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Morphometric Analysis of the Human Trachea A Cadaveric Study in the Gujarati Population

Dr Mohit Changani[1*], Dr Urvik Kukadiya[2], Dr Pratik Trivedi[3], Dr Mayankkumar Javia[4]

[1]Associate Professor, Department of Anatomy, Saraswati Medical College, Unnao, UP
[2]Assistant Professor, Department of Anatomy, GMERS Medical College, Junagadh, Gujarat
[3]Tutor, Department of Anatomy, GMERS Medical College, Junagadh, Gujarat
[4]Associate Professor, Department of Anatomy, Banas Medical College & Research Institute, Palanpur, Gujarat

Corresponding author: Dr Mohit Changani
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Abstract

Background: Precise knowledge of tracheal morphometry is vital for various clinical procedures, including endotracheal intubation, tracheostomy, and surgical reconstructions. Tracheal dimensions are known to vary significantly across different ethnic populations. This study aimed to establish baseline morphometric standards for the human trachea specifically within the Gujarati population.

Methods: A cadaveric study was conducted on 50 adult specimens (34 males, 16 females; age range 15–83 years). Morphometric parameters, including anteroposterior (AP) diameter, transverse (T) diameter, and external circumference, were measured at three anatomical levels: upper (below cricoid), middle, and lower (above bifurcation) using a sliding vernier caliper and the flexible thread method.

Results: The mean (±SD) AP diameters for the total cohort at the upper, middle, and lower levels were 1.82±0.31 cm, 1.72±0.28 cm, and 1.61±0.26 cm, respectively. The corresponding transverse diameters were 1.96±0.31 cm, 1.92±0.32 cm, and 1.97±0.33 cm. Tracheal circumference averaged 6.29±0.93 cm at the upper level and 6.13±0.94 cm at the lower level. Highly significant sexual dimorphism ($p < 0.01$) was observed across all parameters, with male dimensions consistently exceeding those of females. In both sexes, the transverse diameter generally exceeded the AP diameter.

Conclusion: The Gujarati population exhibits unique tracheal dimensions that are larger than South Indian cohorts but smaller than Western populations. These findings provide essential population-specific data for anesthesiologists and surgeons to optimize airway management and for forensic experts in sex determination.

Keywords: Trachea, Morphometry, Gujarati Population, Cadaveric Study, Sexual Dimorphism, Airway Management.

Introduction

The respiratory system is a fundamental prerequisite for life in living animals. Throughout evolution, this system has undergone significant changes, developing into the complex branching network known as the tracheobronchial tree in higher animals like humans.[1] The normal anatomy of this tree is of paramount importance across multiple medical disciplines, including bronchoscopy, otorhinolaryngology, anesthesiology, forensic medicine, surgery, radiology, and pulmonology.[2]

As the essential organs of respiration, the lungs facilitate the uptake of oxygen and the removal of carbon dioxide from the blood. Any anatomical or physiological alteration to these organs necessitates urgent medical intervention.[1] Consequently, a precise understanding of the normal anatomy and various dimensions—such as diameters, circumference, and length—of the human respiratory tract is inevitable for clinical success.[3,4]

The trachea serves as the first-generation respiratory passageway, distributing air to the

lungs via the bronchi and bronchioles.[1] Accurate morphometric measurements of the trachea are especially critical for several clinical applications:

1. Airway Management: Assisting bronchoscopists and anesthesiologists in performing procedures such as endotracheal intubation and bronchoscopic interventions with precision.[2,5]
2. Clinical Procedures: Choosing the appropriate size for endotracheal tubes and guiding the safe execution of tracheostomies.[5]
3. Pathological Correlation: Identifying crucial predisposing factors for respiratory diseases like chronic bronchitis and emphysema, where variations in the width-depth ratio of the tracheal lumen play a significant role.[5]
4. Surgical Reconstruction: Providing the anatomical foundation required for the successful resection and reconstruction of the tracheobronchial tree.[3]

Anatomically, the trachea is a tube composed of cartilaginous rings and a fibro-muscular membrane. It begins at the lower border of the cricoid cartilage (C6 level) and typically terminates at the level of the fourth or fifth thoracic vertebra.[3,4] While general anatomical standards exist, tracheal dimensions are known to vary significantly by ethnicity and geographic population.[5]

Despite its immense clinical importance, identical morphometric studies are scarcely found specifically for the Gujarati population. This study aims to address this gap by establishing normal standards for tracheal dimensions—specifically anteroposterior diameter, transverse diameter, and circumference—within this regional demographic through detailed cadaveric dissection.

