COMPUTED TOMOGRAPHY OF THE BODY

With Magnetic Resonance Imaging

Volume One
Thorax and Neck

COMPUTED TOMOGRAPHY OF THE BODY

With Magnetic Resonance Imaging

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Dedication for Volume One

This volume is dedicated to Gay, Jessica,
colleagues at the University of California, San Francisco,
and the numerous investigators whose efforts
have shaped our knowledge of thoracic imaging and disease.

GORDON GAMSU

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PREFACE

The second edition of *Computed Tomography of the Body* has been extensively updated and is presented as a comprehensive, state-of-the-art text on computed tomography (CT) of the body that now includes an integration of magnetic resonance (MR) imaging in all sections of the book. Since the first edition, there have been great advances in CT and its application to patient care. Although the impact of CT has been enormous, magnetic resonance imaging is undergoing explosive growth and is having an ever-increasing impact on body imaging.

As in the first edition, this text is organized so that basic anatomy and CT and MR techniques are discussed for each region of the body. The features of disease entities in these two imaging modalities are described and illustrated, and the relationship of CT to MR and other imaging techniques is discussed in depth. Recommendations are offered as to the role of each modality in specific clinical situations. The book presents an integrated approach, reflecting our current standard of practice. Knowledge of CT and MR imaging will continue to expand, and recommendations, techniques, and patterns of use will undoubtedly change in the future.

In writing this book, now expanded to three volumes, there have been many people without whose support, guidance, insight, and help this work could not have been completed. We thank our colleagues who contributed their time and case material, and we acknowledge the illustration departments at the University of California, San Francisco, and the University of Washington, as well as the secretarial and editorial support of Jan Taylor, Isabel Rosenthal, and Denice Nakano.

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INTRODUCTION TO VOLUME ONE

Computed tomography (CT) was developed for brain imaging in the late 1960s. Technical improvements rapidly allowed its application to the entire body. CT is now universally applied for imaging most thoracic pathologies and has all but replaced such procedures as conventional tomography and bronchography. Although advances in CT have tended to stabilize over the past several years, investigation of its uses and efficacy continues. The impact of CT on thoracic radiology and medicine has been enormous, and it is difficult to conceive of the practicing of these specialties without daily use of CT.

Magnetic resonance (MR) was introduced for human imaging in the mid-1970s. It has gained widespread acceptance for imaging the brain, spinal column, and musculoskeletal system. Within the thorax, however, its role has been less easily established. Cardiac, vascular, and neck imaging with MR are widely seen. In most other areas, such as the mediastinum, CT can provide comparable or more precise information. Thoracic MR with the imaging techniques currently available is limited by the physicomagnetic properties of lung tissue. The conceptual and technical developments required for successful pulmonary imaging with MR are several years away.

This volume is a comprehensive and practical update and expansion of the thorax and neck sections of the previous edition of this text. Since the publication of the first edition in 1983, thoracic CT and MR imaging have been greatly expanded and refined. For instance, recent studies on the staging of lung cancer have provided new information about the imaging of the most common fatal malignancy. High-resolution CT has been a significant advance for imaging parenchymal lung disease, and we have an important section on recent developments in this area. New chapters on interventional thoracic techniques and trauma are presented. Chapters on the physics of CT and MR imaging are included in Volume III.

The insight and guidance of many have shaped this text. We thank our co-authors and colleagues who have contributed time and effort. We also thank Isabel Rosenthal and Barbara Fougier for their editorial and secretarial support. Finally, we offer thanks to those mentors who taught us respect for patients, medicine, and scientific integrity: Doctors David Gamsu, George Simon, Leo Rigler, Ben Felson, Robert Fraser, Richard Greenspan, and Alexander Margulis.

GORDON GAMSU, M.D.

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CHAPTER 1

TRACHEA AND CENTRAL BRONCHI

GORDON GAMSU

Computed tomography (CT) is an excellent method for visualizing mediastinal and hilar structures, including the central airways. The normal CT anatomy of the trachea and bronchi has been described.[1-4] CT scanning of abnormalities of the trachea and bronchi has also been reported in several articles. The trachea and major bronchi generally lie in a plane perpendicular to the CT image, and their lumina are well displayed in cross-sectional images. The tracheobronchial tree is visible in continuity on CT as far peripherally as segmental and subsegmental bronchi.[5-7] This chapter deals with these airways and almost exclusively with CT scanning. The present temporal and spatial resolution of magnetic resonance (MR) imaging precludes its clinical use for imaging of the trachea and central bronchi. Those circumstances in which mediastinal and hilar masses encroach on the trachea and bronchi are discussed in Chapters 2 and 3.

