VIA MEDICA

REVIEW ARTICLE

Folia Morphol.
Vol. 82, No. 3, pp. 457–466
DOI: 10.5603/FM.a2022.0073

ISSN 0015–5659
eISSN 1644–3284
journals.viamedica.pl

Systematic literature study of trachea and bronchus morphology in children and adults

Z.K. Coşkun, K. Atalar, B. Akar

Department of Anatomy, Faculty of Medicine, Gazi University, Ankara, Turkey

[Received: 24 May 2022; Accepted: 1 August 2022; Early publication date: 17 August 2022]

Understanding the dimensions of the lower airway is critical for performing respiratory surgery, selecting and designing appropriate airway equipment, and removing aspirated foreign bodies via bronchoscopy, anaesthesia, and radiography. The purpose of this study was to analyse the trachea and bronchus morphologically in children and adults, as well as to standardise the data for these structures' measurements. Various databases were reviewed for studies on lower airway dimensions. The criteria for inclusion and exclusion were established. Finally, it was agreed to look into 28 studies that took place between 1984 and 2021. The length of the trachea, its anterior-posterior (AP) and transverse dimensions, the lengths and transverse diameters of the right and left major bronchus, and the subcarinal angle were also investigated in the study. In studies where measurements were performed with different methods and procedures. It was revealed that age and gender were effective in the difference in lower respiratory tract dimensions. The mean values of all parameters were greater in adults than in children, the AP diameter of the trachea in adults was greater than the transverse diameter. In children, it was observed that the transverse diameter was larger than the AP diameter on average, the left main bronchus was longer than the right main bronchus, and the transverse diameter was smaller than the right main bronchus in most of the studies. The articles reviewed for this study revealed that measurements were done using a variety of different procedures and approaches, and the resulting data were inconsistent and could not be standardized. The data collected will be beneficial both conceptually and clinically; we believe that additional comparison research involving children and adults in bigger groups are necessary. (Folia Morphol 2023; 82, 3: 457–466)

Key words: trachea, bronchus, morphology, adult, child

INTRODUCTION

The trachea is a tubular organ 10–13 cm long with muscles and membranes [1, 39]. It begins at the lower edge of the C6 vertebra and divides into two bronchi: bronchus principalis dexter and bronchus principalis sinister at the T4–T5 vertebra level. After giving rise to the superior lobar bronchus, the right main bronchus descends as the intermediate bronchus. The middle and inferior lobar bronchi separate the intermediate bronchus into two lobar bronchi. Two lobar bronchi, bronchus lobaris superior and inferior, split the left main bronchus [29]. The term "normality" in anatomy refers to a variety of morphologies, including the

Address for correspondence: Dr. Z.K. Coşkun, Department of Anatomy, Faculty of Medicine, Gazi University, Emniyet Mahallesi, Mevlâna Bulvarı, No: 29, 06500, Yenimahalle, Ankara, Turkey, tel: +90 532 467 8501, fax: +90 312 202 4647, e-mail: zcoskun@gazi.edu.tr

most prevalent ones, and "variations" are used to describe uncommon anatomical variation [40, 43]. In the medical literature, anatomical differences are referred to as anomalies [43]. Variations can influence disease susceptibility, symptomatology, clinical examination, and patient care in operational surgery and can affect any area of the human body [40]. Contrary to its overall anatomical structure, the tracheobronchial tree may also have distinctive characteristics and numerous variations [3]. The accessory cardiac bronchus and tracheal bronchus are frequently major anomalies or variations in the tracheobronchial tree [41]. The accessory cardiac bronchus is an excess bronchus that extends from the inner wall of the right main bronchus or intermediate bronchus to the pericardium [13], whereas the tracheal bronchus is an abnormal or accessory bronchus that primarily arises from the right lateral wall of the trachea [26]. Tracheobronchial abnormalities occur between 0.1% and 2% of cases [41]. Clinical practice should take anatomical variances into account [43]. Surgeons must have a thorough understanding of anatomical variations in order to appropriately identify anatomical structures during surgery [40]. In anaesthesia and respiration, knowing these airway dimensions are critical in conditions such as endotracheal tube, double lumen tube, rigid and flexible bronchoscopes, bronchial blockers, or stent size selection [11]. Furthermore, understanding the standard reference values for airway dimensions in radiology allows for the differentiation of normal and pathological airway findings in various age groups, as well as the design and manufacture of appropriate airway equipment [10]. In surgical approaches to the thoracic cavity, in the application of various airway techniques in anaesthesiology, and in the removal of aspirated foreign bodies by bronchoscopy, accurate knowledge of the anatomy and morphology of the tracheobronchial tree is essential [17]. Airways can be measured using computed tomography (CT) scans, cadaver measurements, chest X-ray and three-dimensional (3D) reconstruction, ultrasound, and bronchoscopy [38].

The purpose of this study was to compare the dimensions of the trachea and bronchus in children and adults using existing data and to standardise the measurement values. Our study of the literature revealed no systematic study comparing the morphological measurements of the trachea and bronchus in children and adults.

