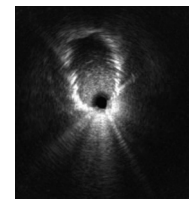
Chapter 2



Relevant Thoracic Anatomy

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1. Central Airway Anatomy

This section outlines the basic anatomy of the tracheobronchial tree, including lengths and diameters (**Fig. 2.1**). This serves as a reference for bronchoscopic procedures because a critical understanding of airway anatomy is vital to the planning of any airway procedure. Knowledge of airway anatomy allows the bronchoscopist to correlate radiographic findings with endoluminal anatomy, ensuring accurate biopsies and lavage specimens. In addition to specimen acquisition, anatomic accuracy is essential when communicating with surgical, oncology and radiation oncology colleagues. In addition, comfort with bronchoscopic landmarks will prevent the operator from becoming disoriented during the procedure and give them the confidence and flexibility to perform bronchoscopy from multiple positions including head of the bed, facing the patient or other positions that best serve the patient and operator's needs. This chapter hopes to familiarize the reader with common bronchoscopic anatomy and landmarks that will enhance performance, accurate specimen acquisition and communication with colleagues.

2. Upper Airway

The central airways may be accessed with the bronchoscope either through the nose or the mouth; each has its own unique anatomy and each serves as a conduit to the central airways below.

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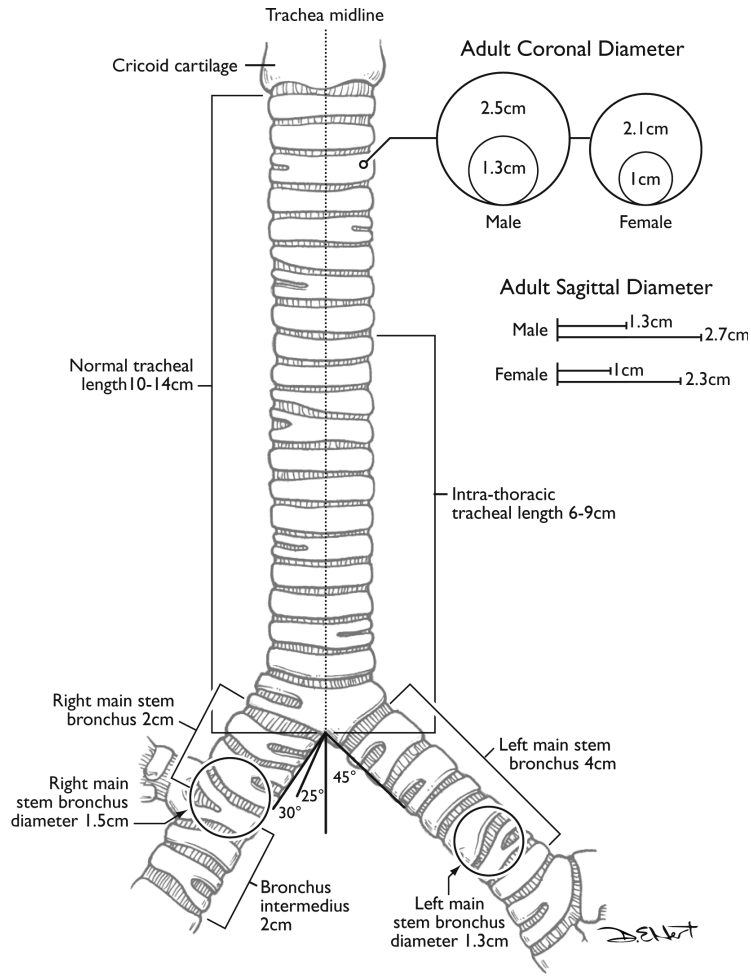

Fig. 2.1. Basic anatomy of the tracheobronchial tree. Reprinted with permission from Gorden JA, Wood DE. Rigid bronchoscopy. In: Simoff MJ, et al. (eds). Thoracic Endoscopy. Oxford: Wiley-Blackwell; 2006: 121–133.

