Interventions in Pulmonary Medicine

José Pablo Díaz-Jiménez
Alicia N. Rodríguez
Editors

Third Edition

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To all the colleagues and people involved in medical care who died during the COVID-19 pandemic. Our appreciation and heartfelt thanks to those who gave their lives to save others.

Foreword

The care of patients with pulmonary disorders requires a combination of both cognitive expertise and procedural skills. My personal journey in this field began when asked to join the bronchoscopy team at Mayo Clinic. This small group of five clinicians was responsible for all the flexible and rigid bronchoscopies in adult and pediatric patients. It was a unique opportunity and privilege to be trained and mentored by some of the original pioneers of both flexible and rigid techniques. I have also been blessed to work with and train many physicians in the art of advanced pulmonary procedures. Several are the current and future leaders in this field and authors of this book.

One of the highlights of my professional journey has been developing a friendship with Professor José Pablo Díaz-Jiménez. I first met Dr. Díaz-Jiménez over 30 years ago when he took a 6-month sabbatical at Mayo Clinic to train in the application of photodynamic therapy for early lung cancer. It was during this sabbatical that we became lifelong colleagues and friends. I am privileged to witness Pablo's development from a young pulmonary physician with procedural interests into a master clinician and master educator in the artful application of both flexible and rigid bronchoscopy.

A Mayo Clinic tradition, as in other academic institutions, has been to share and learn new knowledge through collaborative relationships with national and international physicians. Dr. Diaz Jimenez exemplifies this principle as evidenced by his own travels and by the many physicians he has trained in the art and appropriate application of rigid bronchoscopy for various benign and malignant airway disorders. It was during one of many trips to Barcelona in 1998 that I met another young clinician Dr. Alicia N. Rodríguez from Mar de Plata, Argentina. Similar to Dr. Díaz-Jiménez, Dr. Rodriquez subsequently became an internationally recognized leader in the application of advanced pulmonary procedures and a master educator of physicians in this field.

The current edition of *Interventions in Pulmonary Medicine* again highlights new technologies and their application to pulmonary medicine and reviews the various pulmonary procedures and techniques in previous editions. Drs. Díaz-Jiménez and Rodriquez accomplish this by bringing together world experts in the field. Each author provides up-to-date scholarly information that will be useful to both beginners and experts.

Mayo Clinic Eric Edell
Rochester, MN, USA

Preface

The third edition of the book *Interventions in Pulmonary Medicine* was entrusted to us in the midst of the COVID-19 pandemic, hard times for pulmonologists. The pandemic came to change our professional life and made us focus mainly on those pulmonary conditions related to the virus.

With this, the time of professional in-person meetings, congresses, symposiums, and even casual conversations was replaced by online meetings only, and we had a massive number of updates on the situation, day-to-day medical news that kept us up to date with the developments. Now is not the time to make a balance or arrive at conclusions; the future will tell the advantages or disadvantages that the confinement brought about. It is true that for almost 3 years we have learnt many things, even though our daily coexistence with colleagues was very limited.

Vulnerability, the most fragile aspect of humanity, suddenly appeared, highlighting aspects that taught us to reflect on how to manage critical situations, how to handle administrative and economic resources, and how to put in motion all the necessary scientific aspects to deal with the world pandemic. Many good things arose too: human values such as love, solidarity, empathy, and generosity toward those in need showed that we have an innate capacity to work together for the good of us all, to team up to alleviate the pain and suffering that this pandemic brought upon the human race.

In record time the virus was identified and mapped, facilitating the development of new therapies and vaccines that have borne fruit to the point that the disease is now, hopefully, almost under control.

As can be seen in the content of the book, there are many new developments in terms of scientific and practical repercussions that have occurred regarding the application of interventional techniques for pulmonary complications of COVID-19. Likewise, the reader will find, in accordance with the progress of endoscopic techniques, new chapters that will illustrate our knowledge and contributions on that matter.

We have come a long way since the first publications on knowledge and use of Bronchoscopy, from pioneers such as Gustav Killian and Chevalier Jackson at the end of the nineteenth century and the beginning of the twentieth century. It was at that time that the first foundations were laid out for what is now Modern Bronchoscopy.

In 1949, Robert Monod said, in the prologue to his magnificent French book *Bronchologie, Technique endoscopique et Pathologie trachéo-bronchique* by André Soulas and Pierre Mounier-Kuhn, that the most transcendental acquisitions of Pulmonology had been auscultation and fine-tuning of the radiological techniques and later a third acquisition, peroral tracheo-bronchoscopy, giving way to the foundations and flourishing of Interventional Bronchoscopy.

The path of the first bronchoscopists, great experts in the extraction of foreign bodies, broncho-pulmonary suppurations, and bronchial obstruction mechanisms, was not easy at the beginning. They also had to manage pandemics, world wars full of suffering, and of great challenges. The current bronchoscopy field, now essential and involved in many modern advances in the diagnosis and treatment of respiratory diseases, was made easier thanks to the contribution of those pioneers.

Most recent technical advances in the industry have contributed much to the progress and improvement of bronchoscopes and their accessory equipment. With the expansion of modern bronchoscopy in the late sixties of the twentieth century, such as the development of the fiberoptic bronchoscope and its introduction into clinical practice by Shigeto Ikeda, and the advances brought by Prof. J.F. Dumon in the early eighties, the Modern Interventional Pulmonology was firmly established in the medical arena.

We like to consider Prof. J.F. Dumon as the Leonardo da Vinci of Rigid Bronchoscopy, a genius who designed the safest bronchoscope and incredible tools to perform treatments in the tracheobronchial tree in order to improve the patient's quality of life. Though he left us a year ago, it was an honor for us to learn from him, and to consider him a mentor and a friend for almost 40 years. Among his many qualities, we particularly value his willingness and generosity to teach in an easy way. He will be missed and remembered by all of us.

