343	.225	.562	-.092	.470	-.361	.324	NA	NA
Mean AP*	.027	.288	.285	<.001*	.032	.153	.028	.678	.064	.007
Mean TRANS*	.040	.018	.139	.011	.000	.991	-.035	.520	.056	.001
Mean CS*	1.149	.039*	5.263	<.001*	.278	.604	-.484	.756	1.761	.001*


60,00
50,00
40,00
30,00
20,00
Laryngeal Length
140,00
150,00
160,00
170,00
180,00
Height