Bronchoscopy can be performed through the left or right nares. The nasal passage is composed of the external nares, nasal cavity and nasal pharynx. The medial border of each nostril is the nasal septum, the lateral border is the turbinate and the inferior border is the hard palate which separates the nares from the mouth *(1)*. When viewing the larynx through the bronchoscope the most prominent structure is the epiglottis. When performing bronchoscopy from the head of the bed the epiglottis is a prominent curved flap that lies in the anterior and superior position and projects out into the posterior pharynx (**Fig. 2.2**). Advancing the bronchoscope under the epiglottis allows the operator to visualize additional structures of the larynx. The most inferior structure before the esophagus is the interarytenoid notch bounded by the Corniculate tubercule and Cuneiform tubercle,

Fig. 2.2. Bronchoscopy performed from the head of the bed with the patient supine. Prominent central structure is the epiglottis.

respectively. Tethered between the epiglottis superiorly and the interarytenoid notch inferiorly are the vocal folds (true vocal cords) medially and the ventricular folds (false vocal cords) laterally. When the vocal cords are open the bronchoscopist has a view into the proximal portion of the trachea (**Fig. 2.3**); when they are closed the vocal cords should be in apposition at the midline with the false cords stretched to close the opening (**Fig. 2.4**).

The larynx is an important point of inspection for the bronchoscopist. Lack of movement of either of the vocal chords can be a clue to recurrent laryngeal nerve damage or a hidden tumor in the mediastinum below.

3. Trachea

The origin of the trachea is defined as the inferior aspect of the cricoid cartilage at the approximate level of the 6th or 7th cervical vertebra. The distal margin of the trachea is the main carina

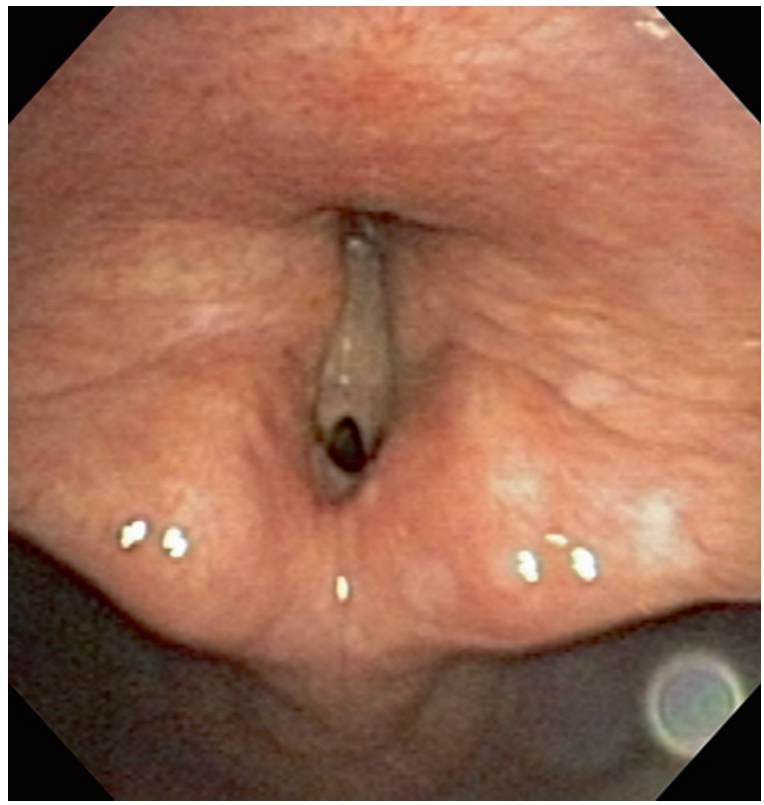

Fig. 2.3. Bronchoscopy performed from the head of the bed with the patient supine. View of the larynx with the vocal chords abducted with the proximal trachea visualized below.