Dumon liked to define Interventional Bronchoscopy as "the art of Bronchoscopy," and we, interventional pulmonologists, should call ourselves artisans in that regard. And so, we would like to thank all the artisan collaborators in the use of bronchoscopy who have participated sharing their expertise in this book, in spite of the overwhelming medical and personal demands during this difficult time. Without their invaluable work, the publication of this Third Edition of *Interventions in Pulmonary Medicine* would have been impossible.

Barcelona, Spain — José Pablo Díaz-Jiménez
Mar del Plata, Buenos Aires, Argentina — Alicia N. Rodríguez

Contents

About the Editors

José Pablo Díaz-Jiménez, MD, PhD, is a Pulmonary Physician, dedicated to Interventional Pulmonology (IP) for more than 35 years. He trained as a Pulmonary Physician at Bellvitge University Hospital in Barcelona, Spain, and then he completed his interventional training with Dr. Dumon at Marseille (France) and Dr. Cortese at the Mayo Clinic, Rochester, Minnesota (USA).

He was Head of the Interventional Pulmonary Department at Bellvitge University from 1991, organizing training programs, international courses, and congresses in Interventional Pulmonology for more than 25 years. He is Adjunct Professor, Department of Pulmonary Medicine-Research, at the MD Anderson Cancer Center, Houston, Texas (USA).

He is recognized as one of the leaders of IP around the world. He is Former Chairman of the World Association for Bronchology and Interventional Pulmonology (WABIP) and Former President of the World Bronchology Foundation (WBF). He is also recipient of Dumon Award and Killian Centenary Medal for the World Association for Bronchology and Interventional Pulmonology (WABIP).

Alicia N. Rodríguez, MD, has been a Pulmonary Physician for more than 20 years. She trained in Internal Medicine and then completed her training in Pulmonary Medicine with Dr. Beamis at the Lahey Clinic in Burlington, MA (USA), and Interventional Pulmonary Medicine with Dr. Díaz-Jiménez at Bellvitge University Hospital in Barcelona (Spain). She settled in Mar del Plata (Argentina), where she became Head of the Pulmonary and Respiratory Endoscopy Department in Clinica Colón. She has taken part in many multicentric research projects and is also performing independent research and teaching at the University of Mar del Plata Medical School.

She belongs to many scientific societies, such as the Argentinian Association of Respiratory Medicine (AAMR), the Argentinian Association of Bronchoesophagologhy (AABE), and Women in Interventional Pulmonology (WIIP).

She is a respected Senior Pulmonary Consultant, well known for both her academic work and dedication to her patients.

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Part I

Basic Bronchoscopy Procedures

1 Tracheobronchial Anatomy

Juan Antonio Moya Amorós
and Anna Ureña Lluveras

Trachea

Introduction

The trachea or windpipe is a tube of approximately 12 cm length. Viewed laterally, it assumes an oblique course, running from superoanterior to inferoposterior, from 23° to 34° related to the body's major axis. It ends up by dividing into two bronchial tubes at the level of the tracheobronchial bifurcation, which usually has an angle of 60°. Changes in the degree of angulation can orient to diagnose some conditions located distally to the bifurcation such as enlarged lymph nodes, or left atrium dilatation in mitral stenosis. The tracheal tube extends from C6 to C7 (limited by the cricoid cartilage superiorly) to D4–D5, approximately at 1 or 2 cm below a horizontal plane passing through the Louis sternal angle. Topographically, its average length (12 cm as stated) is equally divided between the cervical and mediastinal region [1].

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External Morphology

The external tracheal configuration is characterized by the presence of roughness due to incomplete cartilage rings that are staggered, and horizontally and segmentally distributed. Usually 20 rings are identified in the trachea.

In the cervical region, the tube has a flattened shape posteriorly, due to the absence of cartilage, so that the predominant diameter is sagittal or anteroposterior (approximately 16 mm), but inside the chest it predominates the transverse diameter (approximately 16 mm).

In the external tracheal wall, narrowing or depressions can be seen, produced by the imprint of organs in close proximity contacting the tracheal wall. In the left side, two of them are visible: one due to the left thyroid gland lobe (neck) and the other one due to the aortic arch (mediastinum).

The posterior membrane closing the entire tracheal canal is flat, soft, and depressible; it is known as the *membranous pars* (Fig. 1.1).

The special tracheal configuration and its elastic structure make it capable of elongating up to 1/3 of its length. This fact is of particular interest for tracheal reconstruction surgeries.

Dimensions of the trachea vary primarily according to age, and less so with gender. Figures 1.2, 1.3, 1.4, and 1.5 present the normal size variations in all three axes, internal size, area, and volume.