Anatomy

Trachea

The trachea is a fibromuscular and cartilaginous tube 10 to 12 cm long (Fig. 1–1).[8] It extends from the lower border of the cricoid cartilage in the neck to its bifurcation at the tracheal carina in the mediastinum. The trachea is a midline structure except for its few inferior centimeters, which incline slightly to the right. Its walls are parallel except for two minor indentations. The impression of the aortic arch on the left anterolateral wall of the trachea can be seen on CT scans in many normal individuals. An indentation on the right from the arch of the azygos vein is seen less frequently.

The tracheal wall comprises 20 to 22 horseshoe-shaped cartilages connected posteriorly by a thick fibromuscular membrane. The diameter of the trachea is normally 10 to 27 mm in adults (mean: 19.5 mm in males; 17.5 mm in females).[9, 10] Griscom[11] and Effmann and colleagues[12] have studied the CT dimensions of the trachea in infants and children. They found that the tracheal cross-sectional area correlated most closely with body height. Effmann and colleagues[12] found about 20 per cent variation in tracheal dimensions at different levels of the intrathoracic trachea in children. The diameter of the trachea increased with age up to 16 or 18 years.

Six to 9 cm after entering the thorax, the trachea divides into the two main bronchi.[2] The shorter right main bronchus is about 2.2 cm long, whereas the left is about 5 cm in length.[13] The diameter of the right main bronchus averages 15.3 mm, and that of the left 13 mm when measured on chest radiographs at full inspiration.[14] The trachea can change its dimensions and shape with various respiratory maneuvers.