MATERIALS AND METHODS

Our study's methodology was developed in accordance with a paper from the Annals of Anatomy journal titled "Methods of Evidence-Based Anatomy: a guide to conducting systematic reviews and meta-analysis of anatomical studies" [16]. After conducting a literature analysis, it was decided that the focus of our study would be a review of the morphological structure of the trachea and bronchi in both children and adults. Our study's objective was to standardise the data and compare the diameters of the trachea and bronchi in children and adults. The inclusion criteria were carefully chosen. Children under the age of 18 and adults over the age of 18, from any ethnic origin, without airway pathology were included study. We used articles that examined CT scans, cadavers, chest radiographs, and 3D reconstructions as the basis for our work. Our study is a retrospective study that clearly defined the anatomical definitions of the trachea and bronchus. In order to avoid any interviewer bias in our study, care was taken to include articles that presented anatomical data in tabular form. Case reports, letters to the editor, conference summaries, unpublished articles, studies on fetuses, published articles with incomplete or uncertain results, age criteria, and the number of people in the article were excluded from our study. Researchers have identified a broad search strategy to reduce location bias. For literature searches on lower respiratory tracts such the trachea and bronchus, researchers used Google academic, PubMed, and Scopus databases. Searches in these databases returned 45 articles using keywords like "adult," "child," "human," "trachea," "bronchus," "diameter," "dimensions," "bronchial angles," "airway morphology," and their permutations. During the database search, neither historical date nor language restrictions were identified. In addition, the search has been expanded to include additional articles in the study from the journals' websites and by utilizing references from previously selected papers. In deciding the study, the title and abstract of the search-result articles were examined first, followed by the full text of the articles, if relevant to the subject of the study. To reduce the possibility of language and multi-publication bias in the article selection process, we also included data from incomprehensible languages and avoided using duplicate publications of the same study data. Twenty-eight articles that were published between 1984 and 2021 were selected for our study after the articles had been examined by the

Table 1. General descriptive data on lower airway studies in children

Studies	Age	Number of people	Parameter	Method
Griscom and Wohl (1986)	0–18 years	119 people (64 M, 55 F)	Trachea length, AP and transverse diameters, cross-sectional area, volume	CT
Herek et al. (2017)	0–18 years	118 children (67 M, 51 F)	SCA, RBA, LBA, IBA	CT
Breatnach et al. (1984)	10–18 years	48 children (26 M, 22 F)	AP and transverse diameters of trachea	Chest X-ray
Kuo et al. (2018)	0–18 years	240 people (155 M, 85 F)	Trachea length, transverse diameter, right and left main bronchus diameters	CT
Ulusoy et al. (2016)	0–18 years	41 people (26 M, 15 F)	AP and transverse diameters of trachea, trachea cross-sectional area, RBA, LBA, IBA	Multidetector CT
Jit and Jit (2000)	0–18 years	60 children (30 M, 30 F)	Trachea length, AP and transverse diameters, right and left main bronchus lengths and transverse diameters, subcarinal angle	Cadaver study
Chalwadi et al. (2021)	0–18 years	110 children (54 M, 56 F)	AP, transverse diameters and cross-sectional areas of trachea, right and left main bronchus	CT
Tan and Tan-Kendrick (2002)	2 days–16 years	250 children (133 M, 117 F)	Right and left main bronchus transverse diameters	CT
Luscan et al. (2020)	1 day–14 years	192 children (127 M, 65 F)	Trachea length, AP and transverse diameters, right and left main bronchus lengths, AP and transverse diameters	CT
Aslan et al. (2015)	0–16 years	520 people (246 M, 274 F)	Trachea diameters of right and left main bronchus	Chest X-ray
Szelloe et al. (2017)	0–16 years	195 people (118 M, 77 F)	Trachea, right and left main bronchus, AP diameter, transverse diameter, cross-sectional area	CT
Tahir et al. (2009)	< 16 years	156 people (84 M, 72 F)	Trachea, right and left main bronchus transverse diameters, RBA, LBA, SCA	Chest X-ray
Kubota et al. (1986)	0–13 years	259 babies and children	RBA, LBA, SCA	Chest X-ray

M — male; F — female; AP — anterior-posterior diameter; RBA — right bronchial angle; LBA — left bronchial angle; IBA — interbronchial angle; SCA — subcarinal angle; CT — computed tomography image

researchers. Tables 1 and 2 show general descriptive information gathered from papers, including the articles' authors and the year they were published, the number of participants and age groups, the anatomical structures that were measured, and the methodologies that were used. The length of the trachea, the anterior-posterior (AP) and transverse diameters of the trachea, the subcarinal angle, the lengths of the right and left major bronchus, and their transverse diameters, in both adults (> 18 years) and children (under 18 years) are defined independently in the publications included in our analysis.

Analytical statistics

The data was analysed using the SPSS 24.0 software within the scope of this study. For each parameter, the data in the studies were grouped and represented according to child and adult age groups. Minimum and maximum values, range, mean, standard deviation, median, quartiles, and confidence intervals were generated for each parameter as descriptive statistics (Tables 3, 4). Due to the varying age group distributions in the studies and the fact that the parameter measuring method was not consistent, further statistical analysis of the data was limited.

RESULTS

In the scanned studies, total of 2308 children were examined in 13 and 7148 adults in 18 were examined. Eighteen studies were examined used CT scan, 9 relied on cadaver examination, 6 used chest X-ray, and 3 used 3D reconstruction method. Tables 3 and 4 provide descriptive data for trachea and bronchus measurements in children and adults. In Tables 5 and 6, studies that include measurements of trachea and bronchus sizes are presented in detail in children and adults.