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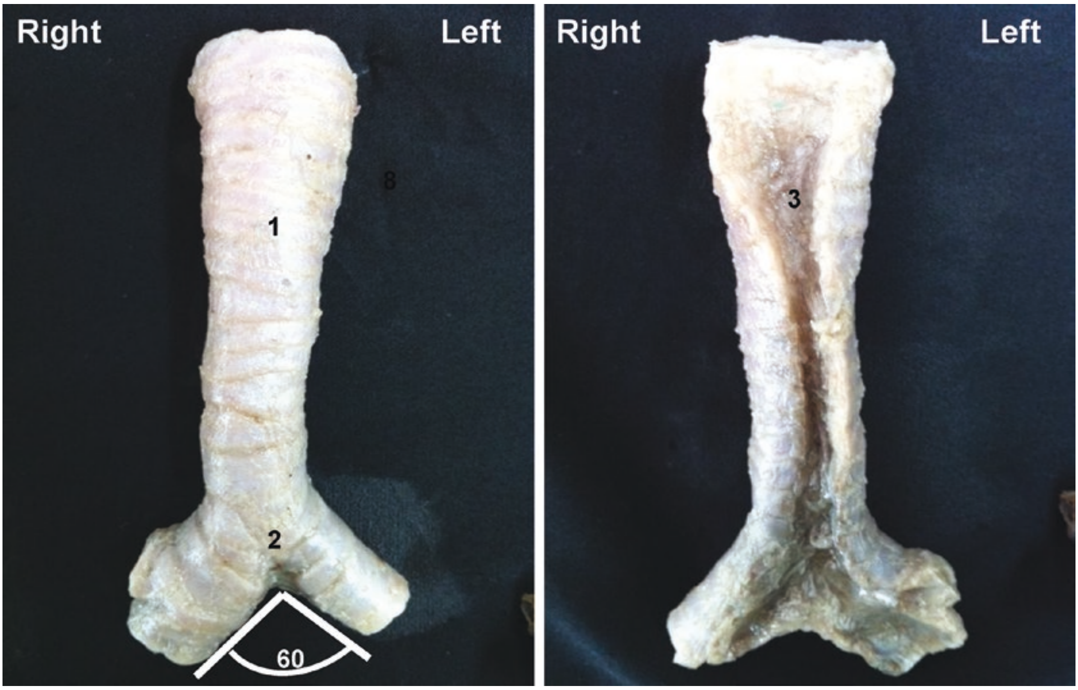
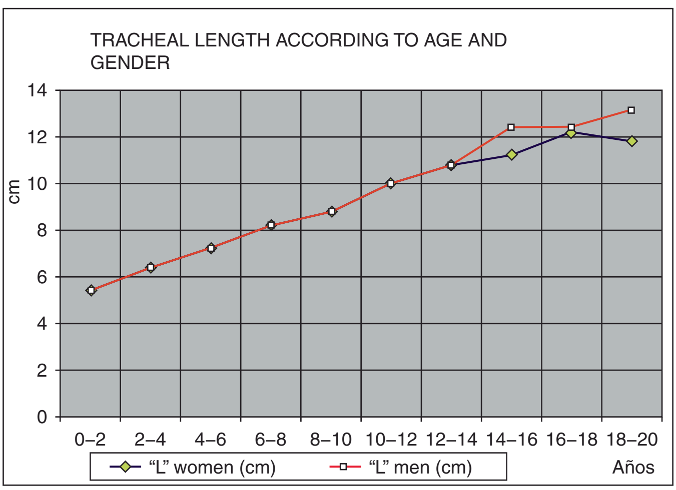


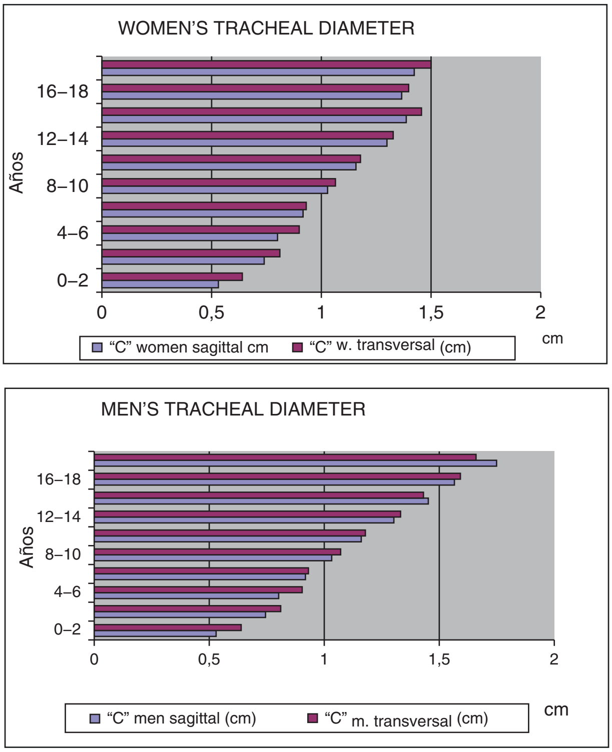
Fig. 1.1 Anterior view of the dissected trachea. Note the tracheal bifurcation angle of 60°: (1) anterior view: trachea and tracheal cartilage; (2) tracheobronchial bifurcation; and (3) membranous pars or tracheal muscle. Unit of Human Anatomy and Embryology, Department of Pathology and Experimental Therapeutics, Universitat de Barcelona



	"L" women (cm)	"L" men (cm)
0–2	5.4	5.4
2–4	6.4	6.4
4–6	7.2	7.2
6–8	8.2	8.2
8–10	8.8	8.8
10–12	10	10
12–14	10.8	10.8
14–16	11.2	12.4
16–18	12.2	12.4
18–20	11.8	13.1

Medium length of the trachea increases similarly in both genders until the age of 14. After that it only increases in men.

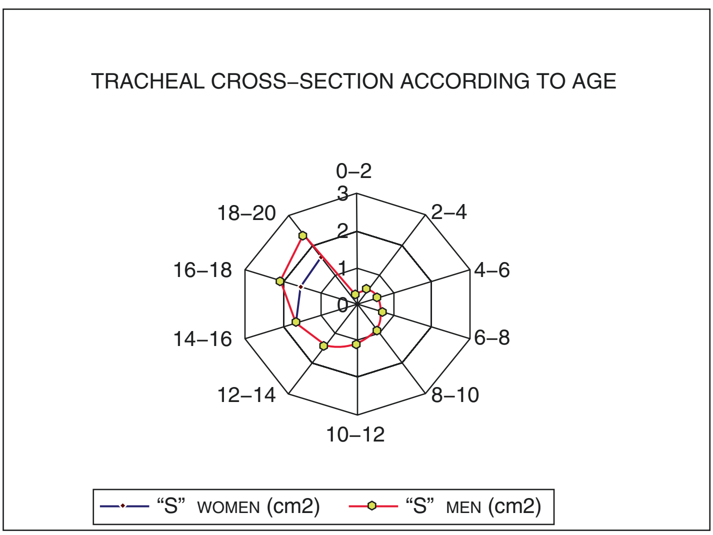
Fig. 1.2 Medium length of the trachea increases similarly in both genders until the age of 14. After that it only increases in men



AGE in years	"C" sagittal women (cm)	"C" transv. women (cm)	"C" sagittal men (cm)	"C" transv. men (cm)
0–2	0.53	0.64	0.53	0.64
2–4	0.74	0.81	0.74	0.81
4–6	0.8	0.9	0.8	0.9
6–8	0.92	0.93	0.92	0.93
8–10	1.03	1.07	1.03	1.07
10–12	1.16	1.18	1.16	1.18
12–14	1.3	1.33	1.3	1.33
14–16	1.39	1.46	1.45	1.43
16–18	1.37	1.4	1.57	1.59
18–20	1.42	1.49	1.75	1.66

Medium tracheal diameter increases similarly in both genders until the age of 14. After that it only increases in men.