MATERIAL AND METHODS

The present study was conducted in the Department of Anatomy, M P Shah Government Medical College, Jamnagar to investigate the morphometry of the human trachea in the Gujarati population.

Sample Selection and Ethics

5. **Study Group:** A total of 50 adult cadaveric specimens were analyzed, comprising 34 males and 16 females.
6. **Age Range:** The age of the subjects ranged from 15 to 83 years.
7. **Inclusion/Exclusion Criteria:** Only those specimens were included that showed no evidence of pathology, trauma, or surgery involving the neck and thoracic regions that could alter the normal anatomy of the trachea.

Dissection and Measurement Procedure

8. **Dissection:** The trachea was exposed through a midline neck dissection and the removal of the anterior chest wall. It was carefully dissected from its origin at the lower border of the cricoid cartilage (C6 level) to its bifurcation (carina) at the level of the T4-T5 vertebrae.
9. **Measurement Points:** To ensure a comprehensive morphometric profile, measurements were taken at three specific levels:
   1. Upper End: Immediately below the cricoid cartilage.
   2. Middle: Mid-way between the origin and the bifurcation.
   3. Lower End: Immediately above the tracheal bifurcation.

Parameters Measured

10. **Anteroposterior (AP) Diameter:** Measured as the maximum distance between the anterior and posterior walls of the trachea at each of the three levels using a sliding vernier caliper.[2]
11. **Transverse Diameter:** Measured as the maximum distance between the lateral walls of the trachea at the same three levels.[2]
12. **Circumference:** The external circumference of the trachea was measured at the upper, middle, and lower levels using a flexible graduated thread, which was then laid against a metric scale for recording.[5]

Statistical Analysis

The collected data were categorized by gender and level of measurement. Statistical analysis, including Mean and Standard Deviation (±SD),

was performed to evaluate the differences between male and female tracheal dimensions.[6]

RESULTS

The study analyzed 50 adult cadaveric specimens, including 34 males and 16 females. The measurements for the three primary parameters are detailed below.

1. **Anteroposterior (AP) Diameter**

The mean (±SD) AP tracheal diameters at the upper, middle, and lower levels were 1.82±0.31 cm, 1.72±0.28 cm, and 1.61±0.26 cm, respectively. Sexual dimorphism was highly evident, with males exhibiting significantly larger AP diameters than females at all three anatomical levels ($p < 0.01$). In males, mean values ranged from 1.96±0.27 cm (upper) to 1.72±0.23 cm (lower), while female values ranged from 1.52±0.12 cm (upper) to 1.39±0.14 cm (lower). Standard error of the mean (SEM) across all levels remained low (range: 0.031–0.046), underscoring the precision of the measurements.

Table 1: AP diameter of trachea taken at upper, middle and lower levels of trachea (dissection method) and its statistical analysis

	No	Diameter	Range	Mean (cm)	± SD (cm)	Std. Error of mean	P value	Result
Male	34	Upper	1.4 – 2.9	1.96	0.27	0.046	< 0.01	Highly signific–ant
		Middle	1.4 – 2.3	1.86	0.22	0.038		
		Lower	1.4 – 2.2	1.72	0.23	0.040		
Female	16	Upper	1.3 – 1.7	1.52	0.12	0.031		
		Middle	1.2 – 1.8	1.44	0.16	0.040		
		Lower	1.2 – 1.6	1.39	0.14	0.036		
Total	50	Upper	1.3 – 2.9	1.82	0.31			
		Middle	1.2 – 2.3	1.72	0.28			
		Lower	1.2 – 2.2	1.61	0.26			

2. **Transverse Diameter**

The mean (±SD) transverse tracheal diameters for the total cohort (n=50) at the upper, middle, and lower levels were 1.96±0.31 cm, 1.92±0.32 cm, and 1.97±0.33 cm, respectively. Analysis by gender revealed that transverse diameters were significantly larger in males (n=34) than in females (n=16) across all anatomical points ($p < 0.01$). Male dimensions ranged from 2.06±0.27 cm to 2.10±0.31 cm, while female dimensions were notably smaller, ranging from 1.63±0.18 cm to 1.69±0.17 cm. The low standard error of mean (range: 0.042–0.053) confirms the high reliability of these measurements. Notably, the transverse diameter consistently exceeded the anteroposterior diameter in both sexes.

