Original Article

A morphometric analysis of laryngeal anatomy: A cadaveric study

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ABSTRACT

Objectives: This study aims to describe morphometric measurements of the laryngeal framework and discuss their implications for phonosurgery among Turkish subjects.

Patients and Methods: Larynges from 40 male and 20 female fresh cadavers were extracted during autopsy in a forensic science institution between January 2015 and December 2015. Measurements were taken of the length of membranous and cartilaginous vocal fold (mVF, cVF), width and thickness of VF (wVF, tVF), anterior and posterior subglottic distance (AS, PS), width and height of thyroid cartilage (wTC, hTC), and distance between projection of anterior commissure to thyroid cartilage inferior border (pAC to TIB).

Results: For all parameters, median and mean values were higher in male groups, but the differences were significant only in pAC to TIB, wTC, cVF and mVF groups ($p<.05$). No statistically significant difference between age groups was found. The location of AC was observed above the midpoint of the thyroid cartilage, and the mean distance between the pAC to TIB was 10.2±2.9 mm in males and 7.8±1 mm in females. The mean AS value was 13.14±3.67, whereas the posterior subglottic distance mean value was 7.14±1.35.

Conclusion: Although sex is an important factor to define laryngeal morphometrics, age may not be a significant factor. The significant difference in mean distance from pAC to TIB among males and females is an important consideration in laryngeal framework surgery. However, studies with larger samples are needed to confirm our findings.

Keywords: Anatomy; laryngoplasty; larynx.

The first laryngeal framework surgery for medialization was an anterior based cartilage flap reported in 1915 by Payr.[1] In 1975 Isshiki et al.[2] described medialization by displacing and stabilizing a rectangular cartilage. Koufman[3] popularized medialization laryngoplasty with the use of a silastic block in 1986. Since then laryngeal framework surgeries become popular and widely used in otolaryngology clinics, and are now accepted as one of the workhorses of laryngology.

Laryngoplasty and partial laryngectomies (both represented in this paper as laryngeal framework surgery) heavily depend on laryngeal morphometrics for landmarks during surgery. It is vital for the surgeons to understand the anatomical differences between races, genders and age groups to modify technical details during surgery.

Type 1 thyroplasty is one of the laryngeal framework surgeries first described by Isshiki

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in 1974, that has become one of the most commonly used procedures by laryngologic surgeons.[2,4] This procedure was named medialization thyroplasty in the 2007 guideline to classify phonosurgeries by the European Laryngology Society.[5] The most important step of this surgery is localizing the anterior commissure and vocal process of the arytenoid cartilage.[6]

The aim of this study is to define clinically important anatomical measurements of laryngeal structures among genders and different age groups to establish the normal range of variation in laryngeal framework measurements in a Turkish sample, and with the help of this data to discuss traditional surgical landmarks of laryngeal framework surgery (LFS).

PATIENTS AND METHODS

This study was granted ethical approval by the Education and Science Commission of Council of Forensic Medicine (CFM) on 17/02/2015 with approval number: 21589509/233. Informed consent was obtained from the families of participants, whose identities were hidden. The study was conducted in accordance with the principles of the Declaration of Helsinki.

A total of 60 fresh cadaver larynges were harvested from 40 males and 20 females during autopsy. Only fresh (time of death less than 24 hours) adult cadavers with proven Turkish nationality were used in this study. Data including age, weight, height, sex and ethnicity were gathered from CFM database. Causes of death varied, including head injuries, heart attacks, abdominal hemorrhage, gunshot injuries and drug abuse. Patients with a history of neck trauma, neck operation or any incidence affecting neck muscles were excluded from the study.

Measurements

Measurements including dimensions of the thyroid cartilage, position of the anterior

Table 1. Measurements

Measurement	Description
Length of membranous vocal fold (mVF)	From anterior commissure to anterior edge of vocal process
Length of cartilaginous vocal fold (cVF)	From anterior edge of vocal process to posterior commissure
Width of vocal fold (wVF)	Distance from thyroid cartilage inner perichondrium to free margin of vocal fold on the anterior edge of vocal process
Depth of vocal fold (dVF)	Distance from superior surface of the vocal fold to the inferior surface of vocal fold on the anterior edge of vocal process
Anterior subglottic distance	From anterior commissure to inferior border of thyroid cartilage on the endolaryngeal side
Posterior subglottic distance	From the midline of posterior commissure to inferior border of thyroid cartilage on the endolaryngeal side
Width of thyroid cartilage	From pAC to posterior border of thyroid cartilage on the right side
Height of thyroid cartilage	From thyroid notch to inferior thyroid border in midline
Superior distance of anterior commissure (pAC to TN)	Distance from pAC to TN
Inferior distance of the anterior commissure (pAC to ITB)	Distance from pAC to ITB in midline

VF: Vocal fold; pAC: Projection of anterior commissure; TN: Thyroid notch; ITB: Inferior thyroid border.

commissure, length of vocal folds and subglottic distances were taken with a caliper (Karl Storz SE & Co. KG Tuttlingen, Germany). All measurements were taken by the same operator using the same instrument (Table 1).