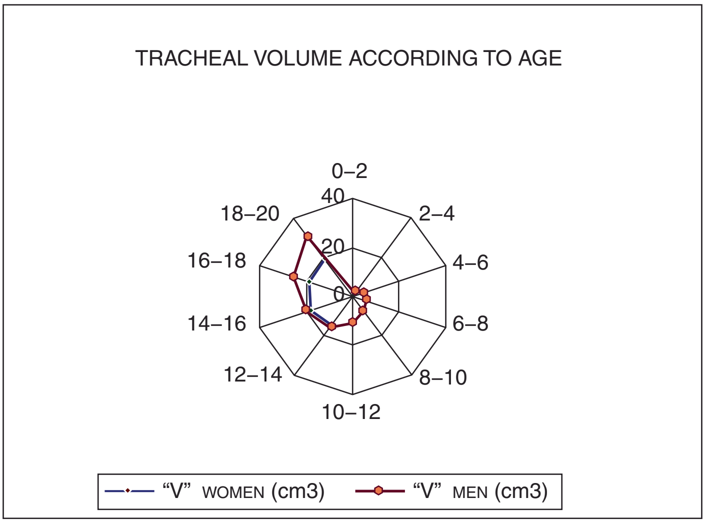
Fig. 1.3 Medium tracheal diameter increases similarly in both genders until the age of 14. After that it only increases in men



AGE	"S" WOMEN (*cm²*)	"S" MEN (*cm²*)
0–2	0.28	0.28
2–4	0.48	0.48
4–6	0.58	0.58
6–8	0.69	0.69
8–10	0.89	0.89
10–12	1.1	1.1
12–14	1.39	1.39
14–16	1.62	1.62
16–18	1.54	2.01
18–20	1.59	2.3

- Medium tracheal area increases similarly in both genders until the age of 14.
- At age 20. tracheal area is 44.6% larger in men than in women.

Fig. 1.4 Medium tracheal area increases similarly in both genders until the age of 14. At age 20, the tracheal area is 44.6% larger in men than in women



AGE	"V" WOMEN (cm^3)	"V" MEN (cm^3)
0–2	1.57	1.57
2–4	3.11	3.11
4–6	4.16	4.16
6–8	5.67	5.67
8–10	7.87	7.87
10–12	11.1	11.1
12–14	15.4	15.4
14–16	18.2	20.2
16–18	18.8	25.1
18–20	18.9	30.3

- Medium tracheal volumen increases similarly in both genders until the age of 14
- By age 20. men's tracheal volume is 60% larger than in women's.

Fig. 1.5 Medium tracheal volume increases similarly in both genders until the age of 14. By age 20, men's tracheal volume is 60% larger than women's

Among both genders, there are also differences in tracheal size, especially in the sagittal and transverse axes, which are evident in tomographies and three-dimensional (3D) reconstruction (Figs. 1.6 and 1.7).

Internal Morphology

The tracheal tube has two covers or layers:

Main, Fibro-Chondro Elastic Layer It is a completely circular, soft, and elastic connective tissue fundamental matrix. It affects the entire circumference of the windpipe. It presents tiny holes that represent the point of vascular entrance or exit to and from inside the trachea.

Enclosed to this layer there are bands of incomplete hyaline cartilage rings, horseshoe-shaped. The cartilage forms about four-fifths of the circumference of the trachea. Given that the posterior border of the trachea is formed by a fibromuscular membrane, the tracheal cross-

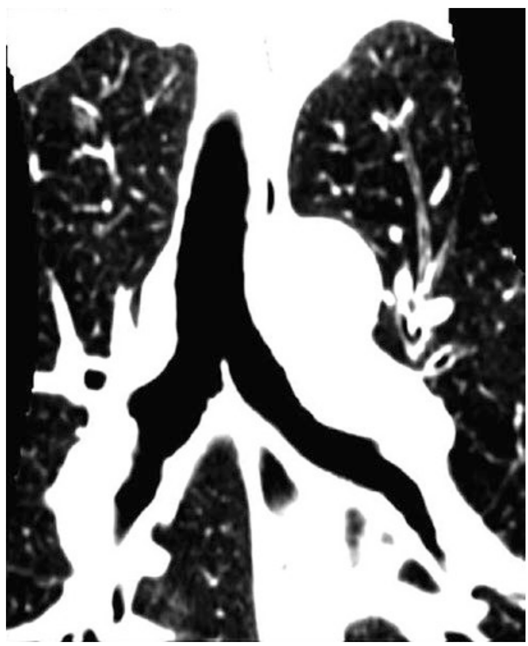


Fig. 1.6 At age 20, men's sagittal and transverse tracheal axes are 23% and 11.4% larger than women's, respectively. Coronal computerized tomography: view of mediastinal trachea, tracheobronchial bifurcation, and main bronchi

