

Trachea & Bronchi

The trachea and bronchi are part of the passageway for conducting air between the respiratory cells of the lungs and the atmosphere external to the body.

Trachea

- 1) a musclocartilaginous tube – distinctive shape in cross-section (e.g. CT scan) due to C-shaped rings of cartilage anterolaterally and a flat layer of smooth muscle (called trachealis) posteriorly
- 2) begins in the neck immediately below the larynx (level of C6 vertebra)
- 3) descends through the superior thoracic aperture immediately anterior to the esophagus
- 4) bifurcates near the level of the sternal angle into left and right main bronchi
 - a) carina - a distinctively shaped (resembles the upside down keel of a boat) cartilage located at the bifurcation of the trachea; a prominent landmark in bronchoscopy

Bronchi

Main (Primary) Bronchi

- 1) left and right main bronchi (one for each lung)
- 2) descend laterally from the bifurcation of the trachea to the hila of the lungs
- 3) structurally similar to the trachea
- 4) right main bronchus - wider caliber, shorter length, and more a direct continuation of the trachea than the left main bronchus
- 5) bronchial tree - a main bronchus and its descendents

Lobar (Secondary) Bronchi

- 1) arise from main bronchi in or just outside the hila
- 2) one for each lobe of a lung, i.e. 3 for the right lung, 2 for the left lung
 - a) named right upper lobar bronchus, right middle lobar bronchus, right lower lobar bronchus, etc.

Segmental (Tertiary) Bronchi

- 1) arise within the lung from lobar bronchi
- 2) one for each bronchopulmonary segment (a structural and functional unit of lung tissue)
- 3) divide into progressively smaller passages; approximately 20 generations of divisions below a segmental bronchus

Clinical Notes: 1) Bronchoscopy - the use of an instrument called a bronchoscope to visualize the interior of the respiratory passages for diagnostic (e.g. visual inspection, biopsy) or therapeutic (e.g. removal of an inspired object) purposes. 2) Bronchial obstruction - reduction in the ability of a respiratory passage to conduct air due to a reduction in its lumen. Among the etiologies are a) intraluminal (within the lumen) lesions such as an inhaled foreign object, b) mural (pertaining to or occurring in the wall of) lesions such as tumors arising in or infiltrating into the walls of the respiratory passages, and c) extrinsic compression of the respiratory passages as may occur from aortic aneurysms, mediastinal tumors, or enlarged hila lymph nodes. 3) Inhaled foreign objects - there is a higher incidence of inhaled foreign objects entering the right main bronchus than the left main bronchus due to the right bronchus' wider caliber and it being a more direct continuation of the trachea.

Lungs & Pleurae

The lungs are the organs of respiration in which gases are exchanged between inspired air and the blood. There are two lungs, a left lung and a right lung. The pleurae and their associated pleural cavities provide a frictionless environment for the respiratory movements of the lungs and play a major role in keeping the lungs expanded.

Lungs

Lobes & Fissures

- 1) right lung
 - a) two fissures - horizontal and oblique
 - b) three lobes - upper (superior), middle (intermediate), and lower (inferior)
- 2) left lung
 - a) one fissure - oblique
 - b) two lobes - upper (superior) and lower (inferior)
- 3) bronchopulmonary segments
 - a) a structural and functional unit of lung tissue with its own vascular and airway supply
 - b) 10 per lung (one for each segmental bronchus)

Surfaces

- 1) costal - faces the ribs and intercostal spaces
- 2) diaphragmatic (syn. base) - faces the diaphragm
- 3) mediastinal - faces the mediastinum

Borders

- 1) anterior - where costal surface meets mediastinal surface anteriorly (thin & sharp)
 - a) are the anterior medial limits of the lungs; lie largely posterior to the sternum
 - b) cardiac notch of left lung – lateral deviation in the anterior border; accommodates the heart
- 2) posterior - where costal surface meets mediastinal surface posteriorly (curved)
 - a) difficult to precisely identify
 - b) lie along the paravertebral gutters
- 3) inferior - where diaphragmatic surface meets mediastinal and costal surfaces (thin & sharp)
 - c) are the lower limits of the lungs - cross the 6th, 8th, and 10th ribs near the midclavicular, midaxillary, and scapular lines respectively.