marking the bifurcation of the right and left main stem bronchi at the approximate level of the 5th thoracic vertebra. The trachea is divided into the extra- thoracic trachea, which lies above the suprasternal notch approximately one-third of its total length, and the intrathoracic trachea, which falls below the suprasternal notch making up two-thirds of its total length. The length of the normal adult trachea is 10–14 cm. Computed tomography (CT) guided measurements of the intrathoracic tracheal length range from 6–9 cm in adults. The coronal diameter of the normal trachea in adult males ranges from 1.3 cm to 2.5 cm; the sagital diameter ranges from 1.3 cm to 2.7 cm. The coronal diameter of the normal trachea in women ranges from 1 cm to 2.1 cm, the sagital diameter 1 cm to 2.3 cm *(2–4)*. The length of the pediatric trachea is the same for males and females representing similar gender growth rates from birth to adulthood. At age 14 the female trachea ceases to grow while the male trachea continues to enlarge, but not lengthen until maximum adult diameter is achieved *(5)*. The trachea maintains its structure with the rigid structural support of 18–24 C-shaped cartilaginous anterior rings. The posterior wall of the trachea is a membranous band and lacks cartilaginous support

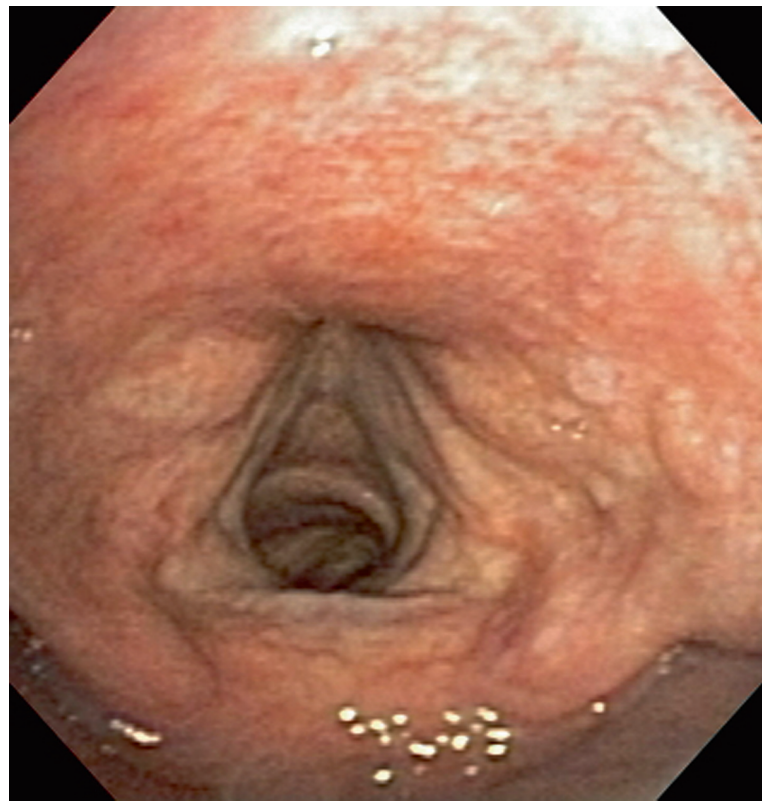

Fig. 2.4. Bronchoscopy performed from the head of the bed with the patient supine. View of the larynx with the vocal chords adducted. The central stripe is the true left and right vocal chords in apposition. At the 12 o'clock position is the base of the epiglottis.

(**Fig. 2.5**). The presence of the membranous trachea allows the diameter of the intrathoracic trachea to be dynamic, expanding with inspiration and recoiling upon expiration.

The structural difference of the anterior and posterior trachea is critical to maintaining orientation during bronchoscopy. The experienced bronchoscopist is required to be facile, performing bronchoscopy from the patient's front and with the patient supine from the head; knowing that the cartilaginous portion of the trachea is anterior and the membranous portion is posterior ensures correct orientation of the left and right mainstem bronchi, regardless of bronchoscopic position.

4. Main Carina

The main carina denotes the first branching of the airway. The main carina marks the bifurcation of the trachea into the right and left main stem bronchi (**Fig. 2.6**). For orientation the membranous