As a part of the autopsy, each larynx was harvested and soft tissues around the thyroid and cricoid cartilage were excised (Figure 1). To begin measurements, the projection of anterior commissure (pAC) was marked at the outer part of the thyroid cartilage with the help of a 24G needle by penetrating the cartilage inside to out. Laryngeal framework (external measurements) and endolaryngeal measurements were done. Results were assessed according to sex and age groups.

External measurements included *(i)* distance between pAC and thyroid cartilage inferior border (TIB), *(ii)* distance between pAC and thyroid notch (TN), *(iii)* distance between pAC and laryngeal prominence (LP). and *(iv)* distance between the pAC to lateral border of thyroid cartilage width (wTC) and height (hTC) (Figure 2 and 3).

Endolaryngeal measurements included *(i)* vocal fold (VF) length, *(ii)* membranous (mVF) and cartilaginous (cVF) VF length, *(iii)* Vocal fold width (wVF) (Figure 4), *(iv)* vocal fold depth (dVF), *(v)* anterior subglottic distance (AS), and *(vi)* posterior subglottic (PS) length.

Thirteen different measurements were taken from each larynx specimen for a total of 780 measurements. For each parameter, a mean value, a median value, standard deviation and lowest and highest values were calculated. The differences between mean values of parameters in male and female groups were calculated with Mann-Whitney U test due to low subject numbers of the female group.

Differences between age groups were calculated for each parameter by dividing subjects into three subgroups: *(i)* below 40 years of age, *(ii)* between 40 and 60 *(iii)* over 60 years of age. ANOVA test was used for wTC, mVF, cVF and AS measurements which were suitable for normal distribution, and for all other parameters Kruskal-Wallis test was applied.

Figure 1. *A fresh larynx specimen with the surrounding fat tissue.*

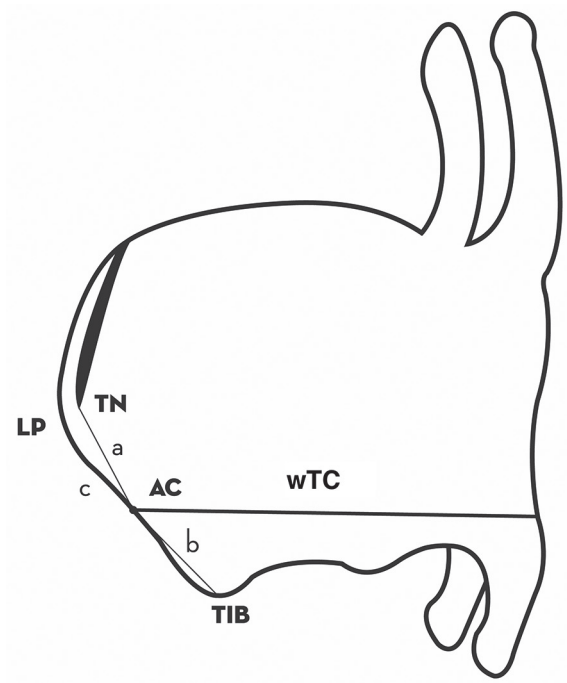

Figure 2. *Lateral view of the thyroid cartilage showing external measurements.* *LP: Laryngeal prominence; TN: Thyroid notch; AC: Anterior commissure; wTC: Width of thyroid cartilage; TIB: Thyroid cartilage inferior border.*