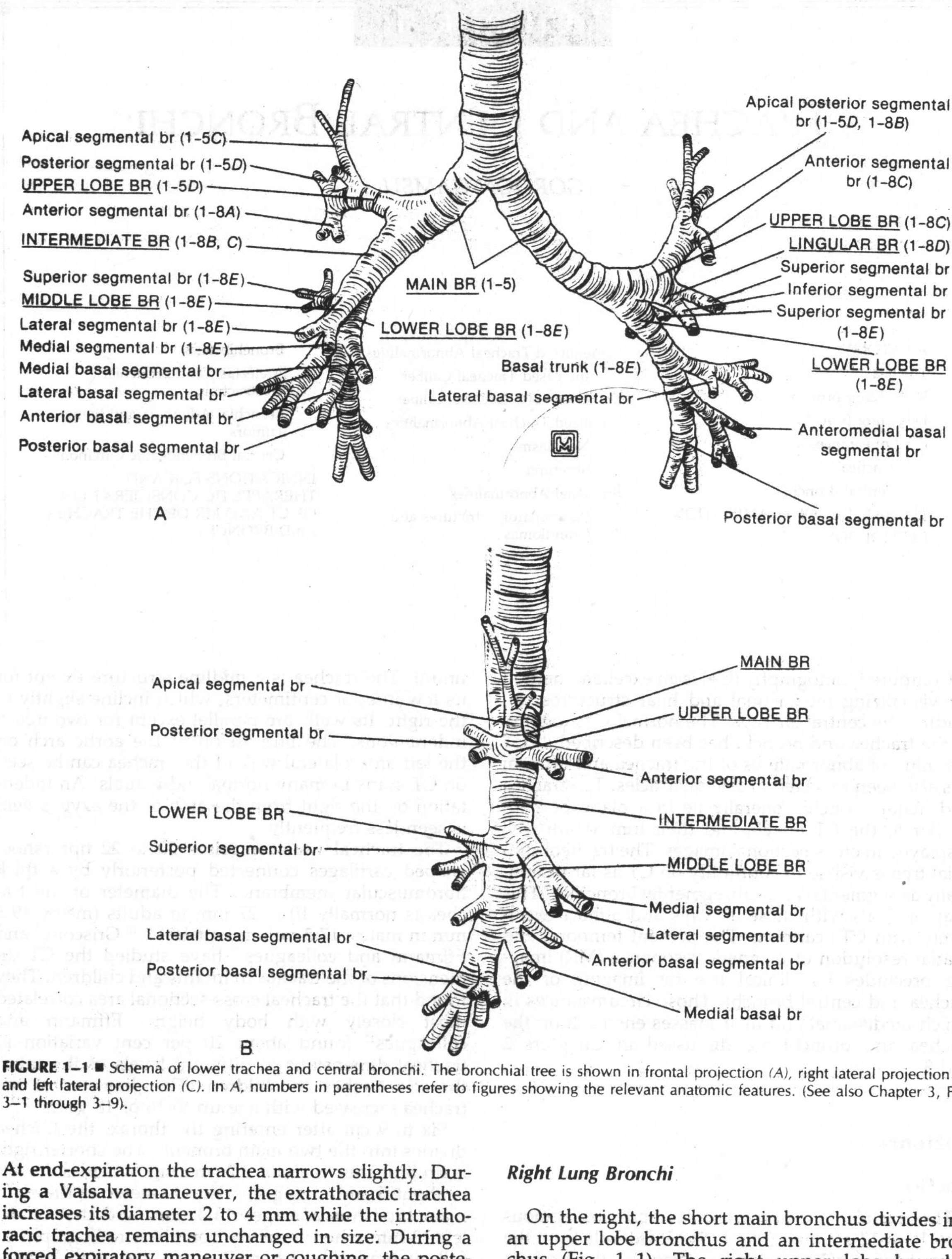

FIGURE 1–1 ■ Schema of lower trachea and central bronchi. The bronchial tree is shown in frontal projection *(A)*, right lateral projection *(B)*, and left lateral projection *(C)*. In *A*, numbers in parentheses refer to figures showing the relevant anatomic features. (See also Chapter 3, Figs. 3–1 through 3–9).

At end-expiration the trachea narrows slightly. During a Valsalva maneuver, the extrathoracic trachea increases its diameter 2 to 4 mm while the intrathoracic trachea remains unchanged in size. During a forced expiratory maneuver or coughing, the posterior tracheal membrane invaginates to greatly reduce the cross-sectional area of the trachea, whereas the lateral and anterior walls are minimally altered.

Right Lung Bronchi

On the right, the short main bronchus divides into an upper lobe bronchus and an intermediate bronchus (Fig. 1–1). The right upper lobe bronchus courses laterally for 1 to 2 cm before dividing into its three segmental bronchi.[3, 4] The branching pattern is moderately variable, but on CT scans, all three seg-