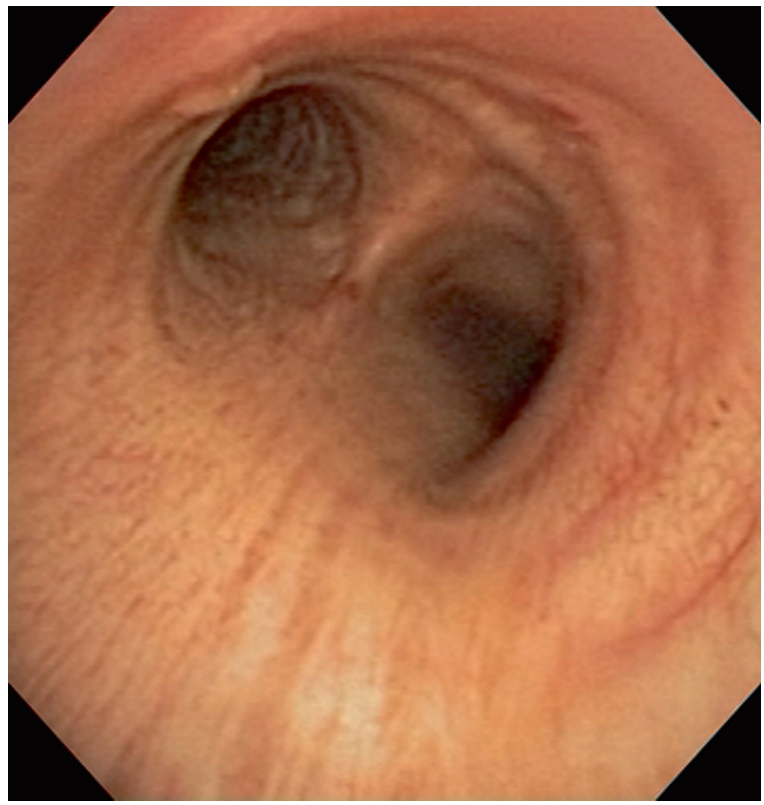

Fig. 2.5. Bronchoscopy performed from the head of the bed with the patient supine. This view is of the distal trachea with the main carina in view. Prominent cartilaginous rings form the anterior structure; the membranous trachea is seen forming the posterior wall.

portion of the airway remains posterior and the cartilaginous rings support the anterior structure; this is critical to confirm right and left orientation during bronchoscopy. Anatomically the main carina relates to the manubriosternal junction or the 5th–6th thoracic vertebrae. There is wide variability in the accepted normal subcarinal angle, with mean angles ranging from 56–61 degrees *(2)*. In adults the left main stem bronchus branches at a more obtuse angle relative to the midline trachea in contrast to the right main stem bronchus. In the pediatric population, ages birth to 15 years, there is no statistical difference in the right and left main stem bronchial angles when measured from the midline trachea *(2)*.

5. Right Bronchial Tree

5.1. Right Main Stem Bronchus

The right main stem bronchus (RMSB) is defined at its proximal end by the main stem carina and at its distal end by the right upper lobe orifice. In adults the course of the right main stem bronchus

Fig. 2.6. Bronchoscopy performed from the head of the bed with the patient supine. The main carina forms the central structure. The *left* and *right* main stem bronchi are in view. The length of the *left* main stem bronchus is well illustrated. Continuation of the anterior cartilaginous support and membranous posterior wall is well represented in this view of the *left* main stem bronchus.

off the trachea is more direct than that of the left main stem bronchus. The right main stem bronchus diverges off the trachea at an angle of 25–30 degrees from the midline. The approximate diameter of the right main stem bronchus is 1.5 cm. The approximate length of the right main stem bronchus is 2 cm *(2–3)*.

5.2. Right Upper Lobe Bronchus

The right upper lobe bronchus is the first airway visible off the right main stem bronchus. The origin of the RUL is the lateral wall of the RMSB. The rapid branching of the right bronchial tree with its short RMSB distinguishes it from its left-sided companion and serves as another anatomic clue of left and right orientation. Upon entry, the right upper lobe immediately trifurcates into the anterior, apical and posterior segments (**Fig. 2.7**). From the mouth of the right upper lobe the anterior segment is at the nine o'clock position, the apical at 12 o'clock and the posterior at three o'clock.