As a result of the studies analysed, the mean values in children and adults, respectively, were as follows: trachea length 7.52 (6.19–9.36) and 10.08 (8.13–13.25) cm; the AP diameter of the trachea 1.19 (0.78–1.58) cm and 1.75 (1.11–2.14) cm; the transverse diameter of the trachea 1.28 (0.95–1.74) cm and 1.66 (1.23–2.57) cm. It was observed that the pa-

Table 2. General descriptive data on lower airway studies in adults

Studies	Age	Number of people	Parameter	Method
Breatnach et al. (1984)	20–79 years	760 people (404 M, 356 F)	Trachea length, AP and transverse diameters, cross-sectional area, volume	CT
Tuncer (2019)	Average: 52 years	150 people (81 M, 69 F)	Trachea length, AP and transverse diameters, right and left main bronchus lengths, lobar bronchus lengths	CT
Ulusoy et al. (2016)	19–74 years	212 people (116 M, 96 F)	AP and transverse diameters of trachea, cross-sectional area of trachea, RBA, LBA, IBA	Multidetector CT
Jit and Jit (2000)	18–75 years	370 people (220 M, 150 F)	Trachea length, AP and transverse diameters, right and left main bronchus lengths and diameters, RBA, LBA, SCA	Cadaver study
Zahedi-Nejad et al. (2011)	20–85 years	200 people (132 M, 68 F)	AP and transverse diameters of trachea, cross-sectional area of trachea, diameters of right and left main bronchus	CT
Mi et al. (2015)	18–89 years	2107 people (1143 M, 964 F)	Trachea length, AP and transverse diameters, right and left main bronchus lengths and diameters, RBA, LBA, right upper lobe bronchus length and angle	CT 3D
Tamang et al. (2017)	Adult individuals	40 people (20 M, 20 F)	Length and transverse diameter of trachea, SCA	Cadaver study
Sakuraba et al. (2010)	Average: 58 years	146 people (55 M, 91 F)	Trachea transverse diameter	Chest X-ray CT
Chen et al. (2020)	18–89 years	2093 people (1136 M, 957 F)	Length and diameter of right main bronchus, right upper lobe length, diameter and angle of the bronchus, RBA	CT
Premakumar et al. (2018)	70–96 years	10 people (8 M, 2 F)	Trachea, AP and transverse diameters	Cadaver study
Lee et al. (2014)	21–78 years	160 people (80 M, 80 F)	Right-left main bronchus length, AP and transverse diameters	3D CT
Kim and Song (2017)	47–91 years	48 cadavers (33 M, 15 F)	Right and left main bronchus, lenght, AP and transverse diameters, SCA	Cadaver study
Bhandari et al. (2018)	over 18 years	182 cadavers (132 M, 50 F)	Trachea, AP and transverse diameters	Cadaver study
Kamel et al. (2009)	CT image: 22–88 years Cadaver study: 68–101 years	CT: 60 people (40 M, 20 F) Cadaver: 10 people (7 M, 3 F)	Trachea length, AP and transverse diameters, tracheal volume, SCA	CT Cadaver study
Otoch et al. (2013)	18–83-years-old male patients	134 people	Trachea, length of right main bronchus	Cadaver study
Datta et al. (2019)	20–65 years	60 cadavers (30 M, 30 F)	Trachea, AP and transverse diameters	Cadaver study
Hampton et al. (2000)	Adult individuals	206 people (130 M, 76 F)	Trachea diameter, right and left main bronchus diameters	Chest X-ray
Kim et al. (2014)	19–80 years	200 people (100 M, 100 F)	Right and left main bronchus lengths, AP and transverse diameters	CT 3D

M — male; F — female; AP — anterior-posterior diameter; RBA — right bronchial angle; LBA — left bronchial angle; IBA — interbronchial angle; SCA — subcarinal angle; CT — computed tomography image; 3D — three-dimensional reconstruction

rameters increased with age. The transverse diameter of the trachea was greater than the AP diameter in children, and the AP diameter was greater than the transverse diameter in adults.

When the mean values in children and adults were compared, the length of the right main bronchus was 2.05 (1.76–2.47) and 2.93 (1.23–11.35) cm, the length of the left main bronchus was 4.09 (3.48–5.17) cm and 5.25 (3.68–10.15) cm, the transverse diameter of the right main bronchus was 0.97 (0.73–1.34) cm and 1.40 (1.08–1.91) cm, and the transverse diameter of the left main bronchus was 0.85 (0.68–1.10) cm and 1.26 (0.94–1.69) cm. The mean subcarinal angle was 71.53° (56.1°–83°) and 72.14° (52.48°–82.12°) in children and adults, respectively. It has been observed that the left main bronchus is longer than the right main bronchus in children and adults, and the transverse diameters of the right main bronchus are wider than the left main bronchus. On average, all parameter values were found to be higher in adults than in children.

When the parameters were compared according to gender, all values, except the subcarinal angle, were

Table 3. Descriptive statistics of measurements of trachea and bronchus in children

	LMB TR diameter	LMB length	RMB TR diameter	RMB length	SCA	Trachea AP diameter	Trachea TR diameter	Trachea length
Age	0–18	0–18	0–18	0–18	0–18	0–18	0–18	0–18
Min	0.68	3.48	0.73	1.76	56.10	0.78	0.95	6.19
Max	1.10	5.17	1.34	2.47	83.00	1.58	1.74	9.36
Range	0.42	1.69	0.61	0.71	26.90	0.80	0.79	3.17
Mean	0.85	4.09	0.97	2.05	71.53	1.19	1.28	7.52
SD	0.14	0.94	0.20	0.37	10.25	0.29	0.27	1.36
95.0% lower CI for mean	0.73	1.77	0.81	1.13	60.77	0.92	1.07	5.36
95.0% upper CI for mean	0.96	6.42	1.14	2.97	82.28	1.46	1.49	9.68
Median	0.83	3.63	0.98	1.93	73.12	1.10	1.14	7.27
95.0% lower CI for median	0.70	3.48	0.75	1.76	63.25	0.94	1.13	6.19
95.0% upper CI for median	0.96	5.17	1.10	2.47	80.56	1.58	1.60	9.36
Percentile 05	0.68	3.48	0.73	1.76	56.10	0.78	0.95	6.19
Percentile 25	0.75	3.48	0.83	1.76	63.25	0.94	1.13	6.56
Percentile 75	0.92	5.17	1.06	2.47	80.56	1.50	1.50	8.48
Percentile 95	1.10	5.17	1.34	2.47	83.00	1.58	1.74	9.36