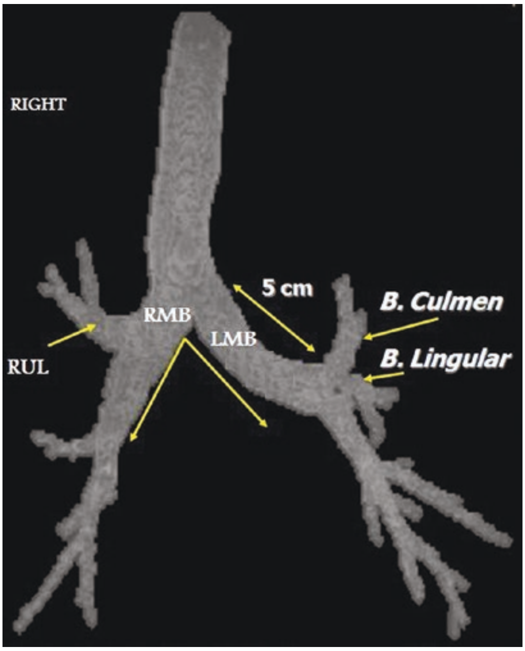


Fig. 1.7 Medium tracheal diameter is 1.5 mm larger in men than in women. Medium bronchial diameter is 1 mm larger in men. Two-dimensional (2D) tomographic reconstruction of the tracheobronchial tree. Note that the intracarinal angle is 60°. Lengths are 5 cm for the left main bronchus, and 2.5 cm for the right main bronchus

sectional shape is similar to a letter D, with the flat side located posteriorly. These are known as the tracheal muscles, and have vegetative involuntary innervation. The tracheal muscles cross transversely and obliquely, forming continuous entangled fibers that constitute a large muscle: the common tracheal muscle. Contraction of this muscle produces adduction of the free cartilage edges, thus modulating the internal tracheal caliber. Wrapping the outer tracheal tube, we found the adventitia, a membrane that acts as a false pretracheal fascia. Between the adventitia and the tracheal wall vascular and nervous branches are located, and they incorporate to the tracheal tube wall at the level of the interchondral spaces.

Mucous Layer

The trachea is lined by pseudostratified columnar epithelium that sits in an elastic *lamina propia*, and covers the inside of the tracheal tube. Goblet mucous cells and small subepithelial glands that secrete into the luminal surface are interspersed among the ciliated columnar cells. The produced mucus adheres to inhaled foreign particles, which are then expelled by the action of cilia propelling the mucus lining upward toward the pharynx from which they can be coughed and sneezed out of the airway. At the end of the tracheal duct, when it is divided into the main bronchi, the mucosa presents a middle-line elevation known as carina, similar to a medial ridge. The tracheal carina indicates the entrance to the right and left main bronchi (Fig. 1.8a–c).

Blood Supply

Arterial blood supply is established by two arterial systems on each side of the trachea, communicating the aorta artery with the subclavian artery:

- From the aorta, originates the left paratracheal ascending artery (Demel arteries) and the tracheobronchial esophageal artery. Of the latter, the right bronchial artery, the esophageal artery, and the right paratracheal ascending artery are born.
- From both subclavian arteries, inferior thyroid arteries emerge and from these in turn emerge the right and left paratracheal descending arteries (Haller arteries).

  Each paratracheal descending artery anastomoses with the paratracheal ascending artery of the corresponding side, closing the vascular circuit at the back of the tracheal wall and along its side edges. From these two vascular axes, tracheal perforating arteries are born that supply tracheal layers entering through the interchondral spaces.

Anatomo-Clinical Relationships

The trachea is related to their surroundings through the peri-tracheal fascia, as if it were a hanger between the neck and the mediastinum [2]. Vascular and nerve structures are hung from or are in contact with it.