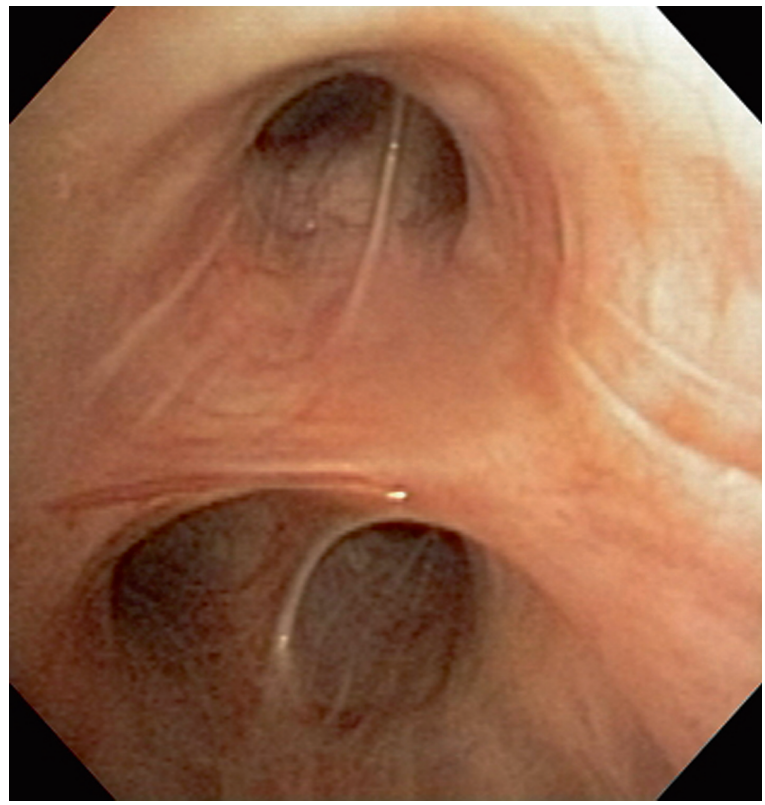

Fig. 2.7. Bronchoscopy performed from the head of the bed with the patient supine. The trifurcation of the right upper lobe is illustrated in this image. The anterior segment is inferior and 9 o'clock, the apical segment is at 12 o'clock, the posterior segment is inferior and at 3 o'clock.

Entry into the RUL from the RMSB comes at an acute angle and often requires a clockwise rotation of the bronchoscope and flexion of the bronchoscope tip.

5.3. Bronchus Intermedius

The bronchus intermedius is the continuation of the right bronchus distal to the right upper lobe take off. The proximal border is the right upper lobe bronchus, and the distal border is the right middle lobe and right lower lobe bifurcation. The length of the bronchus intermedius is approximately 2 cm long *(2)*.

5.4. Right Middle Lobe

The right middle lobe orifice is found on the medial and slightly anterior aspect of the right bronchial tree (**Fig. 2.8**). The opening of the right middle lobe is often described as having a fishmouth appearance. The right middle lobe forms the distal border of the bronchus intermedius. The right middle lobe bronchus is 1–2 cm in length and then bifurcates to form the medial and lateral branches.

