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Radiological and Anatomical Evaluation of the Tracheal Morphology and Morphometry in Turkish Adults

Evaluación Radiológica y Anatómica de la Morfología y Morfometría Traqueal en Adultos Turcos

Sema Polat[1]; Mahmut Öksüzler[2]; Fatma Yasemin Öksüzler[3]; Esin Özsahin[4] & Pinar Göker[1]

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SUMMARY: The trachea is a tubular organ lying between larynx and lungs containing smooth muscle, membranes, and cartilage. This paper evaluated the dimessions of the trachea and main bronchi morphometry in healthy adults using Computed Tomography. This retrospective observational study was performed with 170 healthy adult subjects (89 females, 52.35 %; 81 males,47.65 %). The length of the trachea, the anteroposterior and transverse diameter of the trachea and the right and left main bronchi were measured. From these measurements, the trachea shape were calculated and four types of trachea were identified as circular, oval, horseshoe-shaped, and rectangular. All measurements were significantly higher in males than females (excluding tracheal bifurcation angle). According to the value obtained by dividing the anteroposterior by the width of the trachea, tracheal shapes are considered; the circular shape was seen 104 subjects (61.2 %), followed by oval type (34 subjects), horseshoe type (24 subjects) and rectangular type.(8 subjects). Also, the most frequently seen was circular type in both females and males. Hovewer, there was no significant difference between sex in terms of trachea shape. Additionally, a striking finding was that trachea morphometry and morphology showed the significance according to age dependent changes. Trachea measurements were affected several reasons such as used methods, age, sex, or race. This study has many clinical importance as it may reduce the risk of accidental damage to these area by clinicians such as cardiothoracic surgeons, anesthetist, or radiologist.

KEY WORDS: Trachea length; Age and sex-related changes; Trachea shapes; Morphometry.

INTRODUCTION

The trachea is a tubular organ lying between the larynx and lungs containing smooth muscle, membranes, and cartilage. It has a width of approximately 2 cm and a length of 10-12cm. It extends at the level of C6-T4-T5. It divides into right and left main bronchi at T4-T5. The carina trachea, the last line of reflex defense and the most sensitive area, is a mucosal fold on the inner surface of the tracheal bifurcation and on the last tracheal ring (Willan & Humpherson, 1999; Arıncı, 2005; Coskun *et al*., 2023). The trachea is a conducting airway and is essential for the passage of oxygen and other gasses to travel to the alveoli for diffusion. The pathway from the main bronchi formed by smaller bronchi, preterminal bronchioles, terminal bronchioles, respiratory bronchioles, alveolar ducts, alveolar sacs, and lastly alveoli for diffusion provides humidness, warming, or cooling to inhaled gas like air, oxygen, and inhalational anesthetics (Mieczkowski & Seavey, 2023). Especially, tracheobronchial tree and tracheal bronchus mostly have variations. In any surgery approach related to this area, anatomical variations, or reference values of those should be taken into consideration, or identification's anatomical structures. Additionally, many professionals should know airway dimensions for the endotracheal tube, double lumen tube, bronchoscopes, bronchial blockers, or stent size choice, or appropriate airway equipment design and selection (Dave *et al*., 2018, 2019; Coskun *et al*., 2023). Moreover, the trachea has much clinical significance such as deviation of the right (25°) and left bronchus (45°) from the trachea at different angles, tracheitis, tracheal deviation, and a variety of tumors arising from the respiratory system or adjacent structures, in thoracic cavity surgical approaches, application of many airway tecniques in anesthesiology,

[1] Cukurova University Faculty of Medicine, Department of Anatomy, Adana, Turkey.
[2] Izmir Bozyaka Education and Research Hospital, Department of radiology, I˙zmir, Turkey.
[3] Izmir Democracy University Buca Seyfi Demirsoy Training And Research Hospital, Department of Radiology, Izmir, Turkey.
[4] Baskent University Faculty of Medicine, Department of Anatomy, Adana, Turkey.

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removal of aspirated foreign bodies by bronchoscopy (Coskun *et al*., 2022; Mieczkowski & Seavey, 2023). Some methods used to study tracheal morphometry include cadaveric studies, X-Ray, or bronchoscopy, and Computed Tomography (CT). The CT technique has many advantages over other modalities: More easily standardized and scans can be viewed in multiple planes (Kamel *et al*., 2009).