Table 2: Transverse diameter of trachea taken at upper, middle and lower levels of trachea (dissection method) and its statistical analysis

	No. Of subjects	Diameter	Range (cm)	Mean (cm)	± SD (cm)	Std. Error of mean	P value	Result
Male	34	Upper	1.6 – 2.8	2.09	0.24	0.042	< 0.01	Highly significant
		Middle	1.6 – 2.9	2.06	0.27	0.047		
		Lower	1.5 – 2.8	2.10	0.31	0.053		
Female	16	Upper	1.4 – 2.1	1.66	0.20	0.050		
		Middle	1.3 – 1.9	1.63	0.18	0.044		
		Lower	1.4 – 2.1	1.69	0.17	0.043		
Total	50	Upper	1.4 – 2.8	1.96	0.31			
		Middle	1.3 – 2.9	1.92	0.32			
		Lower	1.4 – 2.8	1.97	0.33			

3. **Tracheal Circumference**

The mean (±SD) external tracheal circumference for the entire study group (n=50) was recorded as 6.29±0.93 cm at the upper level, and 6.13±0.94 cm at both the middle and lower levels. Statistical analysis confirmed a highly significant sexual dimorphism ($p < 0.01$), with male circumferences consistently exceeding those of females at all three anatomical points. In males (n=34), the mean circumference ranged from 6.66±0.74 cm (upper) to 6.48±0.79 cm (lower), while in females (n=16), the values ranged from 5.51±0.78 cm (upper) to 5.29±0.72 cm (middle). The standard error of mean (SEM) for these measurements ranged between 0.127–0.135 for males and 0.180–0.198 for females, indicating a reliable degree of precision in the cadaveric assessment.

Table 3: Circumference of trachea taken at upper, middle and lower levels of trachea (dissection method) and its statistical analysis

	No. Of subjects	Diameter	Range (cm)	Mean (cm)	± SD (cm)	Std. Error of mean	P value	Result
Male	34	Upper	5.1 – 8.5	6.66	0.74	0.127	< 0.01	Highly significant
		Middle	4.7 – 7.8	6.52	0.75	0.129		
		Lower	4.7 – 8.0	6.48	0.79	0.135		
Female	16	Upper	4.3 – 6.8	5.51	0.78	0.196		
		Middle	4.3 – 6.8	5.29	0.72	0.180		
		Lower	4.3 – 7.0	5.38	0.79	0.198		
Total	50	Upper	4.3 – 8.5	6.29	0.93			
		Middle	4.3 – 7.8	6.13	0.94			
		Lower	4.3 – 8.0	6.13	0.94			

Statistical Summary

Sexual Dimorphism: Across all parameters (AP diameter, Transverse diameter, and Circumference), male dimensions were consistently larger than female dimensions.

Statistical Significance: The difference between the means of the two sexes was found to be highly significant for all three parameters ($P < 0.01$) using the student's 't' test.

Positional Variation: For the AP diameter and circumference, the dimensions were largest at the upper end and tended to decrease toward the lower end.

DISCUSSION

The morphometric parameters of the human trachea are critical for clinical and surgical interventions, yet population-specific data remains sparse for the Gujarati demographic. The present study evaluated the anteroposterior (AP) diameter, transverse diameter, and circumference through dissection, providing a comprehensive anatomical profile.

Our findings demonstrate significant sexual dimorphism in the AP diameter. In the Gujarati population, the mean AP diameter for males (1.72–1.96 cm) and females (1.39–1.52 cm) was found to be lower than values reported by Kamel[7] et al. (2.26 cm in males, 1.92 cm in females) in a New Zealand cohort. However, our range (1.5–2.6 cm in males, 1.3–2.1 cm in females) was broadly similar to the American population studied by Breatnach et al[8]. Interestingly, the mean AP diameter in our study was higher than that reported by Fraser and Pare[9] (1.75 cm in males, 1.55 cm in females). Locally, the AP diameter in the Gujarati population exceeded measurements reported for the South Indian population in Chennai[10].

The transverse diameter in our study (approx. 2.06–2.10 cm in males) was slightly higher than that found in Mexican males (1.9 cm) by Munguia Canales[11]. For females, our findings (1.63–1.69

cm) were closely comparable to the Mexican (1.7 cm) and Swedish (1.71 cm) cohorts studied by Munguia Canales[11] and Randestad[12], respectively.

Comparisons with other Indian studies show that the Gujarati population has a similar transverse tracheal width to the population of Kolkata studied by Chunder et al[13]. However, Gujarati males appear to have wider tracheas than their counterparts in Chennai[10], while the female dimensions remain similar between the two regions. Our dissection results align closely with the standards set in Gray's Anatomy[3], which lists an external transverse diameter of 2 cm for males and 1.5 cm for females.