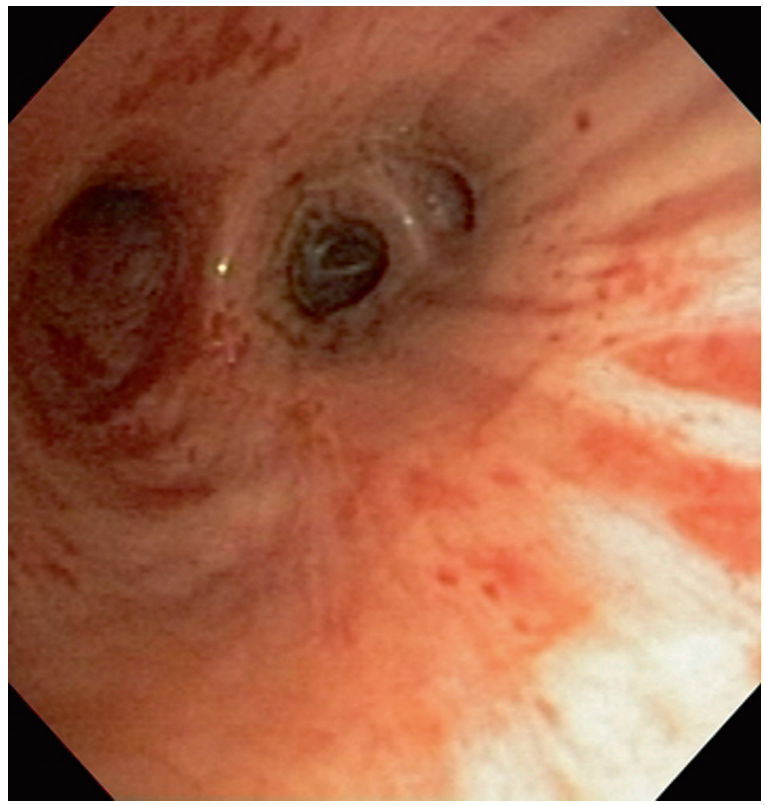

Fig. 2.8. Bronchoscopy performed from the head of the bed with the patient supine. For this image the bronchoscope is positioned in the bronchus intermedius. The right middle lobe is the large orifice at 9 o'clock, in the middle the distal lower lobes are visualized and at 9 o'clock the superior segment of the lower lobe is in view.

5.5. Right Lower Lobe Basilar Segments

The posterior wall of the bronchus intermedius gives rise to the airway supplying the superior segment of the lower lobe, which is nearly directly across from the right middle lobe orifice. Distally the right lower lobe divides into the medial basilar, anterior, lateral and posterior segments *(2)* (**Fig. 2.9**). The medial basilar segment is the next orifice after the superior segment of the lower lobe; its origin is the medial wall of the airway inferior to the right middle lobe. The more distal anatomically accessible airways are the anterior, lateral and posterior segments. These segments often go by the acronym ALPs, meaning (A) anterior, (L) lateral and (P) posterior segments. There is often normal anatomic variation to the positioning of these structures, but in most cases these three orifices fall in the same linear plane with the anterior segment in the most medial and anterior position, the lateral segment falling in the middle and the posterior segment being the most lateral and posterior structure.

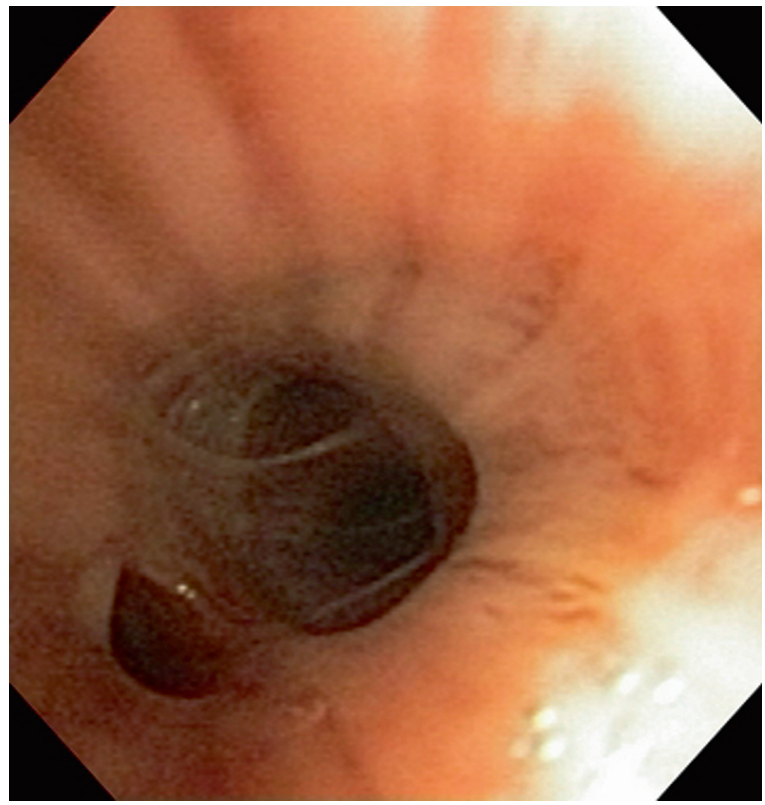

Fig. 2.9. Bronchoscopy performed from the head of the bed with the patient supine. Right lower lobe segments. At the 8 o'clock position is the entrance to the medial basilar segment. Centrally the ALPs are visualized. At 11 o'clock (A) anterior segment, in the middle position sits the (L) lateral segment, and the most posterior orifice is the (P) posterior segment.

