Fiberoptic Bronchoscopy Human Tracheal Tree Model

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**Introduction**

Fiberoptic bronchoscopy is a widely performed procedure that is generally considered to be safe. The first performed bronchoscopy was done by Gustav Killian in 1897; however, the development of flexible fiberoptic bronchoscopy was accomplished by Ikeda in 1964 (1). Flexible fiberoptic bronchoscopy is a key diagnostic and therapeutic procedure (2). It is estimated that more than 500,000 of these procedures are performed each year by pulmonologists, otolaryngologists, anesthesiologists, and cardiothoracic and trauma surgeons (3). Despite the widespread practice of diagnostic flexible bronchoscopy, there are no firm guidelines that assure a uniform acquisition of basic skills and competency in this procedure, nor are there guidelines to ensure uniform training and competency in advanced diagnostic flexible bronchoscopic techniques (4).

The purpose of this workshop is to provide an update on tracheobronchial anatomy and flexible fiberoptic bronchoscopy exam.

**Anatomy of the Trachea and Bronchus**

The trachea is a cartilaginous and fibromuscular tubular structure that extends from the inferior aspect of the cricoid cartilage to the level of the carina (5). The adult trachea is, on average, 15 cm long. The trachea is composed of 16–22 C-shaped cartilages. The cartilages compose the anterior and lateral walls of the trachea and are connected posteriorly by the membranous wall of the trachea, which lacks cartilage and is supported by the trachealis muscle. The average diameter in a normal trachea is 22 mm in men and 19 mm in women. In men, the coronal diameter ranges from 13 to 25 mm and the sagittal diameter ranges from 13 to 27 mm. In women, the average coronal diameter is 10–21 mm and the sagittal diameter is 10–23 mm (5, 6). The tracheal wall is about 3 mm in thickness in both men and women, with a tracheal lumen that is often ovoid in shape. The trachea is located in the midline position, but often can be deviated to the right at the level of the aortic arch, with a greater degree of displacement in the setting of an atherosclerotic aorta, advanced age, or in the presence of severe chronic obstructive pulmonary disease (COPD). With COPD or aging, the lateral diameter of the trachea may decrease with an increase in the anteroposterior diameter. Conversely, COPD may also lead to softening of the tracheal rings with a decrease in the anteroposterior diameter of the trachea (7). The cricoid cartilage is the narrowest part of the trachea with an average diameter of 17 mm in men and 13 mm in women. The trachea bifurcates at the carina into the right and left mainstem bronchus. An important fact is that the tracheal lumen narrows slightly as it progresses towards the carina. The tracheal bifurcation is located at the level of the sternal angle anteriorly and the 5th thoracic vertebra posteriorly. The right mainstem bronchus lies in a more vertical orientation relative to the trachea, whereas the left mainstem bronchus lies in a more horizontal plane. The right mainstem bronchus continues as the bronchus intermedius after the take-off of the right upper lobe bronchus. In men, the distance from the tracheal carina to the take-off of the right upper lobe bronchus is an average of 2.0 cm, whereas it is approximately 1.5 cm in women. One in every 250 individuals (incidence 0.1–3%) from the general population may have an abnormal take-off of the right upper lobe bronchus emerging from above the tracheal carina on the right side (8–10). The diameter of the right mainstem bronchus is an average of 17.5 mm in men and 14 mm in women. The trifurcation of the right upper lobe bronchus consists of the apical, anterior, and posterior division. This is a very important
landmark to identify while performing fiberoptic bronchoscopy in order to distinguish the right from the left mainstem bronchus (11). Also, a bifurcated or quadrivial patterns in the right upper lobe, two with vertical keels and two with horizontal keels, have been reported. This quadrivial pattern is more predominant in males and its incidence is reported to be 2.9% (12). The bronchus intermedius gives rise to the middle lobe bronchus, with its medial and lateral divisions and the lower lobe bronchus. The segmental bronchi of the right lower lobe consist of the superior, anterior basal, medial basal, lateral basal, and posterior divisions. The distance from the tracheal carina to the bifurcation of the left upper and left lower lobe is approximately 5.0 cm in men and 4.5 cm in women. The left mainstem bronchus is longer than the right mainstem bronchus, and it divides into the left upper and the left lower lobe bronchus. The left upper lobe bronchus has a superior and inferior division (also known as the lingular bronchus). The segmental bronchi of the superior division of the left upper lobe consist of the apicoposterior and anterior segments. The segmental bronchi of the lingular bronchus are the superior and inferior segments. The left lower lobe consists of the superior, anterior medial basal, lateral basal, and posterior basal segmental bronchi. Figure 1 displays the tracheobronchial anatomy.