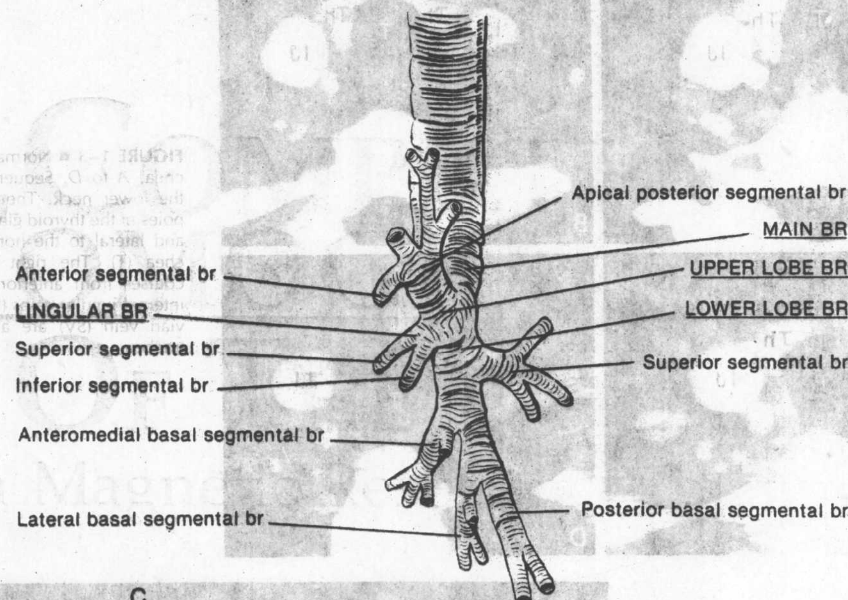

FIGURE 1–1 *Continued*

mental bronchi are usually visible. The intermediate bronchus is 3 to 4 cm long and courses slightly laterally in a superior-inferior direction. The posterior wall of the intermediate bronchus can be seen on CT scans outlined by the right lower lobe from its origin to its bifurcation in virtually all normal subjects.[15] It is a uniformly thin line measuring 0.5 to 2 mm in thickness. Rarely, an anomalous pulmonary vein courses posteriorly behind the intermediate bronchus and should not be mistaken for an abnormal mass. The middle lobe bronchus arises from the right anterolateral wall of the intermediate bronchus and passes inferiorly, laterally, and anteriorly at about a 45° obliquity for 1 to 2 cm before dividing into its medial and lateral segmental bronchi. After giving rise to the middle lobe bronchus, the intermediate bronchus continues as the right lower lobe bronchus. A distinct spur at the junction of the middle and lower lobe bronchi frequently is visible. The first segmental branch of the right lower lobe is the superior segmental bronchus, which arises from the posterior wall of the lower lobe bronchus. Beyond the origin of the superior segmental bronchus, the right basal trunk continues for 1 to 2 cm before dividing into medial, anterior, lateral, and posterior basal segments.

Left Lung Bronchi

The branching pattern of the left bronchial tree is different from that of the right (see Fig. 1–1). The long left main bronchus divides directly into upper and lower lobe bronchi. The upper lobe bronchus gives off a lingular branch from its anteroinferior surface and usually continues as a short common trunk before dividing into anterior and apical-posterior branches.[16] Less commonly, the left upper lobe bronchus trifurcates into anterior, lingular, and apical-posterior bronchi. The lingular bronchus, which is the least frequently visualized major airway on CT, is directed anteroinferiorly for 2 to 3 cm and then bifurcates into superior and inferior segmental bronchi. The absence of an intermediate bronchus on the left results in the left lower lobe bronchus arising at a level 1 to 2 cm cephalad to the right lower lobe bronchus. As on the right, the first branch of the lower lobe is the superior segmental bronchus directed posteriorly. The anteromedial, lateral, and posterior basal segments arise 1 to 2 cm distal to the origin of the superior segmental bronchus.

FIGURE 1–2 ■ Normal extrathoracic trachea. CT shows a normal horseshoe-shaped trachea (T). The posterior tracheal membrane bulges slightly into the tracheal air column. Anteriorly, a calcified tracheal cartilage is visible *(arrows)*.

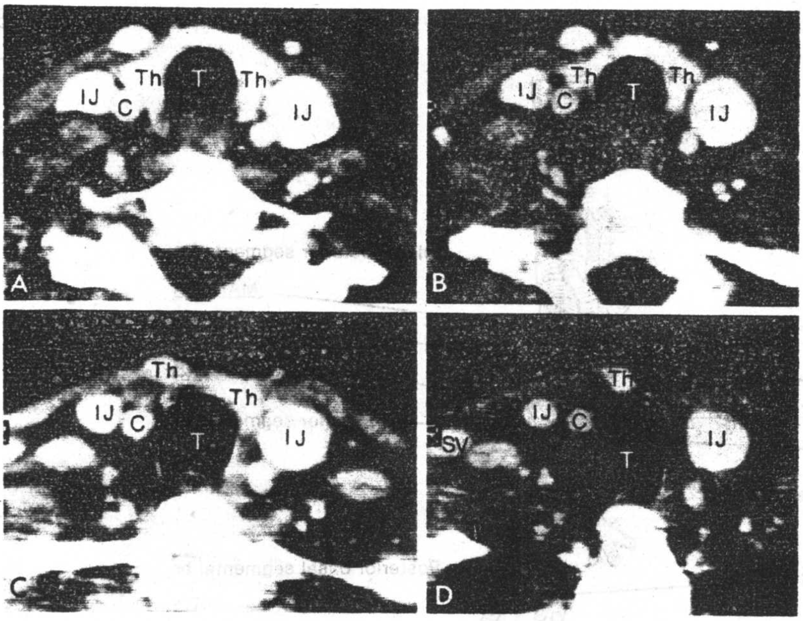

FIGURE 1–3 ■ Normal extrathoracic trachea. *A* to *D*, Sequential scans through the lower neck. The middle and lower poles of the thyroid gland (Th) are anterior and lateral to the horseshoe-shaped trachea (T). The right carotid artery (C) courses from anterior to posterior. The internal jugular veins (IJ) and right subclavian vein (SV) are anterolateral to the trachea.