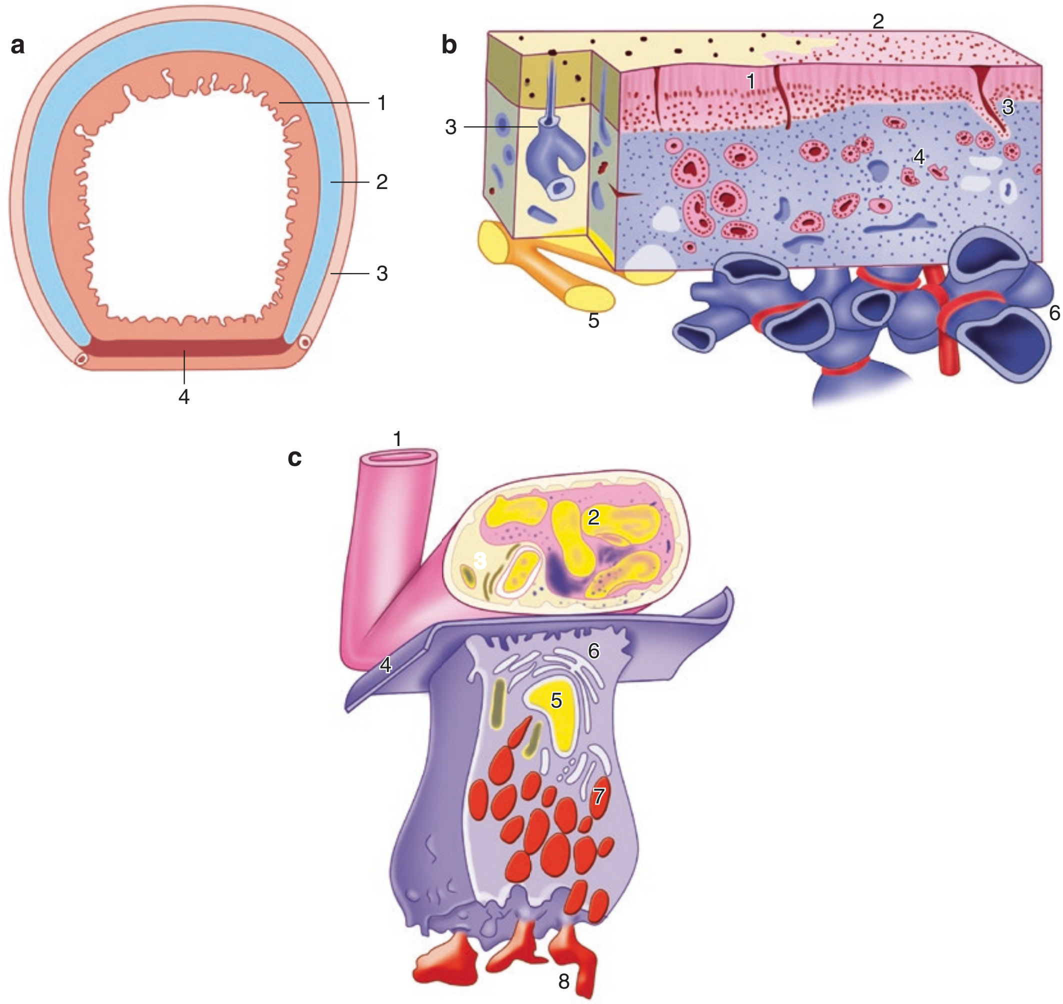


Fig. 1.8 (**a**) Cross-section, trachea: (1) respiratory cylindrical epithelium and mucous glands; (2) horseshoe-shaped cartilage with a posterior opening; and (3) main layer, connective tissue fundamental matrix, surrounded by the adventitia. (**b**) Schematic illustration of the elements of the tracheal wall: (1) Pseudostratified columnar epithelium; (2) gland drainage orifice; (3) gland duct; (4) submucous; (5) vagus nerve; and (6) venules and arterioles. (**c**) Tracheal mucous gland: (1) arteriole; (2) erythrocyte; (3) endothelial cell; (4) basement membrane; (5) Golgi apparatus of a Goblet cell; (6) endoplasmic reticulum; (7) vacuole; and (8) mucus secretion

Regardless of the anatomical details, the tracheal relationships from inside out are:

- Posterior: recurrent nerve, esophagus, and vertebral bodies covered by deep cervical aponeurosis
- Anterior: thyroid gland, medium cervical aponeurosis, anterior jugular veins, and superficial cervical aponeurosis
- Lateral: thyroid gland, vessels and nerves, deep cervical aponeurosis, and superficial cervical aponeurosis (involving the sternocleidomastoid and trapezius muscles; Fig. 1.9a, b)

The tracheobronchial bifurcation has similar topographical relationships in both genders, and it is located 7 cm deep from the skin of the anterior midline chest (Figs. 1.10 and 1.11).

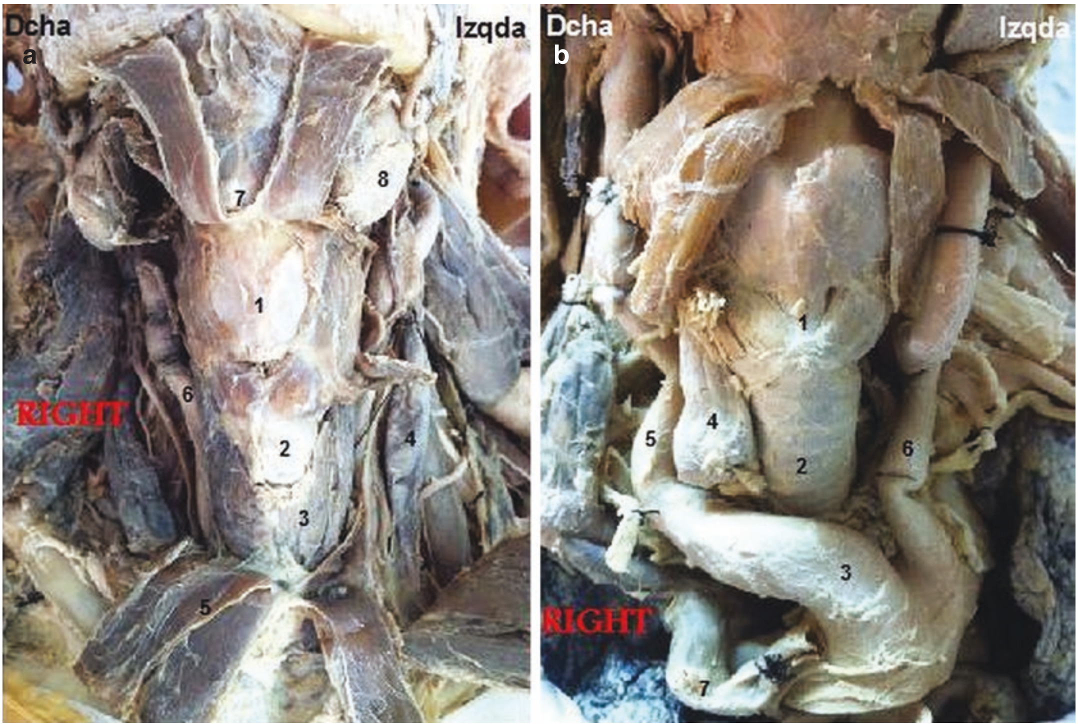


Fig. 1.9 (**a**) Dissection of the cervical trachea: (1) larynx; (2) trachea; (3) left thyroid lobe; (4) left internal jugular vein; (5) right infrahyoid muscles; (6) right common carotid artery; (7) hyoid bone; and (8) left submandibular gland. (**b**) Dissection of the cervical trachea: (1) larynx; (2) trachea; (3) brachiocephalic arterial trunk; (4) right internal jugular vein; (5) right common carotid artery; (6) left common carotid artery; and (7) left venous brachiocephalic trunk or innominate trunk. Unit of Human Anatomy and Embryology, Department of Pathology and Experimental Therapeutics, Universitat de Barcelona

Fig. 1.10 Cranial view of thoracic cross-section at the level of D4. Note the location of the tracheobronchial bifurcation at a depth of 7 cm from the surface: (1) right upper lobe; (2) thoracic esophagus; (3) right lower lobe; and (4) descending thoracic aorta. Unit of Human Anatomy and Embryology, Department of Pathology and Experimental Therapeutics, Universitat de Barcelona