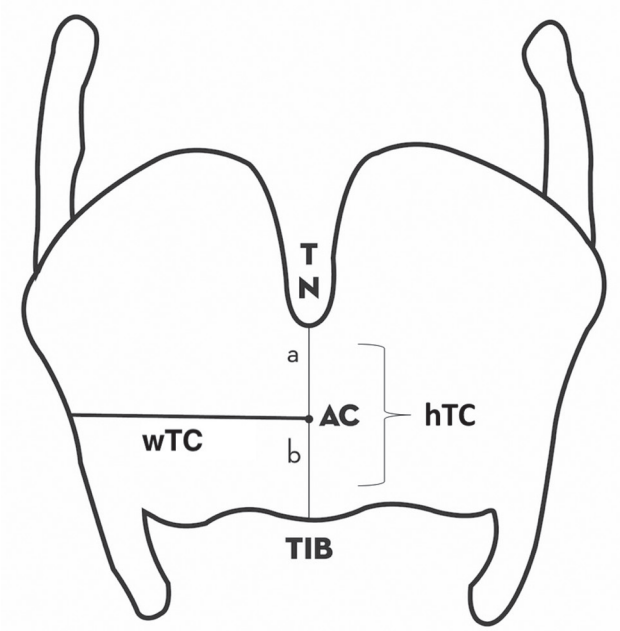

Figure 3. *Anterior view of the thyroid cartilage showing external measurements.* *TN: Thyroid notch; AC: Anterior commissure; wTC: Width of thyroid cartilage; hTC: Height of thyroid cartilage; TIB: Thyroid cartilage inferior border.*

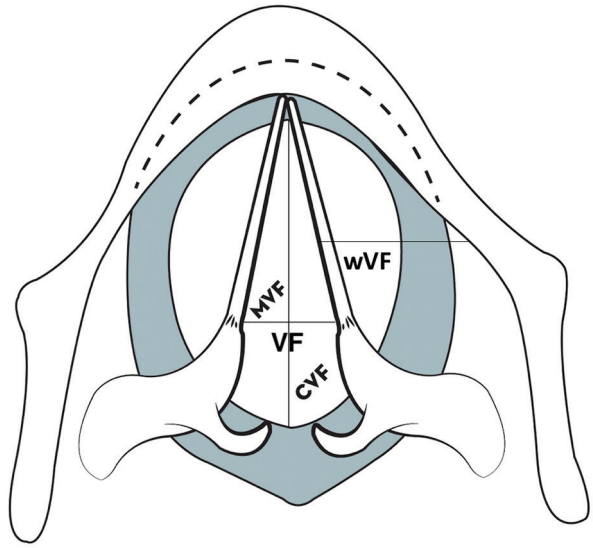

Figure 4. *Superior view of endolarynx showing internal measurements.* *mVF: Membraneous vocal fold; wVF: Width of the vocal fold; VF: Vocal fold; cVF: Cartilaginous vocal fold.*

Correlation of wTC to height was evaluated by using Pearson and Spearman correlation tests respectively.

Statistical analysis

Statistics were computed using IBM SPSS version 21.0 (IBM Corp., Armonk, NY, USA). The Kolmogorov-Smirnov test was applied for each parameter in the study. An ANOVA test was used for these parameters, and for all other parameters that Kruskal-Wallis test was applied.

RESULTS

The mean age was 45.2±18 for males (n=40) and 53.7±20 for females (n=20), with an overall range of 19-85 years. The average height and weight among males was 171±7.9 mm and 84±14 kg, respectively. Among females the average height and weight was 159±3 mm and 69±12.3 kg, respectively.

External and endolaryngeal measurements are provided in Table 2 and Table 3 respectively.

Mean pAC-TIB value was 10.27±2.96 mm for the male group and 7.86±1 mm for the female group. Mean wTC value was 40.2±4 mm for the

Table 2. External laryngeal measurement results

		Mean±SD (mm)	*p*
TN-AC			
Male	40	8.6±2.13	0.074
Female	20	7.14±1.4	
LP-AC			
Male	40	11.55±3.63	0.069
Female	20	9.29±2.63	
AC-TIB			
Male	40	10.27±2.96	0.012
Female	20	7.86±1	
wTC			
Male	40	40.2±4	0.000
Female	20	29.14±4	
hTC			
Male	40	18.8±2.26	0.432
Female	20	14.4±2.92	

SD: Standard deviation; TN: Thyroid notch; AC: Anterior commissure; LP: Laryngeal prominence; TIB: Thyroid cartilage inferior border; wTC: Width thyroid cartilage; hTC: Height thyroid cartilage.