This paper investigated age and sex related changes of trachea morphometry and morphology and importance in terms of radiological and anatomical in Turkish Adults with Computed Tomography

MATERIAL AND METHOD

The retrospective observational study was performed with 170 healthy adult subjects (females,89; males 81). The ratio of males and females who participated in the study was 47.65 % and 52.35 %, respectively. This study was approved by the Institutional Review Ethics Committee at Çukurova University (2023/133;41). Moreover, inclusion criteria for healthy adults were determined:

- No history of cancer related to respiratory system,
- No surgical operation or any disease related to the respiratory system, or any metastasis, or any previous thoracic surgery
- Having no lesions in the mediastinum, no congenital heart diseases, no anatomical abnormalities like roto scoliosis and having no vascular anomalies.

All Computed Tomography (CT) scans measurements were made on the computer screen with an electronic caliper and recorded as millimeters and some specified linear measurements were performed as follows: the length of trachea, the anteroposterior and transverse

Table I. Average measures of trachea diameter according to age groups.

Trachea morphometry	Decade 1 18-19 yrs (n=33; 27 females, 6 males) Means+SD	Decade 2 20-29 yrs (n=44; 32 females) Means+SD	Decade 3 30-39 yrs (n=31; 8 females) Means+SD	Decade 4 40-49 yrs (n=25; 12 females) Means+SD	Decade 5 50-59 yrs (n=16; 4 females) Means+SD	Decade 6 60-69 yrs (n=13; 4 females) Means+SD	Decade 7 70-75 yrs (n=8; 2 females) Means+SD
Trachea length (cm)	10.01±0.28	10.22±0.21	10.09±0.20	10.07±0.15	10.16±0.01	10.11±0.19	9.89±0.23
P value for both sexes				<0.001			
Females	10.00±0.26	10.17±0.22	10.02±0.05	9.99±0.13	10.19±0.029	9.84±0.017	10.11±0.001
P value for females				0.007			
Males	10.05±0.40	10.35±0.14	10.12±0.23	10.15±0.13	10.14±0.11	10.23±0.044	9.82±0.22
P value				<0.001			
Trachea AP length (cm)	1.66±0.21	1.83±0.21	1.76±0.16	1.75±0.14	1.88±0.09	1.77±0.16	1.62±0.23
P value for both genders				<0.001			
Females	1.66±0.20	1.78±0.24	1.74±0.05	1.71±0.13	1.91±0.03	1.56±0.017	1.83±0.01
P value				0.043			
Males	1.77±0.40	2.08±0.14	1.84±0.23	1.87±0.13	1.87±0.11	1.95±0.04	1.54±0.22
P value				<0.001			
Trachea transverse width (cm)	1.62±0.28	1.77±0.27	1.68±0.15	1.63±0.21	1.75±0.11	1.68±0.16	1.66±0.18
P value for both sexes				0.044			
Females	1.60±0.27	1.74±0.22	1.59±0.14	1.58±0.17	1.70±0.06	1.46±0.04	1.41±0.001
P value				0.035			
Males	1.69±0.35	1.86±0.36	1.71±0.14	1.67±0.25	1.83±0.15	1.78±0.03	1.74±0.10
P value				0.255			
Trachea bifurcation angle (degree)	74.07±5.55	74.98±6.89	73.36±5.68	69.16±5.54	75.91±4.07	79.46±9.16	74.44±9.86
P value for sexes				<0.001			
Females	74.87±5.85	75.68±6.99	71.12±2.08	72.00±4.20	72.25±3.17	76.75±7.79	61.50±0.001
P value				0.016			
Males	70.50±2.45	73.12±6.53	74.14±6.34	66.54±5.42	77.12±3.66	80.67±9.88	78.75±6.84
P value				<0.001			
Bronchial length (right) (cm)	2.08±0.54	2.21±0.49	1.89±0.39	1.79±0.54	1.55±0.49	1.68±0.39	1.74±0.30
P value for both sexes				<0.001			
Females	2.02±0.42	2.07±0.57	1.84±0.44	1.92±0.63	1.42±0.39	1.74±0.46	1.69±0.34
P value				0.045			
Males	2.10±0.57	2.26±0.46	2.02±0.08	1.65±0.39	1.94±0.62	1.56±0.092	1.89±0.001
P value				0.021			
Bronchial length (left) (cm)	3.12±0.46	3.08±0.44	3.32±0.53	3.17±0.48	3.09±0.43	3.15±0.21	3.41±0.06
P value for both sexes				0.004			
Females	2.99±0.41	3.05±0.50	3.65±0.78	3.00±0.33	3.42±0.68	2.95±0.012	3.42±0.001
P value				0.005			
Males	3.70±0.66	3.17±0.20	3.20±0.36	3.33±0.55	2.98±0.27	3.24±0.20	3.40±0.71
P value				0.003			
Trachea types							
Round	17 (52.00%)	25 (56.82%)	20 (64.52%)	16 (64.0%)	13 (81.25%)	13 (100.00%)	0 (0.00%)
Oval	10 (30.3%)	9 (20.45%)	3 (9.68%)	3 (12.00%)	3 (18.75%)	0 (0.00%)	6 (75.00%)
Rectangular	1 (3.00%)	3 (6.82%)	3 (9.68%)	1 (4.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)
Horseshoe	5 (15.00%)	7 (15.91%)	5 (16.12%)	5 (20.00%)	0 (0.00%)	0 (0.00%)	2 (25.00%)
P value for trachea types				0.003			