Values are presented as centimetre and degree; LMB — left main bronchus; RMB — right main bronchus; SCA — subcarinal angle; AP — anterior-posterior; TR — transvers; CI — confidence interval; SD — standard deviation; Min — minimum; Max — maximum

Table 4. Descriptive statistics of measurements of trachea and bronchus in adults

	LMB TR diameter	LMB length	RMB TR diameter	RMB length	SCA	Trachea AP diameter	Trachea TR diameter	Trachea length
Age	18–89	18–89	18–89	18–89	18–89	18–89	18–89	18–89
Min	0.94	3.68	1.08	1.23	52.48	1.11	1.23	8.13
Max	1.69	10.15	1.91	11.35	82.12	2.14	2.57	13.25
Range	0.75	6.47	0.83	10.12	29.64	1.03	1.34	5.12
Mean	1.26	5.25	1.40	2.93	72.14	1.75	1.66	10.08
SD	0.28	2.19	0.27	3.24	10.48	0.25	0.33	1.39
95.0% lower CI for mean	1.02	3.22	1.20	0.44	61.14	1.59	1.47	9.09
95.0% upper CI for mean	1.49	7.28	1.61	5.42	83.14	1.91	1.84	11.08
Median	1.17	4.59	1.32	1.68	74.44	1.80	1.65	10.20
95.0% lower CI for median	1.07	4.29	1.25	1.36	71.37	1.72	1.58	9.20
95.0% upper CI for median	1.66	10.15	1.76	3.30	78.00	1.85	1.75	10.38
Percentile 05	0.94	3.68	1.08	1.23	52.48	1.11	1.23	8.13
Percentile 25	1.08	4.29	1.25	1.36	71.37	1.72	1.51	9.20
Percentile 75	1.46	4.83	1.46	2.55	78.00	1.85	1.75	10.38
Percentile 95	1.69	10.15	1.91	11.35	82.12	2.14	2.57	13.25

Values are presented as centimetre and degree; LMB — left main bronchus; RMB — right main bronchus; SCA — subcarinal angle; AP — anterior-posterior; TR — transvers; CI — confidence interval; SD — standard deviation; Min — minimum; Max — maximum

found to be higher in males than females on average. In 4 of the 6 studies in which the subcarinal angle was measured, the values were higher in women than in men, while it was observed that it was higher in men than in women in 2 studies.

DISCUSSION

Twenty-eight studies were analysed in the review of the literature, and lower airway dimensions in children and adults were compared. In both children and adults, measurement values vary. Among the possible

Table 5. Studies examining the sizes of trachea and bronchus in children

Studies	Parameters	
	RMB TR diameter	**LMB TR diameter**
Kuo [23]	M: 1.12; F: 1.06	M: 0.87; F: 0.78
Jit [18]	Average: 0.9	Average: 0.82
Chalwadi [6]	Average: 1.02	Average: 0.96
Tan [35]	Average: 0.75	Average: 0.7
Luscan [25]	Average: 1.01	Average: 0.88
Aslan [2]	Average: 0.94	Average: 0.8
Tahir [33]	M: 0.77; F: 0.68	M: 0.7; F: 0.67
	RMB length	**LMB length**
Jit [18]	Average: 1.93	Average: 3.48
Luscan [25]	Average: 1.76	Average: 3.63
	Trachea AP diameter	**Trachea TR diameter**
Griscom [14]	M: 1.1; F: 1.08	M: 1.14; F: 1.14
Breatnach [5]	M: 1.54; F: 1.45	M: 1.55; F: 1.44
Ulusoy [37]	M: 1.22; F: 0.94	M: 1.37; F: 0.99
Jit [18]	Average: 1.32	Average: 1.13
Chalwadi [6]	Average: 1.1	Average: 1.16
Luscan [25]	Average: 0.78	Average: 1.02
Szelloe [32]	Average: 0.94	–
Kuo [23]	–	M: 1.32; F: 1.2
Aslan [2]	–	Average: 1.14
Tahir [33]	–	M: 1.02; F: 0.91
	Trachea length	**Subcarinal angle**
Griscom [14]	M: 9.45; F: 9.28	–
Kuo [23]	M: 7.06; F: 6.09	–
Jit [18]	Average: 6.09	Average: 56.10°
Luscan [25]	Average: 7.6	–
Herek [17]	–	Average: 80.56°
Ulusoy [37]	–	M: 72.55; F: 69.6°
Aslan [2]	–	Average: 63.25°
Kubota [22]	–	Average: 83°

Values are presented as centimetre and degree; LMB — left main bronchus; RMB — right main bronchus; AP — anterior-posterior; TR — transverse; M — male; F — female