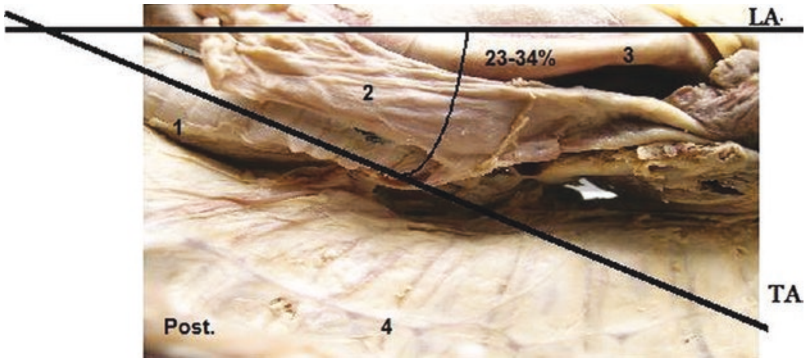


Fig. 1.11 Right lateral view of mediastinum: *TA* tracheal axis; *LA* long axis of the body. (1) Trachea; (2) superior vena cava; (3) ascending aorta; and (4) dorsal spine. Unit of Human Anatomy and Embryology, Department of Pathology and Experimental Therapeutics, Universitat de Barcelona

Bronchi

Main Bronchi

Main bronchi are located in a compartment known as the mediastinum. The mediastinum is delimited by the pleural cavity. This space does not have a regular shape (mediastinum = "servant" or "heart and major vessels service area"). There are two main bronchi, left and right. Each main bronchus is related to some elements of the mediastinum and they are not equal in length or size.

Left main bronchus (LMB) is 5 cm in length. It is longer than the right main bronchus (RMB), passing beneath the aortic arch and the left pulmonary artery.

Right main bronchus is 2.5 cm in length. It is more vertical than the left bronchus and has a bigger diameter.

Inside the lung parenchyma, both bronchi will continue dividing into branches to the 24th order (Fig. 1.12).

Bronchial Division

Left Main Bronchus (LMB)

- **Left upper lobe bronchus:** It divides into:
  - *Apicoposterior segmental bronchus (B1 + 2)*, from where B1 (Apical) and B2 (dorsal or posterior) bronchi are born
  - *Anterior- or ventral-segmental bronchus (B3)*
  - *Lingular bronchus*, divided into *superior lingular segmental bronchus (B4)* and *inferior lingular segmental bronchus (B5)*
- **Left lower lobe bronchus:** It divides into:
  - *Apical segmental bronchus,* which forms the *left lower lobe* or *Nelson's bronchus (B6)*
  - *Posterior or dorsal bronchus (B10)*
  - *Lateral bronchus (B9)*
  - *Trunk (B7 + 8)* or *ventromedial bronchus*, from which *B7 (medial)* and *B8 (ventral)* originate

Right Main Bronchus (RMB)

- **Right upper lobe bronchus:** It divides into:
  - *Apical segmental bronchus (B1)*
  - *Anterior or ventral segmental bronchus (B3)*
  - *Dorsal segmental bronchus (B2)*
- **Right middle lobe bronchus:** It divides into:
  - *Medial segmental bronchus (B5)*
  - *Lateral segmental bronchus (B4)*
- **Right lower lobe bronchus:** It divides into:
  - *Apical bronchus of the right lower lobe (Nelson's bronchus) (B6)*
  - *Posterior or dorsal bronchus (B10)*
  - *Lateral bronchus (B9)*
  - *Anterior bronchus (B8)*
  - *Paramediastinic bronchus (B7)*

The right main bronchus, after the superior lobe bronchus departure, is called *intermedius bronchus*. The intermedius bronchus after approximately 15 mm originates from the right middle lobe bronchus. From that on it is called the right *lower lobe bronchus*.

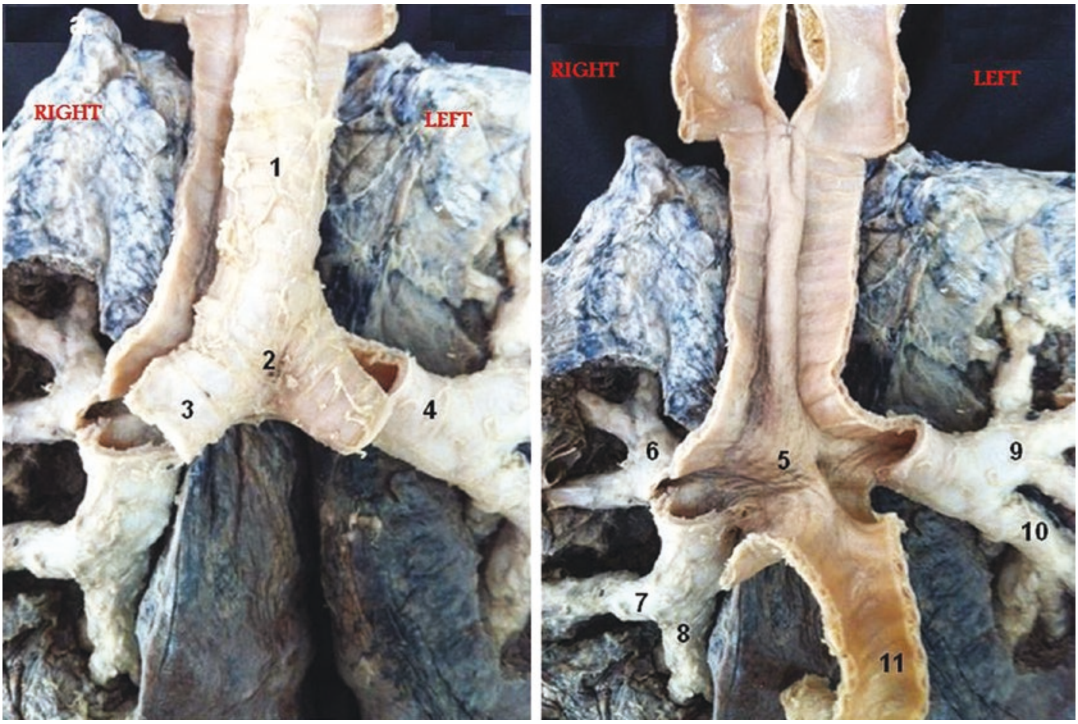


Fig. 1.12 Tracheobronchial bifurcation. Notice in the image on the right a tracheal cross-section with anterior inclination of its ventral side: (1) trachea; (2) tracheobronchial bifurcation; (3) right main bronchus; (4) left main bronchus; (5) bronchial carina; (6) right upper lobe bronchus; (7) right middle lobe bronchus; (8) right lower lobe bronchus; (9) left upper lobe bronchus; (10) left lower lobe bronchus; and (11) inner wall of the anterior trachea. Unit of Human Anatomy and Embryology, Department of Pathology and Experimental Therapeutics, Universitat de Barcelona

Each bronchial division is accompanied by the corresponding segmental pulmonary artery, giving place to the different bronchopulmonary segments.