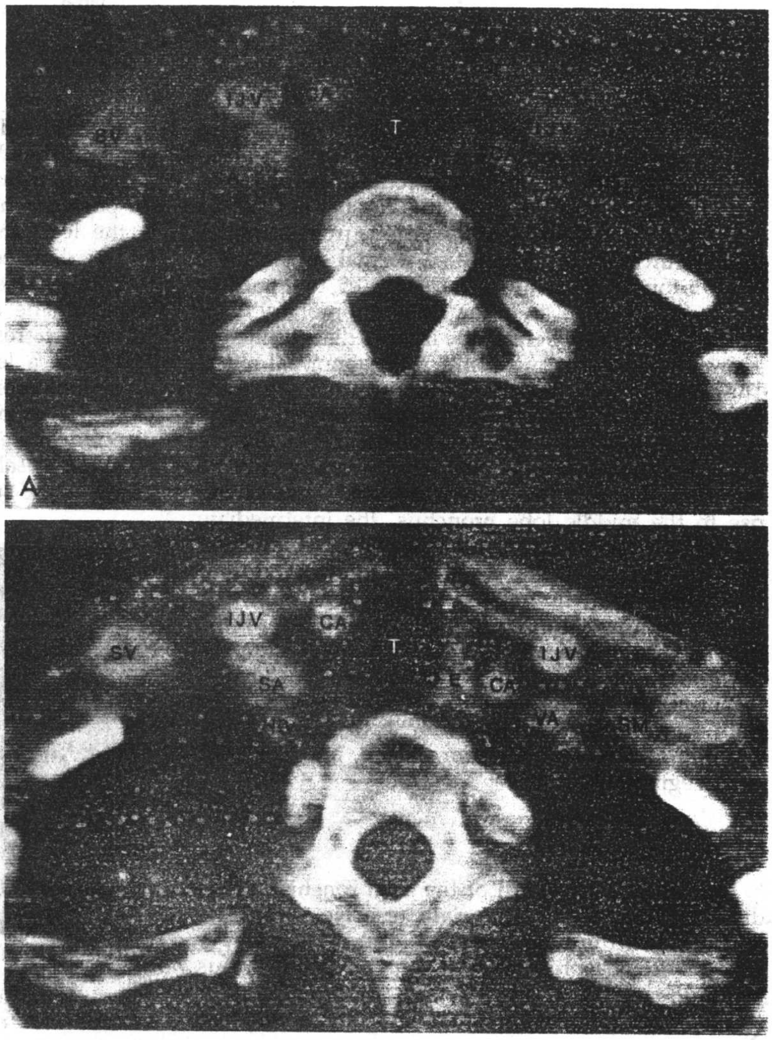

FIGURE 1–4 ■ Normal thoracic inlet. *A* to *D*, Sequential CT scans 5 mm thick through the thoracic inlet from above downward. The trachea (T) is midline, and the esophagus (E) is to the left. On the right side, the subclavian artery (SA) is behind the anterior scalene muscle (SM) in *A*, and is behind the right subclavian vein (SV) and internal jugular vein (IJ) in *B* through *D*. The right common carotid artery (CA) stays close to the trachea. In *A* to *D*, the right highest intercostal vein (HIV) is behind the subclavian artery. On the left, the common carotid artery (CA) is lateral to the esophagus. The left subclavian artery courses from posterior to anterior. The internal jugular vein (IJV) and subclavian vein join anteriorly and laterally to the common carotid artery. In *A* to *C*, the left vertebral artery (VA) is posterior and lateral to the common carotid artery.

CT Appearances

TRACHEA

The extrathoracic trachea begins at the lower border of the cricoid cartilage and ends at the thoracic inlet, a distance of 2 to 4 cm.[2] The subglottic larynx, within the cricoid cartilage, is always circular on CT scans, and the airway is in close proximity to the underlying perichondrium. Immediately below the cricoid cartilage, the extrathoracic trachea assumes a horseshoe, elliptical, or circular configuration (Fig. 1–2). In about 50 per cent of normal people, the posterior tracheal membrane protrudes slightly into the tracheal air column.