Table 6. Studies examining the sizes of trachea and bronchus in adult

Studies	Parameters	
	RMB TR diameter	**LMB TR diameter**
Ulusoy [37]	Average: 1.34	Average: 1.1
Jit [18]	M: 1.36; F: 1.1	M: 1.16; F: 0.94
Mi [27]	M: 1.41; F: 1.21	M: 1.16; F: 1.0
Lee [24] (2D)	M: 1.98; F: 1.84	M: 1.82; F: 1.56
Lee [24] (3D)	M: 1.56; F: 1.21	M: 1.35; F: 1.01
Kim [21]	M: 1.89; F: 1.65	M: 1.7; F: 1.44
Kim [20]	M: 1.51; F: 1.18	M: 1.3; F: 0.99
Hampton [15]	M: 1.5; F: 1.38	M: 1.3; F: 1.18
Zahedi-Nejad [42]	M:1.16; F: 0.93	M: 1.02; F: 0.8
Chen [7]	M: 1.41; F: 1.21	–
	RMB length	**LMB length**
Tuncer [36]	M: 12.56; F: 10,15	M: 11.38; F: 8.71
Ulusoy [37]	Average: 2.47	Average: 5.17
Jit [18]	M: 2.68; F: 2.37	M: 4.81; F: 4.37
Mi [27]	M: 1.41; F: 1.29	M: 5.0; F: 4.62
Lee [24] (2D)	M: 1.38; F: 1.37	M: 4.36; F: 4.19
Lee [24] (3D)	M: 1.34; F: 1.18	M: 4.82; F: 4.36
Kim [21]	M: 1.68; F: 1.69	M: 3.72; F: 3.6
Kim [20]	M: 1.29; F: 1.17	M: 4.78; F: 4.35
Chen [7]	M: 2.37; F: 2.15	–
Otoch [28]	Average: 3.3	–
	Trachea AP diameter	**Trachea TR diameter**
Breatnach [5]	M: 2.01; F: 1.63	M: 1.92; F: 1.62
Tuncer [36]	M: 1.98; F: 1.55	M: 1.85; F: 1.49
Ulusoy [37]	M: 1.76; F: 1.35	M: 1.94; F: 1.51
Jit [18]	M: 2.0; F: 1.62	M: 1.65; F: 1.3
Zahedi-Nejad [42]	M: 1.96; F: 1.47	M: 1.8; F: 1.43
Mi [27]	M: 1.9; F: 1.49	M: 1.71; F: 1.49
Premakumar [30]	Average: 1.72	Average: 1,73
Bhandari [4]	M: 1.89; F: 1.58	M: 1.32; F: 1.05
Kamel [19] (CT)	M: 2.26; F: 1.92	M: 2.71; F: 2.29
Kamel [19] (Cadaver)	M: 2.17; F: 1.55	M: 2.13; F: 1.78
Datta [9]	M: 1.55; F: 1.37	M: 1.29; F: 1.2
Sakuraba [31] (CT)	–	M: 1.74; F: 1.48
Sakuraba [31] (Chest X-ray)	–	M: 1.77; F: 1.58
Otoch [28]	Average: 1.85	–
Tamang [34]	–	M: 1.85; F: 1.34
Hampton [15]	–	Average: 1.79
	Trachea length	**Subcarinal angle**
Jit [18]	M: 8.93; F: 8.19	M: 51.2°; F: 54.3°
Tamang [34]	M: 11.13; F: 9.58	M: 72.15°; F: 70.6°
Kamel [19] (CT)	M: 10.5; F: 9.83	M: 76°; F: 81°

→

explanations for this are the participants' ages, the various assessment methods and procedures performed, gender disparities, and research conducted on various ethnic communities. Due to these discrepancies, standardizing measurement values is difficult.

Length of trachea

The mean value of the length of the trachea was found to be greater in adults than in children (Tables 3, 4). In studies on children and adults, it was found

Table 6. cont. Studies examining the sizes of trachea and bronchus in adult

Studies	Parameters	
Kamel [19] (Cadaver)	M: 10.26; F: 9.6	–
Mi [27]	M: 10.7; F: 10.1	M: 75.2°; F: 80.1°
Tuncer [36]	M: 14.24; F: 12.26	–
Premakumar [30]	Average: 10.38	–
Bhandari [4]	M: 8.28; F: 7.75	–
Otoch [28]	Average: 9.2	–
Datta [9]	M: 10.42; F: 9.81	–
Ulusoy [37]	–	M: 71.5°; F: 76.4°
Kim [20]	–	M: 83.4°; F: 79°

Values are presented as centimetre and degree; LMB — left main bronchus; RMB — right main bronchus; AP — anterior-posterior; TR — transverse; CT — computed tomography; 2D — two-dimensional image; 3D — three-dimensional image; M — male; F — female

that the length of the trachea increases with age (Tables 5, 6). Studies in children have shown that the length of the trachea increases with age and is close to each other in males and females. When the studies conducted by Griscom and Wohl (1986) [14] and Kuo et al. (2018) [23] were examined, it was seen that there was no difference between men and women until puberty, and the main difference began to occur after puberty and the length of the trachea was higher in men than in women. However, in a study by Chunder et al. (2010) [8], it was found that the trachea is shorter in women than in men, who were aged 0–15 years old. Chunder et al. (2010) [8] stated that this may be due to the puberty of children.

In all studies on adults, the length of the trachea increased with age, and it was found to be greater in males than females. However, in the study conducted by Chunder et al. (2010) [8] in the age groups of 41–55 and over 55 years old, it was stated that the length of the trachea decreased in both men and women depending on age. Chunder et al. (2010) [8] stated that this may be due to excessive contraction of the trachea by fibrous tissue due to aging.

Trachea lengths differ according to the method used in the studies. For example, in studies conducted by examining CT images of children [14, 23, 25] and adults [19, 36], it was found that trachea lengths were higher than that reported in studies performed on child [18] and adult [4, 18, 19, 28] cadavers.

AP and transverse diameters of trachea

It was noticed in comparative studies of children and adults that the diameters increased with age [5, 8, 18, 32, 37]. In every study that compared men and women, the diameters of men were found to be greater than those of women.