diameter of the trachea and right and left main bronchi. From these measurements, the trachea shape were calculated according to the ratio of anteroposterior length to the transverse diameter of the trachea. To standardize the identification of trachea types, the ratio of the anteroposterior diameter (a) to the transverse diameter (b) was calculated. With this ratio, four types of trachea were identified as circular (a / b = 1 ± 0.2 mm), oval (a / b < 1 ± 0.2 mm), horseshoe-shaped (a / b > 1 ± 0.2 mm) and rectangular (a / b = 1 / 2 ± 0.2 mm) (Jit & Jit, 2000; Chunder *et al*., 2010; Lee *et al*., 2014; Ulusoy *et al*., 2016; Luscan *et al*., 2020; Coskun *et al*., 2022). The data were divided also into seven groups according to age and showed decades' ranges in Table I.

RESULTS

The ages of 170 healthy individuals (89 females and 81 males) aged between 18-75 years (mean 35.54±16.56 years) between January 2018 and January 2023 and over a 5-year period were determined. However, the length of the trachea, trachea anteroposterior length, trachea transverse width, tracheal bifurcation angle, length of the right and length of the left main bronchus were measured, and trachea morphology or shape was determined in Tables I and II, average values of trachea diameter according to sex were shown and all measurements were significantly higher in males than in females (excluding tracheal bifurcation angle). According to the value obtained by dividing the AP of the trachea by the transverse width of the trachea, tracheal shapes are considered; the circular shape was seen in 104 subjects (61.2 %), followed by oval type (34 subjects), and horseshoe type (24 subjects) and rectangular type.(8 subjects). Also, the most frequently seen trachea type was circular type in both females and males. However, there was no significant difference between sex in terms of trachea shape ($p>0.05$) (Table III). Additionally, in Table I, average trachea diameter according to age groups are shown. There was a significant difference in terms of trachea length, trachea AP, trachea transverse width, and right main bronchial length and left main bronchial length and trachea shape in different age groups. However, all measurements were significant in females ($p<0.05$), and one parameter called trachea transverse width showed no significant difference in males ($p>0.05$).

Table II. Average measures of trachea diameter according to sex.

Trachea morphometry	Males (n=81) Means+SD	Females (n=89) Means+SD	P value
Trachea length (cm)	10.15±0.23	10.09 ±0.22	0.021
Trachea AP length (cm)	1.87±0.23	1.79±0.22	0.021
Trachea transverse length (cm)	1.75±0.22	1.64±0.23	0.002
Tracheal bifurcation angle	74.01±7.36	74.10±6.24	>0.05 (0.928)
Bronchial length (right) (cm)	2.05±0.51	1.82±0.51	0.003
Bronchial length (left) (cm)	3.24±0.36	3.10±0.51	0.041

Table III. The measures of trachea types according to sex.