The thyroid gland encases the anterior and lateral walls of the extrathoracic trachea (Fig. 1–3). It is always visible on CT scans and extends vertically for 2 to 4 cm. The thyroid gland is usually denser than the surrounding soft tissues because of its iodine content. The sternohyoid and sternothyroid muscles, together with a variable quantity of fat, also border the anterior wall of the extrathoracic trachea.

The common carotid arteries and jugular veins are usually lateral to the extrathoracic trachea (Fig. 1–3) but are occasionally slightly behind a coronal plane through the trachea. The right common carotid artery is usually more anterior than the left. The right internal jugular vein lies lateral to the right common carotid artery and is usually larger than the left internal jugular vein, which is anterolateral to the left common carotid artery.

The thoracic inlet is a sloping plane at the junction of the thorax and neck. It extends from the suprasternal (jugular) notch anteriorly, to the first thoracic vertebral body posteriorly. Below this level, the trachea is intrathoracic and makes its first contact with the right lung 1 to 3 cm above the suprasternal notch. The relationship of the great arteries and veins to the trachea changes rapidly at the thoracic inlet (Fig. 1–4). The innominate artery is visible on CT scans on the right, next to the anterior third of the trachea, where it divides to form the right subclavian and common carotid arteries. The right internal jugular

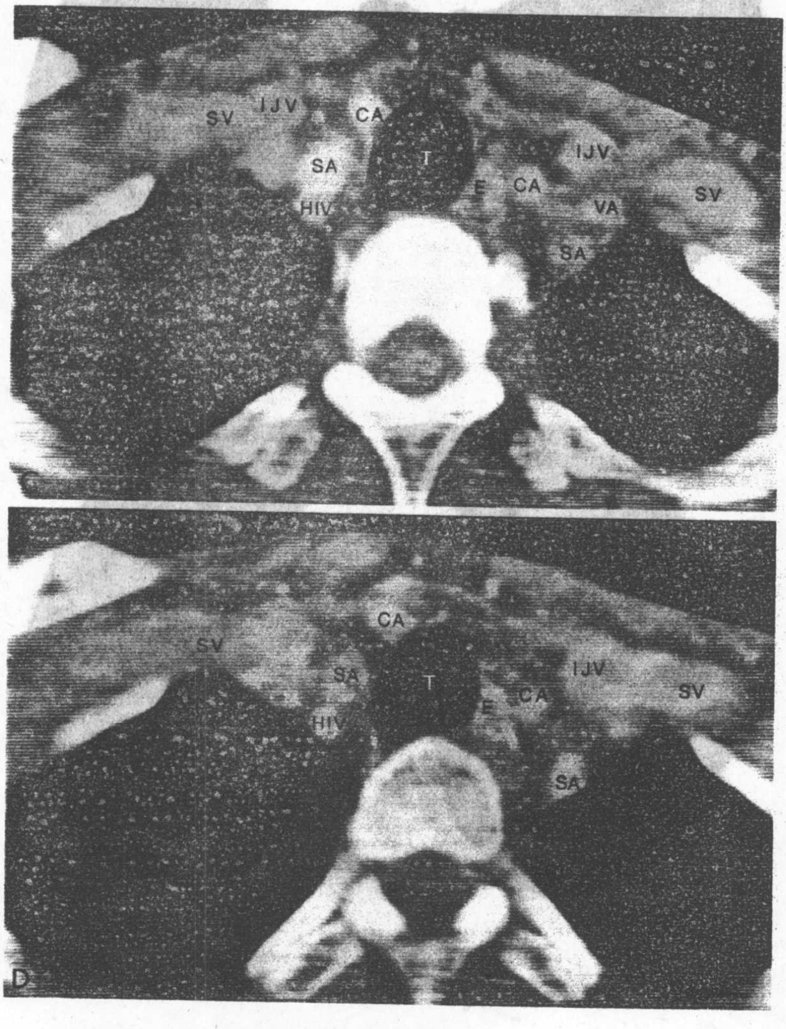

FIGURE 1–4 *Continued*

and subclavian veins join to form the right brachiocephalic vein lateral to the innominate artery. The left common carotid artery is next to the middle or posterior third of the tracheal wall on the left. The left subclavian artery is initially posterior to the trachea and then courses anterolaterally toward the left first rib. The esophagus at the level of the thoracic inlet is always directly behind the trachea at or slightly to the left of the midline. The inferior extensions of the strap muscles are directly anterior to the trachea.