Table 3. Endolaryngeal measurements

		Mean±SD (mm)	*p*
VF			
Male	40	20.77±3.75	0.001
Female	20	16.43±1.51	
mVF			
Male	40	13.75±3	0.001
Female	20	10.71±0.49	
cVF			
Male	40	7.02±2.32	0.220
Female	20	5.71±1.25	
AS			
Male	40	15.77±3.28	0.068
Female	20	13.14±3.67	
PS			
Male	40	8.07±1.18	0.161
Female	20	7.14±1.35	
wVF			
Male	40	8.22±1.18	0.163
Female	20	7.43±1.27	
dVF			
Male	40	7±1.5	0.392
Female	20	6.57±1.27	

SD: Standard deviation; VF: Vocal fold; mVF: Membranous vocal fold; cVF: Cartilaginous vocal fold; AS: Anterior subglottic; PS: Posterior subglottic; wVF: Width vocal fold; dVF: Depth vocal fold.

male group and and 29.14±4 mm for female group. A statistically significant difference was found in pAC-TIB (p<.05) and wTC (p<.0001).

Mean cVF value was 7.02±2.32 mm for the male group and 5.71±1.25 mm for the female group. Mean mVF value was 13.75±3 mm for the male group and 16.43±1.51 mm for the female group. A statistically significant difference was found in cVF (p<.05) and mVF (p<.05).

No statistically significant difference was found in any parameters between age groups.

Correlation of wTC to height showed no significant differences.

DISCUSSION

To the best of our knowledge, this study is the most extensive study with the largest group on larynx morphometrics in Turkey. Previous studies showed vocal cord localizations, but were inadequate in evaluating overall larynx morphometrics.[7] This study presents important additional information for acoustic, biomechanical, forensic, and radiologic studies, and especially for laryngeal framework surgeries.

Sexual dimorphism was observed in laryngeal measurements of male and female cadavers. All measurements were lower in females than males. However, this difference was statistically significant only for pAC-TIB, wTC, cVF, mVF measurements (p<.05). In a study by Jotz et al.[8] in 2014 among a South Brazilian population, other laryngeal morphometric values were also found significantly different. This difference may be caused by the lower number of woman subjects in our study.

In our study, we found a mean wTC value of 40.2±4.1 mm in males and 29.14±4.14 mm in females. Our literature review showed that these results in a Turkish population resemble the East European population results of Kovac et al.[9] (M:F 39.2:28.3 mm) Results among Indian,[10] African[11] and South American[8] and Asian[12] populations are also in close range.

Our mean thyroid cartilage height value was 14.4±2.92 mm in females and 18.8±2.26 mm in males. Similar results can be found in the literature; Eckel et al.[13] found 23±3.9 mm in males and 15.0±2.1 mm in females, Jotz et al.[8] found 20.77±2.7 mm in males and 15.39±2.3 mm in females. The only study on anterior commissure and vocal process localization in a Turkish population was by Çınar et al.[7] in 2003, in which the mean thyroid cartilage height was measured at 19.62 mm in males and 13.23 mm in females. Our results are consistent with that study.

The key points in describing the localization of the anterior commissure during surgery are the upper and lower ends of the midpoint of thyroid cartilage. In our study the distance between TIB and pAC was 7.86±1 mm in females and 10.27±2.96 mm in males. The highest value was 23 mm and the lowest was 6 mm. The distance between pAC and TN was 7.14±1.4 mm in females and 8.6±2.13 mm in males. In our Turkish sample the ratio between TIB-AC to

thyroid cartilage height was 0.53±0.05 in females and 0.54±007 in males. These results show that the position of pAC is just above the midpoint. Using the distance from the inferior border to pAC and midpoint of the thyroid cartilage as two landmarks may increase success rates of phonosurgery.

As mentioned above, Çınar et al.[7] investigated the distances between pAC and vocal process of the arytenoid cartilage, and the distances between these projection points to the inferior border of the thyroid cartilage.[7] In their study the mean value for AC-TN and AC-TIB was 7.88±2.8 mm and 7.49±2.57 mm in females and 9.94±2.96 and 10.83±2.55 in males.[7] In their study the position of the anterior commissure was also found slightly above the midpoint in males but slightly below the midpoint in females.[7] These results suggest that in type 1 thyroplasty, instead of opening a window from 5 to 7 mm superior to the inferior border of the thyroid cartilage (as shown in the literature and used commonly by otolaryngologists), it may be more useful to consider the entire height of the thyroid cartilage and open a window just below the midpoint of the thyroid cartilage in order to access the vocal cord level.[2,14,15]

Mean vocal cord lengths in our study were 20.77±3.75 mm in males and 16.43±1.51 mm in females which were significantly different ($p<.05$). Similar differences were also shown by Jotz et al.[8] in a South American population (24.46±2.66 in males and 17.91±2.15 in females) and by Eckel et al.[13] in a German population (22.09±3.07 in males and 17.55±0.92 in females).