In studies comparing the AP and transverse diameters of the trachea in children and adults, it was discovered that there were differences (Tables 5, 6). The mean value of the transverse diameter of the trachea was found to be greater than the AP diameter in children's studies [6, 14, 25, 37]. While the average value of the diameters was equal in the study by Breatnach et al. (1984) [5], the mean value of the AP diameter of the trachea was found to be larger than the transverse diameter in the study by Jit and Jit (2000) [18]. In a study conducted by Chunder et al. (2010) [8] in the 0–15 age group, it was discovered that men had a larger AP diameter and women had a larger transverse diameter. Jit and Jit (2000) [18] stated that these differences may be racial, due to the variability of the subjects' height and neck length.

Studies in adults were reviewed and studies were found in which the mean value of the AP diameter of the trachea was larger [4, 5, 9, 18, 36, 42] and smaller [19, 30, 37] than the mean value of the transverse diameter.

The trachea's AP and transverse diameters differ depending on how they are measured. The values of the transverse and AP diameters of the trachea measured on CT images were larger than the values measured on cadavers, according to Kamel et al. (2009) [19]. The transverse diameter of the trachea measured on the chest X-ray was found to be higher than the value of the transverse diameter measured on the CT images in studies conducted by Sakuraba et al. (2010) [31].

Lengths of right and left main bronchus

In studies comparing the lengths of the right and left main bronchus in children and adults, the average values of main bronchus lengths in adults were found to be higher than in children (Tables 3, 4). In studies conducted on adults, the lengths of the main bronchus were found to be greater in males than in females [7, 18, 20, 24, 27, 36]. In studies examining the lengths of the right and left main bronchus in children [18, 25] and adults [18, 20, 21, 24, 27, 37] comparatively, the length of the left main bronchus is compared to the length of the right main bronchus and found to be larger.

The lengths of the main bronchus differ according to the measurement methods. In a study by Lee et al. (2014) [24], in which measurements were made on two-dimensional (2D) and 3D images in adults, it was

found that the length of the right main bronchus was larger in 2D images than in 3D images. The length of the left main bronchus was found to be smaller in 2D images than in 3D images.

Transverse diameters of right and left main bronchus

The mean values of the transverse diameters of the main bronchus in adults were larger than in children, according to studies comparing the transverse diameters of the right and left main bronchus in children and adults (Tables 3, 4). The diameters of the right and left main bronchus were found to be larger in men than in women in all of the studies (Tables 5, 6). All studies measuring the transverse diameters of the right and left main bronchus in children [2, 6, 18, 23, 25, 33, 35] and adults [15, 18, 20, 21, 24, 27, 37, 42] found that the right main bronchus was larger than the left main bronchus.

The transverse diameters of the main bronchus vary depending on the method of measurement. Lee et al. (2014) [24] determined that the transverse diameters of the right and left main bronchus were smaller in 3D images than in 2D images in adults.

Subcarinal angle

Considering the studies examining the subcarinal angle in children [2, 17, 18, 22, 37] and adults [18, 19, 20, 27, 34, 37], it is seen that the mean value of the subcarinal angle is higher in adults than in children (Tables 3, 4). In a comparative study by Ulusoy et al. (2016) [37] in children and adult, it was reported that the mean value of the subcarinal angle was higher in adults. In the studies conducted by Jit and Jit (2000) [18] and Chunder et al. (2010) [8], the mean value of the subcarinal angle was found to be higher in children. It was stated by Farrukhabad and Chunder (2015) [12] that with increasing age, the ossification of the chest wall and ribs is about to be completed, relatively hardening and causing the subcarinal angle to narrow by directing the lower growth of the lungs.

The subcarinal angle varies by gender. It was found to be higher in men than women in some studies [8, 20, 34], but higher in women in others [18, 19, 27, 37].

Understanding the subcarinal angle is critical in some clinical scenarios. Enlargement of mediastinal structures or pulmonary diseases can dramatically modify the subcarinal angle. Due to the fact that the right main bronchus is almost parallel to the trachea, the right subcarinal angle, which is a component of the subcarinal angle, is smaller than the left subcarinal angle. For this reason, the probability of foreign bodies entering the right lung is higher [12].

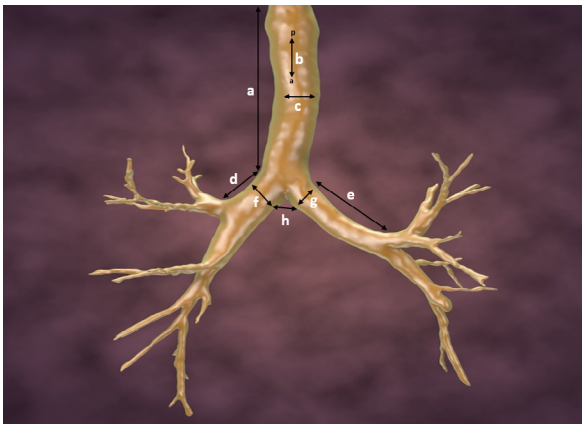

Figure 1. Three-dimensional model of tracheobronchial tree; a — trachea length; b — trachea anterior-posterior diameter; c — trachea transvers diameter; d — right main bronchus length; e — left main bronchus length; f — right main bronchus transvers diameter; g — left main bronchus transvers diameter; h — subcarinal angle.

CONCLUSIONS

The literature reviews on the trachea and bronchus in children and adults were compared according to age and gender in this study. The mean values of all parameters in the studies increased with age, and gender differences were found to have an impact on the differences in measured parameter values. The AP diameter of the trachea was discovered to be lower than the transverse diameter in children, whereas the AP diameter of the trachea was found to be higher than the transverse diameter in adults. According to studies, the right main bronchus transverse diameter is greater than the left main bronchus transverse diameter in children and adults. Despite the fact that the mean value in subcarinal angle studies is higher in adults than in children, there are research that contradict these findings [8, 18]. The data collected from the parameters varies since the measurements were done with varied methods and techniques in the investigations, and it is assumed that standardisation is difficult. We believe that the data gained will be valuable in terms of theory and clinic, and that it will be useful to perform additional research in a larger population, including children and adults, in a comparative manner, in conjunction with creating methodologies and procedures.