Tracheal circumference is a vital metric for selecting endotracheal tube sizes. In this study, male circumference (mean 6.48–6.66 cm) was significantly larger than female circumference (mean 5.29–5.51 cm). These values are lower than the findings of Mehta[5] in an English population, where the mean was 6.87 cm for males and 5.76 cm for females. However, the Gujarati population showed a significantly larger tracheal circumference compared to the South Indian population in Chennai[10].

A consistent trend across all parameters was that measurements obtained via dissection were slightly higher than those obtained via internal casting methods. This is attributed to the fact that dissection measures external diameter (including the tracheal wall), whereas casting or radiological methods often measure the internal lumen. Furthermore, the slightly lower values in cadaveric measurements compared to living subjects (via CT) may result from post-mortem tissue contraction and the absence of positive airway pressure.[7]

The morphometric data established in this study serves as a critical anatomical roadmap for several clinical interventions. Primarily, the population-specific mean values for tracheal diameters and circumference provide anesthesiologists in Western India with an evidence-based guideline for the selection of appropriately sized endotracheal tubes, thereby minimizing the risk of ischemic mucosal injury or subglottic stenosis caused by over-sized cuffs. Furthermore, the precise identification of the tracheal caliber at the upper, middle, and lower levels is indispensable for surgeons performing tracheostomies or complex tracheal resections and reconstructions, ensuring that surgical planning accounts for the natural tapering of the airway. In the realm of critical care and pulmonology, these dimensions offer a baseline for the early radiological identification of tracheomegaly or tracheal stenosis. Finally, the significant sexual dimorphism observed reinforces the utility of tracheal measurements in forensic medicine as a reliable adjunct for sex determination in skeletal remains.

CONCLUSION

The present study establishes definitive anatomical norms for tracheal morphometry in the Gujarati population, revealing a significant pattern of sexual dimorphism where male dimensions consistently exceed those of females ($p < 0.01$). Characterized by a transverse diameter that is generally larger than the anteroposterior diameter, the Gujarati trachea occupies a unique mid-range position—measuring larger than South Indian cohorts but remaining smaller than Western populations. These population-specific baselines for AP diameter, transverse diameter, and circumference provide indispensable data for forensic sex determination and clinical airway management, offering anesthesiologists and surgeons in Western India a precise anatomical guide for selecting endotracheal tube sizes and planning surgical interventions.

REFERENCES

1. Guyton AC, Hall JE. Textbook of medical physiology. 9th ed. Philadelphia: W.B. Saunders Company; 1996. p. 486.
2. Singh V. Textbook of anatomy: upper limb and thorax. Vol. 1. 1st ed. New Delhi: Elsevier; 2008. p. 5-10.
3. Standring S, editor. Gray's anatomy: the anatomical basis of clinical practice. 40th ed. Spain: Churchill Livingstone; 2008.

4. Romanes GJ. Cunningham's manual of practical anatomy. 15th ed. Oxford: Oxford Medical Publications; 1986.
5. Mehta S, Myat HM. The cross-sectional shape and circumference of the human trachea. Annals of the Royal College of Surgeons of England. 1984 Sep;66(5):356-8.
6. Das R, Das PN. Biomedical research methodology including bio statistical applications. 1st ed. New Delhi: Jaypee Brothers Medical Publishers (P) Ltd; 2011.
7. Kamel KS, Lau G, Stringer MD. In vivo and in vitro morphometry of the human trachea. Clin Anat 2009; 22:571-579.
8. Breatnach E, Abbott GC, Fraser RG. Dimensions of the normal human trachea. AJR Am J Roentgenol, 1984; 141:903-906.
9. Fraser RG, Pare JAP. Diagnosis of diseases of the chest. 2nd ed vol. 1. Chapter 1. W.B.Saunders Company. 1977. Pg 56.
10. 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 Jan;66(Suppl 1):261-6. doi: 10.1007/s12070-012-0477-x.
11. Munguia Canales DA, Flores JR, Vargas Mendoza GK, Morales Gomez J, Mendez Ramirez I, Murata C. Tracheal dimensions in the Mexican population. Cir cir, 2011; 79:465-510.
12. Randestad A, Lindholm CE, Fabian P. Dimensions of the cricoid cartilage and the trachea. Laryngoscope 2000; 110:1957-1961.
13. Chunder R, Nandi S, Guha R & Satyanarayana N. A morphometric study of human trachea and principal bronchi in different age groups in both sexes and its clinical implication. Nepal Med Coll J. 2010; 12 (4):207-214.