Mean cartilaginous vocal fold length in our study was 702±232 mm in males and 5.71±1.25 mm in females. Similar results were obtained by Eckel et al.[13] (8.6±1.8 mm in males and 6.93±0.71 mm in females) and Jotz et al.[8] (9.49±1.58 mm in males and 6.73±1.13 mm in females). Although our results are consistent with the literature, lower scores in men are noteworthy.

In our study the mean wVF value for males and females was 8.22±1.18 mm and 7.43±1.27 mm, respectively. Hu et al.[16] measured wVF of 6.23±0.53 mm in males, and 4.90±0.35 mm in females by ultrasonographic evaluation of the true and false vocal cords. Our findings are consistent with their results. Furthermore, Eckel et al.[13] measured 4.2 mm in males, and 3.1 mm in females in their cadaver study. Although there is consistency between our findings and those in the literature, there is a distinct difference in some measurements such as vocal fold length and thyroid cartilage size. Also, findings that show smaller thyroid cartilage size in Asian people and bigger in European people supports the idea of ethnic effects on cartilage and bone growth. These findings may be due to ethnicity, but it may also be due to different delineation of the parameters or difference in observers.

In conclusion it is worth considering that laryngeal morphology is highly variable among patients even in the same society. These differences can affect surgical landmarks. Even though the number of cases included in our study is similar with the literature, future studies with bigger sample sizes are necessary to make better judgments about how laryngeal morphometrics can influence surgical plans in the operation room.

Declaration of conflicting interests

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REFERENCES

1. Payr E. Plastik am Schildknorpel zur Behebung der Folgen einseitiger Stimmbandlähmung. Dtsch med Wochenschr 1915;41:1265-70.
2. Isshiki N, Morita H, Okamura H, Hiramoto M. Thyroplasty as a new phonosurgical technique. Acta Otolaryngol 1974;78:451-7.
3. Koufman JA. Laryngoplasty for vocal cord medialization: an alternative to Teflon. Laryngoscope 1986;96:726-31.
4. Isshiki N. Phonosurgery. Tokyo: Springer Japan; 1989.
5. Friedrich G, Remacle M, Birchall M, Marie JP, Arens C. Defining phonosurgery: a proposal for classification and nomenclature by the Phonosurgery Committee of the European Laryngological Society (ELS). Eur Arch Otorhinolaryngol 2007;264:1191-200.
6. Kikkawa YS, Tsunoda K, Niimi S. Prediction and surgical management of difficult laryngoscopy. Laryngoscope 2004;114:776-8.

7. Cinar U, Yigit O, Vural C, Alkan S, Kayaoglu S, Dadas B. Level of vocal folds as projected on the exterior thyroid cartilage. Laryngoscope 2003;113:1813-6.
8. Jotz GP, Stefani MA, Pereira da Costa Filho O, Malysz T, Soster PR, Leão HZ. A morphometric study of the larynx. J Voice 2014;28:668-72.
9. Kovac T, Popović B, Marjanović K, Wertheimer V, Kovacević M, Nikolić V, et al. Morphometric characteristics of thyroid cartilage in people of Eastern Croatia. Coll Antropol 2010;34:1069-73.
10. Joshi M, Joshi S, Joshi S. Morphometric study of cricoid cartilages in Western India. Australas Med J 2011;4:542-7.
11. Ajmani ML. A metrical study of the laryngeal skeleton in adult Nigerians. J Anat 1990;171:187-91.
12. Tayama N, Chan RW, Kaga K, Titze IR. Geometric characterization of the laryngeal cartilage framework for the purpose of biomechanical modeling. Ann Otol Rhinol Laryngol 2001;110:1154-61.
13. Eckel HE, Sittel C, Zorowka P, Jerke A. Dimensions of the laryngeal framework in adults. Surg Radiol Anat 1994;16:31-6.
14. Rosen CA, Simpson B. Operative Techniques in Laryngology. Berlin, Heidelberg: Springer, Berlin, Heidelberg; 2008.
15. Shinghal T, Anderson J, Chung J, Hong A, Bharatha A. Effect of Medialization Thyroplasty on Glottic Airway Anatomy: Cadaver Model. J Voice 2016;30:757.e1-757.e6.
16. Hu Q, Zhu SY, Luo F, Gao Y, Yang XY. High-frequency sonographic measurements of true and false vocal cords. J Ultrasound Med 2010;29:1023-30.