Trachea morphometry	Males (n=81) Means+SD	Females (n=89) Means+SD	Percent
Circular (Trachea AP length/trachea transverse length=1.00±0.2 mm)	49 (47.11%)	55 (52.88%)	104 (61.2%)
Oval (Trachea AP length/trachea transverse length<1.00±0.2 mm)	19 (55.88%)	15 (44.12%)	34 (20.0%)
Rectangular (Trachea AP length/trachea transverse length=1/2±0.2 mm)	4 (50.00%)	4 (50.00%)	8 (4.7%)
Horseshoe (Trachea AP length/trachea transverse length>1.00±0.2)	9 (37.5%)	15 (62.5%)	24 (14.1%)
P value between sex		0.584	100%

DISCUSSION

The adult trachea is approximately 10–12 cm in length, and 2 cm in width. It extends from the sixth cervical vertebra level to the fourth and fifth thoracic vertebra level. Trachea shape is decided with the transverse diameter being greater than the anterioposterior diameter (Paul & Colson, 2023). The pathway begins the mouth or nare and continues pharynx, larynx, trachea and finishes alveoli for diffusion. This system is necessary the humidity, warming or cooling

to inhaled gas like air, oxygen, and inhalational anesthetics (Mieczkowski & Seavey, 2023). As with all surgical procedures involving the airway, a surgeon should always be ready and alert to perform emergency airway intervention. The trachea is of clinical importance in many ways: The presence of tracheitis, tracheal deviation that can be detected on clinical examination or radiological imaging and can cause an increase in intrathoracic pressure or tension pneumothorax, or haemothorax, metastases, scoliosis, the presence of various tumors that can originate from the respiratory system or from adjacent structures. All these causes can alter the anatomy and morphometry of the trachea (Mieczkowski & Seavey, 2023).

The tracheal bifurcation angle is between the central axis of right and left main stem bronchi. The 40° and 80° can be accepted normal value. The angle greater than 100° may indicate left atrial enlargement, although it is not very sensitive (Anderson *et al*., 2023). Trachea has several variations in length, transverse width, anteroposterior length, tracheal bifurcation angle and shape in both same age group and different age groups.

Trachea morphometry may facilitate clinicians to understand the aetiology of many pulmonary diseases and it is considered as predisposing factor for chronic bronchitis, or emphysema (Hasleton, 1996; Chunder *et al*., 2010). Some knowledge such as conducting and respiratory tube's shape, or width/depth is important in terms of allergic states, lungs fibrosis, and tuberculosis. Additionally, a clear anatomical knowledge provides accurate resection and reconstruction procedures of the tracheobronchial tree. The detailed trachea anatomy plays an important role in practice such as anatomists, pulmonologists, anesthetists and bronchoscopists in many respects such as for skillful and expert contemplation of various diagnostic and therapeutic maneuvers, endotracheal intubation, and bronchoscopic procedures using bronchoscopes without producing any undue complications. Trachea length is affected by some reasons such as methods (CT or cadavers), or population (adult or child), or sex (female or male). Additionally, this measurement is important for accurately selection of the bronchoscope of proper gauge for person of different age groups (Chunder *et al*., 2010).

In a literature review including 28 studies, the trachea length was shown to be increased with age, and also it was found to be high in males than in females (Coskun *et al*., 2022). Additionally, in Indians the highest and lowest values of trachea length were obtained in 41-55 years and 0-15 years of females, respectively, whereas in males the highest and lowest values were in subjects aged between 16-25 years and 0-15 years (Chunder *et al*., 2010). The mean values of trachea length changed from 8.93cm to 10.7cm in adult males, 8.19cm to 10.1cm in adult females (Jit & Jit, 2000; Kamel *et al*., 2009; Mi *et al*., 2015). Our mean trachea values were higher in males (10.15cm) than in females (10.09cm), and this value was closer to the Chinese and New Zealand population, whereas this is higher than Indians. The possible reason may be race or age. Chunder *et al*. (2010), reported that this may be due to excessive contraction of the trachea by fibrous tissue due to aging.