Acknowledgements

We thank Prof. Dr. Tuncay Veysel Peker from Gazi University Medical Faculty Anatomy Department and Research Assistant Ayşe Erkaya from Lokman Hekim University Medical Faculty Anatomy Department for creating the 3D model of the tracheobronchial tree (Fig. 1).

Conflict of interest: None declared

REFERENCES

1. Arıncı K. Arıncı Anatomi. 4. Baskı, Güneş Kitabevi, Ankara 2005.
2. Aslan A, Aslan M, Soysal A, et al. Pediatrik yaş grubunda akciğer grafisi bulguları. Kocatepe Tıp Dergisi. 2015; 15(1): 32–40.
3. Beder S, Küpeli E, Karnak D, et al. Tracheobronchial variations in Turkish population. Clin Anat. 2008; 21(6): 531–538, doi: 10.1002/ca.20667, indexed in Pubmed: 18698650.
4. Bhandari R, Ranjit N, Shrestha R, et al. Morphometric study of trachea in adult cadavers. J Institute Med. 2018; 40(1): 59–63.
5. Breatnach E, Abbott GC, Fraser RG. Dimensions of the normal human trachea. Am J Roentgenol. 1984; 142(5): 903–906, doi: 10.2214/ajr.142.5.903, indexed in Pubmed: 6609569.
6. Chalwadi UK, Swamy N, Agarwal A, et al. Determining normal values for lower trachea and bronchi size in children by computed tomography (CT). Pediatr Pulmonol. 2021; 56(9): 2940–2948, doi: 10.1002/ppul.25536, indexed in Pubmed: 34133085.
7. Chen Y, Guo Y, Mi W, et al. Anatomy of the right upper lobe revisited and clinical considerations in Chinese population. PLoS One. 2020; 15(11): e0242178, doi: 10.1371/journal.pone.0242178, indexed in Pubmed: 33237948.
8. Chunder R, Nandi S, Guha R, et al. A morphometric study of human trachea and principal bronchi in different age groups in both sexes and its clinical implications. Nepal Med Coll J. 2010; 12(4): 207–214, indexed in Pubmed: 21744760.
9. Datta D, Kundu D, Pal P, et al. A morphometric study of adult human trachea in West Bengal population. Int J Med Res Rev. 2019; 7(1): 36–42, doi: 10.17511/ijmrr.2019.i01.07.
10. Dave MH, Kemper M, Schmidt AR, et al. Pediatric airway dimensions: a summary and presentation of existing data. Paediatr Anaesth. 2019; 29(8): 782–789, doi: 10.1111/pan.13665, indexed in Pubmed: 31087466.
11. Dave MH, Schmid K, Weiss M. Airway dimensions from fetal life to adolescence: A literature overview. Pediatr Pulmonol. 2018; 53(8): 1140–1146, doi: 10.1002/ppul.24046, indexed in Pubmed: 29806162.
12. Farrukhabad UP, Chunder RA. morphometric study of human subcarinal angle in different age groups in both sexes and its clinical implications. Indian J Basic Applied Med Res. 2015; 4(2): 424–430.
13. Ghaye B, Szapiro D, Fanchamps JM, et al. Congenital bronchial abnormalities revisited. Radiographics. 2001; 21(1): 105–119, doi: 10.1148/radiographics.21.1.g01ja06105, indexed in Pubmed: 11158647.
14. Griscom NT, Wohl ME. Dimensions of the growing trachea related to age and gender. Am J Roentgenol. 1986; 146(2): 233–237, doi: 10.2214/ajr.146.2.233, indexed in Pubmed: 3484568.
15. Hampton T, Armstrong S, Russell WJ. Estimating the diameter of the left main bronchus. Anaesth Intensive Care. 2000; 28(5): 540–542, doi: 10.1177/0310057X0002800510, indexed in Pubmed: 11094671.
16. Henry BM, Tomaszewski KA, Walocha JA. Methods of Evidence-Based Anatomy: a guide to conducting systematic reviews and meta-analysis of anatomical studies. Ann Anat. 2016; 205: 16–21, doi: 10.1016/j.aanat.2015.12.002, indexed in Pubmed: 26844627.
17. Herek D, Herek O, Ufuk F. Tracheobronchial angle measurements in children: an anthropometric retrospective study with multislice computed tomography. Clin Exp Otorhinolaryngol. 2017; 10(2): 188–192, doi: 10.21053/ceo.2016.00185, indexed in Pubmed: 27334508.
18. Jit H, Jit I. Dimensions and shape of the trachea in the neonates, children and adults in northwest India. Indian J Med Res. 2000; 112: 27–33, indexed in Pubmed: 11006658.
19. Kamel KS, Lau G, Stringer MD. In vivo and in vitro morphometry of the human trachea. Clin Anat. 2009; 22(5): 571–579, doi: 10.1002/ca.20815, indexed in Pubmed: 19544298.
20. Kim D, Son JS, Ko S, et al. Measurements of the length and diameter of main bronchi on three-dimensional images in Asian adult patients in comparison with the height of patients. J Cardiothorac Vasc Anesth. 2014; 28(4): 890–895, doi: 10.1053/j.jvca.2013.05.029, indexed in Pubmed: 24103712.
21. Kim I, Song C. The morphometric study of main bronchus in Korean cadaver. Korean J Physical Anthropol. 2017; 30(1): 7, doi: 10.11637/kjpa.2017.30.1.7.
22. Kubota Y, Toyoda Y, Nagata N, et al. Tracheo-bronchial angles in infants and children. Anesthesiology. 1986; 64(3): 374–376, doi: 10.1097/00000542-198603000-00015, indexed in Pubmed: 3954135.
23. Kuo W, Ciet P, Andrinopoulou ER, et al. Reference values for central airway dimensions on CT images of children and adolescents. AJR Am J Roentgenol. 2018; 210(2): 423–430, doi: 10.2214/AJR.17.18597, indexed in Pubmed: 29261353.
24. Lee JW, Son JS, Choi JW, et al. 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. 2014; 66(3): 189–194, doi: 10.4097/kjae.2014.66.3.189, indexed in Pubmed: 24729839.
25. Luscan R, Leboulanger N, Fayoux P, et al. Developmental changes of upper airway dimensions in children. Paediatr Anaesth. 2020; 30(4): 435–445, doi: 10.1111/pan.13832, indexed in Pubmed: 31995659.
26. McLaughlin FJ, Strieder DJ, Harris GB, et al. Tracheal bronchus: association with respiratory morbidity in childhood. J Pediatr. 1985; 106(5): 751–755, doi: 10.1016/s0022-3476(85)80348-6, indexed in Pubmed: 3998915.
27. Mi W, Zhang C, Wang H, et al. Measurement and analysis of the tracheobronchial tree in Chinese population using computed tomography. PLoS One. 2015; 10(4): e0123177, doi: 10.1371/journal.pone.0123177, indexed in Pubmed: 25894917.