Flexible Fiberoptic Bronchoscopy Examination
Flexible fiberoptic bronchoscopy is a diagnostic and therapeutic procedure of great value in the clinical practice of anesthesia. The most common method to perform flexible fiberoptic bronchoscopy is with the use of a single-lumen endotracheal tube. When using a single-lumen endotracheal tube (i.e., 8.0 mm internal diameter), an adult fiberoptic bronchoscope should be used (i.e., 5.0 mm outer diameter). The internal diameter (ID) of the single-lumen endotracheal tube relative to the external diameter of the bronchoscope is an important consideration. Bronchoscopes in the non-intubated patient occupy only 10–15% of the cross-sectional area of the trachea. In contrast, a 5.7 mm bronchoscope occupies 40% of a 9 mm ID single-lumen endotracheal tube and 66% of a 7 mm ID single-lumen endotracheal tube. Failure to recognize this may lead to inadequate ventilation of the patient and impaction of or damage to the bronchoscope. Once the tube is advanced beyond the vocal cords and inside the trachea, the tip of the single-lumen endotracheal tube should come to rest 3–4 cm above the tracheal carina. A Portex fiberoptic bronchoscope (SSL Americas, Inc., Norcross, Georgia, USA) swivel adapter with a self-sealing valve is used to facilitate ventilation and manipulation of the bronchoscope at the same time. The channel suction part of the bronchoscope should be attached to suction aspirated secretions. A video screen monitor should be used whenever possible to enhance the views. Another alternative to perform fiberoptic bronchoscopy is with the use of a laryngeal mask airway (LMA). This technique allows visualization of the vocal cords and subglottic structures with lower resistance than a single-lumen endotracheal tube when the bronchoscope is inserted.

A systematic and complete fiberoptic bronchoscopy examination includes a clear view of the anterior wall (tracheal cartilage) and posterior wall (membranous portion) of the trachea below the vocal cords and of the tracheal carina. When advancing the bronchoscope through the right mainstem bronchus, a clear view of the bronchus intermedius should be seen, and at 3 o’clock the orifice of the right upper lobe bronchus should also be seen. As the bronchoscope is advanced inside the take-off of the right upper bronchus, a clear view of the orifices is found: apical, anterior, and posterior segments. This is the only structure in the tracheobronchial tree that has three orifices. Although previously discussed, a quadrivial pattern (four orifices) can be found in <2.9% of the population (Figure 2).

After withdrawing the bronchoscope from the right upper bronchus, it is advanced distally into the bronchus intermedius in order to identify the middle and lower right lobe bronchi. The right middle bronchus has the shape of a letter D. Once the complete examination has been performed on the right mainstem bronchus, the bronchoscope is withdrawn until the tracheal carina is seen again. Then the bronchoscope is readvanced into the left mainstem bronchus in which the bifurcation into left upper and lower lobe is visualized. Figure 3 shows basic fiberoptic bronchoscopy views of the trachea and bronchus.

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Figure 3. (A) Tracheal carina. At 12 o’clock there is a cartilage ring (anterior wall) and at 6 o’clock there is the membranous portion of the trachea. In addition, the longitudinal folds are seen (posterior wall). Also, the entrance of the right mainstem bronchus is seen towards the right, and the entrance of the left mainstem bronchus is seen towards the left. (B, upper) Bronchial carina. To the right, the entrance of the right upper lobe bronchus can be seen, and towards the left the bronchus intermedius is seen. (B, lower) Entrance of the right upper lobe bronchus with three orifices (B-1 apical, B-2 anterior, and B-3 posterior segments). (C) Right middle lobe bronchus at 11 o’clock (resembles the letter D), and right lower lobe bronchus downward. (D) A clear view of the left upper lobe bronchus and lingula bronchus to the right and the left lower lobe bronchus towards the left.
References