6. Left Bronchial Tree

6.1. Left Main Stem Bronchus

The left main stem bronchus (LMSB) rises off the trachea and forms the origin of the left bronchial tree. In adults the left main stem bronchus forms a more obtuse angle of divergence from the midline trachea than the right main stem. The left main stem bronchus diverges from the midline trachea at an approximately 45-degree angle. The diameter of the left main stem is approximately 1.3 cm, and the length is approximately 4 cm. The boundaries of the left main stem bronchus are the main carina at its proximal end and the branching of the left upper and lower lobes at its distal end *(2)*. The left main stem bronchus is considerably longer than its right main stem counterpart, and this is a critical anatomic feature to help maintain orientation. The distal boundary of the LMSB bronchus is the carina dividing the left lower lobes and left upper lobe and lingual.

6.2. Left Upper Lobe and Lingula

The left upper lobe and lingual orifice open anterior to the left lower lobe, often in a roughly 12 o'clock to six o'clock relationship (**Fig. 2.10**).

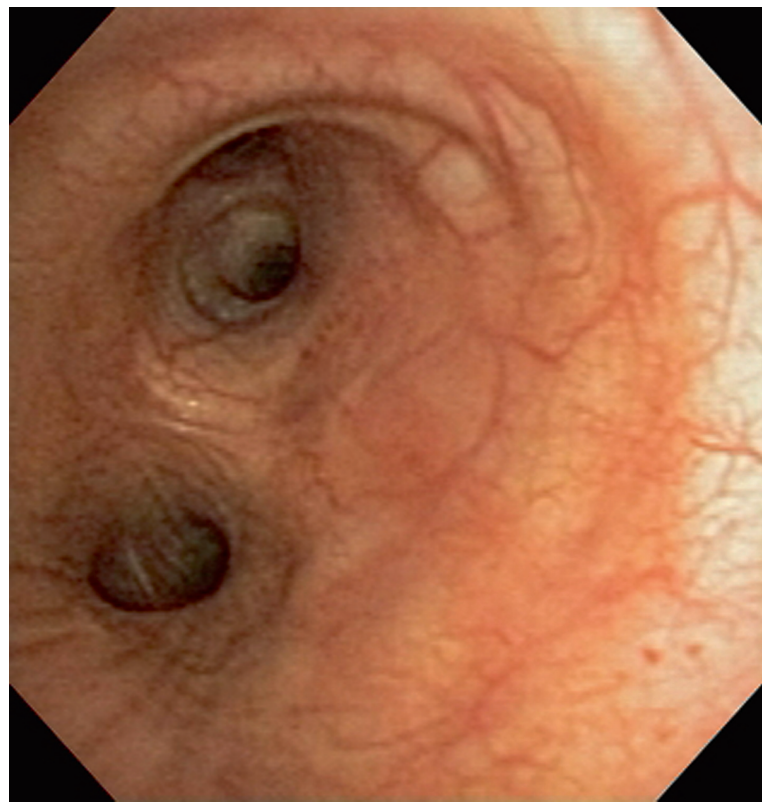

Fig. 2.10. Bronchoscopy performed from the head of the bed with the patient supine. The bronchoscope is positioned in the distal left main stem bronchus. The left upper lobe and lingual are at 12 o'clock with the first orifice at this position being the lingual, and the superior segment of the lower lobes and distal lower lobes are at 6 o'clock.

The lingula is the first orifice to appear and is found in the medial position. The lingula further subdivides into the superior and inferior lingular divisions.

The left upper lobe divides into the apicoposterior and anterior subdivisions.

6.3. Left Lower Lobe

The left lower lobes divide off the posterior wall of the left main stem carina. The lower lobes divide into the superior segment across from the upper lobe takeoff and the anterior medial, lateral and posterior segments. Similar to the right bronchial tree, there is frequent variation to the remaining basilar subsegments.

7. Summary

A comprehensive understanding of airway anatomy is critical to effective bronchoscopy and good communication with colleagues. Developing a pattern for away inspection that methodically inspects each anatomic landmark in order is good practice. With knowledge of airway landmarks the bronchoscopist should be able to withdraw to the last recognized anatomic land in order to regain anatomic orientation.

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