Bronchial tree and proportions contribute functional observations to recognise any abnormalities of the airway like pneumonia, bronchial obstructions, foreign objects, and mediastinal masses, to maintain the posture for patients with lung disorders; for the anesthetist to know the caliber of the trachea for intubation, bronchoscopists (Shaik *et al*., 2017). According to Chunder *et al*. (2010), the subcarinal angle has much clinical importance: Bronchoscopy is easier in adults, and the special angulation of the primary bronchus with the trachea requires more skill to insert the bronchoscope, especially on the left side. Lack of this knowledge might give a wrong interpretation of bronchial obstruction on failing to introduce the bronchoscope. Also, the growth in the mediastinal structures or any pathology of the lung or pleura such as fibrosis, collapse, pleural effusion may alter the subcarinal angle considerably.

The subcarinal angle contributed by the right bronchus is small, as it is more or less in the same line with the trachea. For this reason, the finding of foreign objects is more common in the right bronchus (Chunder *et al*., 2010). A similar view is that: The corresponding angle may alter due to expansion of mediastinal structures or any pulmonary diseases. Because, the right principal bronchus runs almost parallel to the trachea. The left subcarinal angle is larger than the right side (Chunder *et al*., 2010; Coskun *et al*., 2022). As Chunder *et al*. (2010), or classical anatomy resources have said, this will lead to easier entry of foreign bodies into the right lung. In the examination of performed studies with different population, the subcarinal angle was greater in adults than children (Ulusoy *et al*., 2016), conversely, this value was found low in adults in studies with Indians and Nepals (Jit & Jit, 2000; Chunder *et al*., 2010). Subcarinal angle means performed with CT of Indians, New Zealand, and Chinese population were found as 51.2°, 76° and 75.2° in males, respectively, whereas the same values were 54.3°, 81° and 80.1°. In our study, the subcarinal angle was measured as 74.01° in males, 74.10° in females. Contrary to the literature, our data did not show a significant difference between sexes.

It is important to know the diameter, length and bronchial angle of airways, for safe and successful applications of bronchoscopy and double lumen tubes (DLT). Moreover, the trachea AP and the transverse diameter values

gain importance for choosing the appropriate size of DLT. Studies in adults and performed with CT were reviewed and some studies found the trachea AP value higher than transverse diameter (Jit & Jit, 2000; Zahedi-Nejad *et al*., 2011; Mi *et al*., 2015), whereas, some studies found it low according to the trachea transverse diameter (Kamel *et al*., 2009; Ulusoy *et al*., 2016). Additonally, in a textbook of diagnostic surgical pathology, the tracheal diameter is accepted as 2-2.5cm (Rosen *et al*., 2003; Shaik *et al*., 2017). Two values were higher in males than in females. Our same finding was similar to the literature that it was high in favor of males. Also, our trachea AP was greater than the trachea transverse diameter in both sexes.

Many surgical maneuvers used by thoracic surgeons needs to an accurate bronchial anatomy. The principal bronchus plays a major role in transmitting air to the lungs. The subcarinal angle indirectly helps in diagnosis of cardiovascular problems and for surgical resection of segments or lobes in diseases of lungs (Shaik *et al*., 2017). Our right and left bronchus length means were found as 2.05cm and 3.24cm in males, respectively. The same values were 1.82 cm and 3.10 cm in females, respectively. In literature studies comparing the lengths of the right and left main bronchus, the adults'values were higher according to child, and the values were greater in males. The right main bronchus length and left main bronchus length were measured as 2.47 cm and 5.17 cm in the Turkish population, respectively. The same values were reported as 2.68 cm (males), 2.37 cm (females) and 4.81cm (males), 4.37 cm (females) in Indians, respectively. Additionally, in the Chinese population the corresponding values were 1.41 cm (males), 1.29 cm (females), and 5.00cm (males), 4.62 cm (females), respectively. According to Standring *et al*., the mean right and left bronchi lengths are 2.5 cm and 5.5 cm respectively, which was different from our study's left main bronchi. Also, the right main bronchus value according to Snell was accepted as 2.5 cm on average. The left main bronchus value was defined as 4.5 cm (Snell, 2012; Shaik *et al*., 2017).