Endoscopic Vision of the Bronchial Tree and Anatomical Relationships

It is very important to learn the normal endoscopic view of the airways and keep in mind the anatomical relationships. Figure 1.13 depicts the tracheobronchial tree when inspected with a bronchoscope, with the patient in the supine position and the endoscopist located posteriorly. The camera is moving down from head to feet.

The most important anatomic relationships we have to consider are:

- Cervical trachea: Anteriorly, the thyroid gland is located at the level of the second, third, and fourth tracheal rings. Thyroid lobes are in contact with the side walls of the cervical trachea. The veins that drain the thyroid gland are located at the bottom, and head to the left innominate vein. In general these veins are arranged along the tracheal wall and do not constitute a serious hazard. The same occurs for the left innominate vein, which is located in front of the trachea behind the sternal manubrium. Bifurcation of the arterial brachiocephalic trunk is in close contact with the windpipe at the base of the neck, and the main right carotid artery is located right in front of cervical trachea. From behind, the cervical trachea is in close contact with the esophagus, which is slightly more to the left. The right

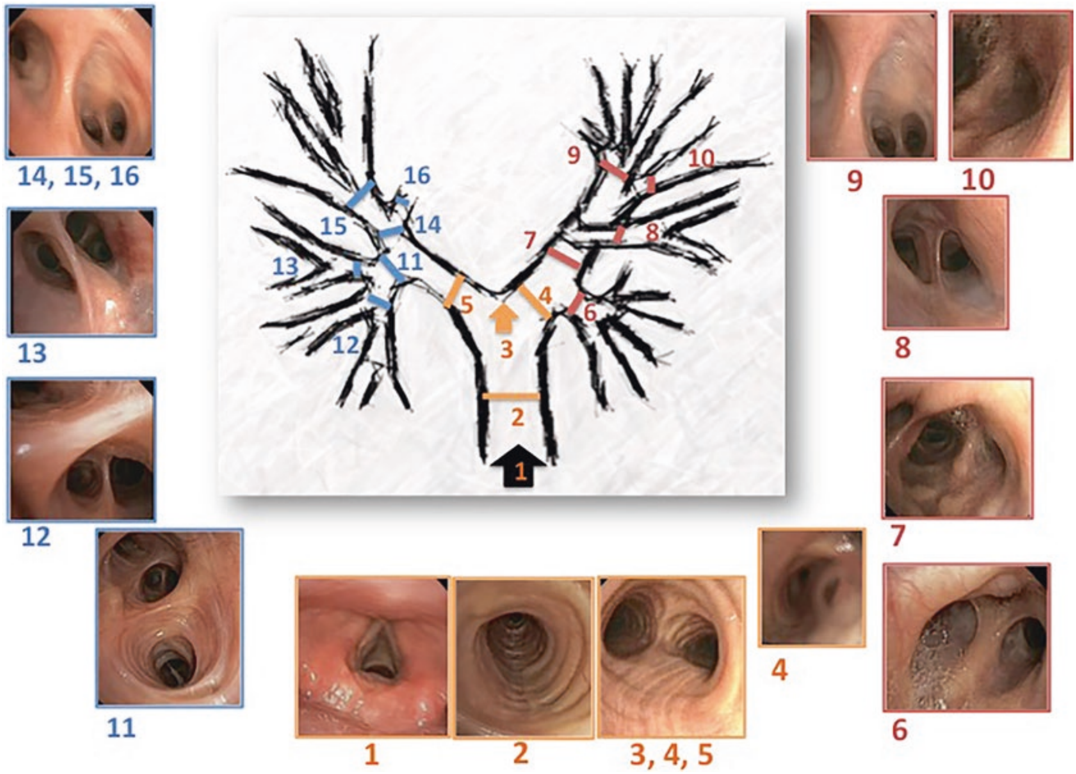


Fig. 1.13 Endoscopic vision of the bronchial tree: (1) vocal cords; (2) trachea; (3) carina; (4) right main bronchus; and (5) left main bronchus. **Right:** (6) right upper lobe bronchus—three apical segments; (7) intermediate bronchus; (8) middle lobe bronchus; (9) basal pyramid bronchus; and (10) six right segment bronchus. **Left: (11)** left upper lobe bronchus; (12) Culmen bronchus; (13) lingular bronchus; (14) left lower lobe bronchus; (15) basal pyramid; and (16) six left segment bronchus

recurrent nerve meets the sixth-level windpipe cartilage ring, running parallel to its rear edge. The left recurrent nerve, coming from below the aortic arch, runs along the posterior tracheal wall in front of the esophagus. Laterally, apart from the thyroid gland, cervical trachea is close to the neurovascular structures of the neck (common carotid artery, internal jugular vein, vagus nerve). From the base of the neck these structures deviate from the windpipe. Only the common carotid artery is in virtual contact with the outer edge of the trachea. The internal jugular vein and vagus nerve are more superficial.

- Thoracic trachea: As already explained, the thoracic trachea is a bit longer than the cervical trachea, and has close contacts with the large vessels of the mediastinum. The danger of massive bleeding at this level is very high. The most important anterior anatomical relationships are vascular. The venous system includes the left innominate vein, right innominate vein, and superior vena cava (which is located below and to the right of the windpipe). The azygos vein is located at the level of the right edge of the windpipe. Important arterial structures are in close contact with the trachea: the aortic arch passes directly from front to back and right to left along the left edge of the trachea, generating a mark on it and deviating it to the right. Then the aorta is curved on the left main bronchus and descends along the column. The arterial brachiocephalic trunk is born in front of the windpipe and