The apices of the lungs are seen on CT on the level at which the trachea becomes intrathoracic. The intrathoracic trachea is 6 to 9 cm long (mean: 7.5 ± 0.8 cm).[2] The shape of the normal intrathoracic trachea on CT scans varies from person to person and at different levels in the same person. The usual shape is circular or slightly oval (Fig. 1–5*A–D*). It may be horseshoe-shaped with a flat posterior wall. Less commonly, it has the shape of an inverted pear or can be almost square. In children the trachea is almost always circular or nearly circular.[17] Mild variations in shape occur at different levels, but the posterior indentation produced by the tracheal membrane is not found in children. The child's trachea is remarkably uniform over its length.

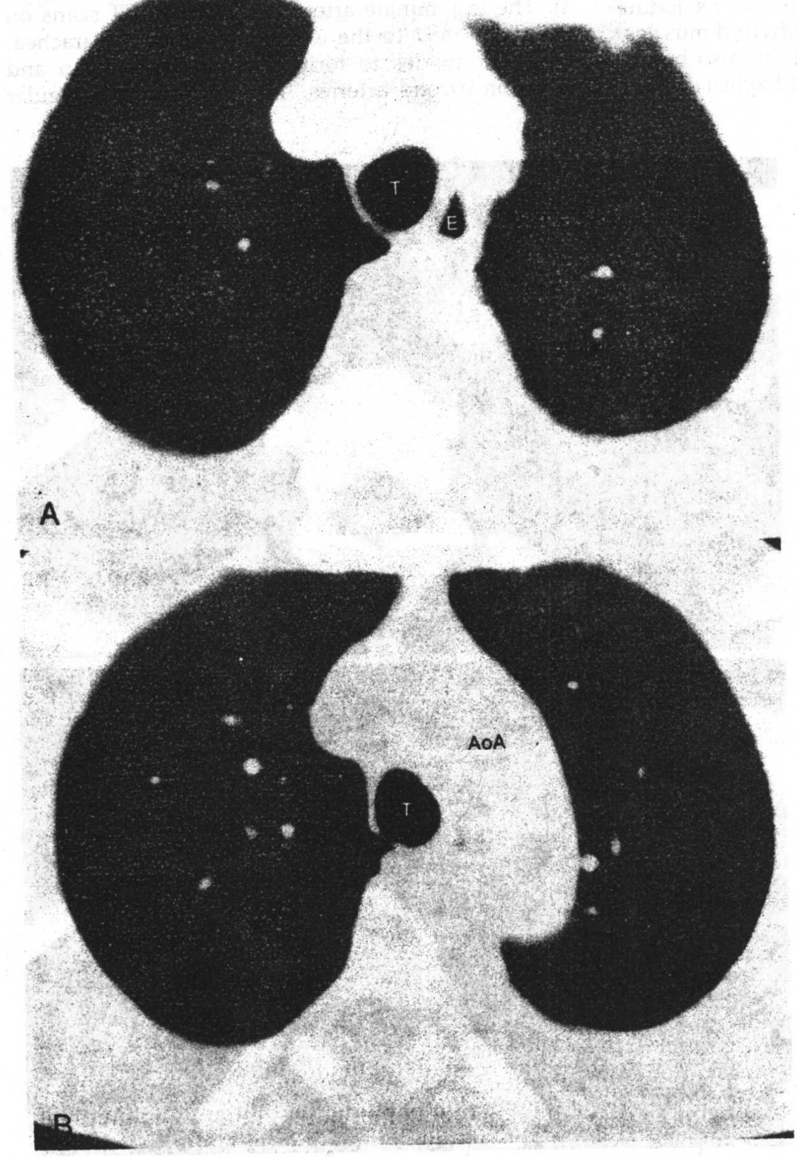

FIGURE 1–5 ■ Normal intrathoracic trachea in a young adult male. CT at 2-cm intervals demonstrate changes in the trachea (T) at various levels. *A*, The right lung contacts the right lateral wall of the trachea. The esophagus (E) is to the left. *B*, At the level of the aortic arch (AoA), the left anterior wall of the trachea is slightly flat.