28. Otoch JP, Minamoto H, Perini M, et al. Is there a correlation between right bronchus length and diameter with age? J Thorac Dis. 2013; 5(3): 306–309, doi: 10.3978/j.issn.2072-1439.2013.03.12, indexed in Pubmed: 23825764.
29. Ozan H. Ozan Anatomi. 3. Baskı, Tıp Kitabevi, Ankara 2014.
30. Premakumar Y, Griffin MF, Szarko M. Morphometric characterisation of human tracheas: focus on cartilaginous ring variation. BMC Res Notes. 2018; 11(1): 32, doi: 10.1186/s13104-018-3123-1, indexed in Pubmed: 29338790.
31. Sakuraba S, Serita R, Kuribayashi J, et al. Comparison of tracheal diameter measured by chest x-ray and by computed tomography. Anesthesiol Res Pract. 2010; 2010, doi: 10.1155/2010/269171, indexed in Pubmed: 20827310.
32. Szelloe P, Weiss M, Schraner T, et al. Lower airway dimensions in pediatric patients: a computed tomography study. Paediatr Anaesth. 2017; 27(10): 1043–1049, doi: 10.1111/pan.13210, indexed in Pubmed: 28846178.
33. Tahir N, Ramsden WH, Stringer MD. Tracheobronchial anatomy and the distribution of inhaled foreign bodies in children. Eur J Pediatr. 2009; 168(3): 289–295, doi: 10.1007/s00431-008-0751-9, indexed in Pubmed: 18500537.
34. Tamang BK, Lakhi K, Sinha P, et al. Study of tracheal dimension in adult cadavers from Eastern India. Indian J Clin Anat Physiol. 2017; 4(2): 144–147, doi: 10.18231/2394-2126.2017.0036.
35. Tan GM, Tan-Kendrick APA. Bronchial diameters in children: use of the Fogarty catheter for lung isolation in children. Anaesth Intensive Care. 2002; 30(5): 615–618, doi: 10.1177/0310057X0203000512, indexed in Pubmed: 12413262.
36. Tuncer I. İnsan Trakeobronşial Ağacının Her İki Cınsıyetın Farklı Yaş Gruplarında Ct ile Morfometrik Çalışması. DÜSTAD Dünya Sağlık ve Tabiat Bilimleri Dergisi. 2018; 1(1): 19–35.
37. Ulusoy M, Uysal II, Kivrak AS, et al. Age and gender related changes in bronchial tree: a morphometric study with multidedector CT. Eur Rev Med Pharmacol Sci. 2016; 20(16): 3351–3357.
38. Wani TM, Simion C, Rehman S, et al. Mainstem bronchial diameters and dimensions in infants and children: a systematic review of the literature. J Cardiothorac Vasc Anesth. 2021; 35(10): 3078–3084, doi: 10.1053/j.jvca.2020.07.002, indexed in Pubmed: 32732101.
39. Waschke J, Böckers TM, Paulsen F. Sobotta Anatomi Konu Kitabı. In: Mustafa Fevzi Sargon (ed.). İmge Kitabevi, Ankara 2016.
40. Willan P, Humpherson J. Concepts of variation and normality in morphology: Important issues at risk of neglect in modern undergraduate medical courses. Clin Anat. 1999; 12(3): 186–190, doi: 10.1002/(sici)1098-2353(1999)12:3<186::aid-ca7>3.0.co;2-6.
41. Wong LM, Cheruiyot I, de Oliveira MH, et al. Congenital anomalies of the tracheobronchial tree: a meta-analysis and clinical considerations. Ann Thorac Surg. 2021; 112(1): 315–325, doi: 10.1016/j.athoracsur.2020.08.060, indexed in Pubmed: 33159867.
42. Zahedi-Nejad N, Bakhshayesh-Karam M, Kahkoei S, et al. Normal dimensions of trachea and two main bronchi in the Iranian population. Pol J Radiol. 2011; 76(4): 28–31, indexed in Pubmed: 22802851.
43. Żytkowski A, Tubbs R, Iwanaga J, et al. Anatomical normality and variability: Historical perspective and methodological considerations. Transl Res Anat. 2021; 23: 100105, doi: 10.1016/j.tria.2020.100105.