Trachea types were determined according to the ratio of anteroposterior diameter to transverse diameter. The intrathoracic trachea is classified as circular, oval, rectangular andhorseshoe and its shape is determined according to its level. The trachea shape is determined by the ratio of the anteroposterior diameter (APT) to the transverse diameter (TDT) of the trachea. With this ratio, four types of trachea were defined as circular (APT/TDT=1), oval (APT/TDT<1), horseshoe shape (APT/TDT>1), and rectangular (APT/TDT=1/2) (Ulusoy *et al*., 2016). According to this formula, we classified the trachea shape. The most frequently seen trachea shape was circular type in both males and females, followed by oval type, horseshoe and the least seen type rectangular type. The trachea shape showed no changes according to sex. Also, the trachea shape showed age related changes.

CONCLUSION

The trachea displays some diversities in terms of both age and sex. This paper has reference data related trachea morphometry and morphology and this knowledge may reduce the risk of accidental damage for cardiothoracic surgeons, or anaesthetist, as well as increase opportunities to sort out radiological blur with succesful CT. Additionally, it may help clinicians understand the etiology of several pulmonary diseases and surgeons to deal with resection and reconstruction of the tracheobronchial tree or, in choosing the proper size of tracheostomy tube and endotracheal tube in emergency situations as well as know aiway disorders' pathophysiology and management. Trachea morphometry measurements were affected by reasons such as used methods (CT, cadaver, X-ray, or bronchcopy, etc), age (neonates, child or adult), sex, or race. Another striking finding was that all our parameters showed significant changes according to age. Especially, trachea length and trachea AP length obtained the lowest value in Decades

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RESUMEN: La tráquea es un órgano tubular que se encuentra entre la laringe y los pulmones y que contiene músculo liso, membranas y cartílago. Este trabajo evaluó las dimensiones de la tráquea y la morfometría de los bronquios principales en adultos sanos mediante Tomografía Computarizada. Este estudio observacional retrospectivo se realizó con 170 sujetos adultos sanos (89 mujeres, 52,35 %; 81 hombres, 47,65 %). Se midió la longitud de la tráquea, el diámetro anteroposterior y transversal de la tráquea y los bronquios principales derecho e izquierdo. A partir de estas mediciones, se calculó la forma de la tráquea y se identificaron cuatro tipos de tráquea: circular, ovalada, en forma de herradura y rectangular. Todas las mediciones fueron significativamente mayores en hombres que en mujeres (excluyendo el ángulo de bifurcación traqueal). Según el valor que se obtiene al dividir el anteroposterior por el ancho de la tráquea, se consideran las formas traqueales; la forma circular fue observada en 104 sujetos (61,2 %), seguida del tipo ovalado (34 sujetos), tipo herradura (24 sujetos) y tipo rectangular (8 sujetos). Además, el tipo más frecuente fue el circular tanto en mujeres como en hombres. Sin embargo, no hubo diferencias significativas entre sexos en términos de forma de la tráquea. Además, un hallazgo sorprendente fue que la morfometría y la morfología de la tráquea mostraron importancia según los

cambios dependientes de la edad. Las mediciones morfométricas de la tráquea se vieron afectadas por varios motivos, como los métodos utilizados, la edad, el sexo o la raza. Este estudio tiene importancia clínica ya que puede reducir el riesgo de daño accidental por parte de médicos como cirujanos cardiotorácicos, anestesistas o radiólogos.

PALABRAS CLAVE: Longitud de la tráquea; Cambios relacionados con la edad y el sexo; Formas de tráquea; Morfometría.

REFERENCES

Anderson, J.; Bickle, I. & Bell, D. *Tracheal bifurcation angle*. Reference article, Radiopaedia.org, 2023.

Arıncı, K. *Arıncı Anatomi*. 4. Baskı, Ankara, Günes¸ Kitabevi, 2005.

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 implications. *Nepal Med. Coll. J., 12(4)*:207-14, 2010.

Coskun, Z. K.; Atalar, K. & Akar, B. Systematic literature study of trachea and bronchus morphology in children and adults. *Folia Morphol. (Warsz.), 82(3)*:457-66, 2023.

Dave, M. H.; Kemper, M.; Schmidt, A. R.; Both, C. P. & Weiss, M. Pediatric airway dimensions—a summary and presentation of existing data. *Pediatr. Anesth., 29(8)*:782-9, 2019.

Dave, M. H.; Schmid, K. & Weiss, M. Airway dimensions from fetal life to adolescence—A literature overview. *Pediatr. Pulmonol., 53(8)*:1140-6, 2018.

Hasleton, P. S. *Spencer's Pathology of the Lung*. In: Hasleton, P. S. & Curry, A. (Eds.). Anatomy of the Lung. 5th ed. New York, Mc Graw-Hill, 1996.

Jit, H. & Jit, I. Dimensions and shape of the trachea in the neonates, children and adults in northwest India. *Indian J. Med. Res., 112*:27-33, 2000.

Kamel, K. S.; Lau, G. & Stringer, M. D. In vivo and in vitro morphometry of the human trachea. *Clin. Anat., 22(5)*:571-9, 2009.

Lee, J. W.; Son, J. S.; Choi, J. W.; Han, Y. J. & Lee, J. R. The comparison of the lengths and diameters of main bronchi measured from two-dimensional and three-dimensional images in the same patients. *Korean J. Anesthesiol., 66(3)*:189-94, 2014.

Luscan, R.; Leboulanger, N.; Fayoux, P.; Kerner, G.; Belhous, K.; Couloigner, V.; Garabedian, E. N.; Simon, F.; Denoyelle, F. & Thierry, B. Developmental changes of upper airway dimensions in children. *Pediatr. Anesth., 30(4)*:435-45, 2020.

Mi, W.; Zhang, C.; Wang, H.; Cao, J.; Li, C.; Yang, L.; Guo, F.; Wang, X. & Yang, T. Measurement and analysis of the tracheobronchial tree in Chinese population using computed tomography. *PLoS One, 10(4)*:e0123177, 2015.

Mieczkowski, B. & Seavey, B. F. *Anatomy, Head and Neck, Trachea*. Treasure Island (FL), StatPearls, 2023. Available from: https://www.ncbi.nlm.nih.gov/books/NBK448070/

Paul, S. & Colson, Y. L. Tracheostomy. In: Sugarbaker, D. J.; Bueno, R.; Colson, Y. L.; Jaklitsch, M. T.; Krasna, M. J.; Mentzer, S. J.; Williams, M. & Adams, A. (Eds.). *Adult Chest Surgery*. 2nd ed. New York, McGraw Hill, 2014. Available from: https://accesssurgery.mhmedical.com/content.aspx?bookid=1317&sectionid=72430441

Rosen, F. S.; Pou, A. M. & Buford, W. L. Tracheal resection with primary anastomosis in cadavers: the effects of releasing maneuvers and length of tracheal resection on tension. *Ann. Otol. Rhinol. Laryngol., 112(10)*:869-76, 2003.

Shaik, Z.; Venkata, R. M. & Hanimann, K. S. A study on anatomical dimensions of bronchial tree. *Int. J. Res. Med. Sci., 4(7)*:2761-5, 2017.

Snell, R. S. *Clinical Anatomy by Regions*. 9th ed. Philadelphia, Lippincott Williams & Wilkins, 2012.

Ulusoy, M.; Uysal, I. I.; Kıvrak, A. S.; Özbek, S.; Karabulut, A. K.; Paksoy, Y. & Dogan, N. U. Age and gender related changes in bronchial tree: a morphometric study with multidedector CT. *Eur. Rev. Med. Pharmacol. Sci., 20(16)*:3351-7, 2016.

Willan, P. L. & Humpherson, J. R. Concepts of variation and normality in morphology: important issues at risk of neglect in modern undergraduate medical courses. *Clin. Anat., 12(3)*:186-90, 1999.

Zahedi-Nejad, N.; Bakhshayesh-Karam, M.; Kahkoei, S.; Abbasi-Dezfoully, A. & Masjedi, M. R. Normal dimensions of trachea and two main bronchi in the Iranian population. *Pol. J. Radiol., 76(4)*:28-31, 2011.

Corresponding author:
Dr. Sema Polat
Cukurova University
Faculty of Medicine
Department of Anatomy
Adana
TURKEY

E-mail:sezaoz@hotmail.com