Other

- 1) apex (syn. cupula) - rounded top; partially extends above the 1st rib into the root of the neck
- 2) hilum (pl. hila) - area on the mediastinal surface where structures enter and exit a lung
- 3) root of the lung - the collective structures that enter and exit a lung at its hilum

Clinical Notes: 1) Pneumonectomy - surgical removal of an entire lung. 2) Lobectomy - surgical removal of the lobe of a lung. 3) Segmental resection - surgical removal of a bronchopulmonary segment. 4) Apex of a lung - since the apex of a lung extends above the 1st rib into the root of the neck, lower neck lesions (e.g. penetrating wounds) must be considered potential lung (thoracic) lesions. 5) Collapsed lung (syn. atelectasis) - a condition in which a lung constricts inward upon itself, thus being expanded to a less than normal volume. Two basic types of atelectasis; a) absorption atelectasis results from a complete bronchial obstruction in which the air trapped behind the obstruction gets absorbed by the respiratory tissue and, since the region behind the obstruction cannot acquire additional air, the lung collapses, and b) compression atelectasis results from a space occupying lesion exerting pressure onto the external surface of a lung, such as may occur with a pneumothorax or a large pleural effusion.

Blood Supply

1) Pulmonary Circulation

- a) carries deoxygenated blood from the heart to the respiratory cells of the lungs and returns oxygenated blood to the heart
- b) pulmonary trunk
 - i) carries deoxygenated blood from the right ventricle of the heart
 - ii) divides into left and right pulmonary arteries, one for each lung
- c) pulmonary veins
 - i) carry oxygenated blood to the left atrium of the heart
 - ii) two pulmonary veins from each lung enter the heart, named left and right superior and inferior pulmonary veins
 - iii) superior pulmonary veins drain upper and middle lobes, inferior pulmonary veins drain lower lobes

Clinical Note: Pulmonary embolism - occurs when an embolus (Greek for “plug”) derived from a blood clot (syn. thrombus) becomes lodged in the pulmonary circulation. 90% of clinically presenting pulmonary emboli arise from the deep veins of the lower extremities. The embolus can result in partial or complete obstruction of blood flow through the pulmonary circulation of a lung. Complications associated with pulmonary embolism are multiple with adverse affects on cardiac function the major concern; a potentially life-threatening condition.

2) Bronchial Circulation

- a) carries oxygenated blood from the systemic circulation to the non-respiratory cells (e.g. connective tissue, smooth muscle) of the lungs and returns the de-oxygenated blood to the systemic circulation
- b) bronchial arteries and veins
 - i) most common origin of the bronchial arteries is the descending thoracic aorta
 - ii) travel along the surface of the trachea and main bronchi to the hila of the lungs
 - iii) bronchial blood vessels are very small in caliber in comparison to pulmonary blood vessels
 - iv) two sets of bronchial veins drain the bronchial capillary beds - “true” bronchial veins drain into the azygos vein of the systemic circulation while “bronchopulmonary veins” unite with tributaries of the pulmonary veins of the pulmonary circulation
 - v) bronchial arteries form anastomoses with precapillary, capillary, and postcapillary vessels of the pulmonary circulation.

Lymphatics

1) efferent lymphatic vessels of a lung flow toward its hilum

2) lymph nodes (LN)

- a) pulmonary LN - within the lungs
- b) bronchopulmonary LN - within the hila and along the main bronchi
- c) tracheobronchial LN - around the bifurcation of the trachea
- d) paratracheal LN - along the sides of the trachea
- e) left and right bronchomediastinal trunks
 - i) large lymphatic ducts into which flow the lymph of paratracheal LN
 - ii) exit the thorax to eventually unite with systemic veins in the root of the neck

Nerve Supply

1) Pulmonary Plexus

- a) a network of autonomic nerve fibers around the root of a lung; axons penetrate hilum and follow the bronchial tree to target cells

- b) includes efferent (motor) and afferent (sensory) components of both parasympathetic and sympathetic systems
- 2) Parasympathetics
 - c) derived from the vagus nerves (CN X)
 - d) cause bronchoconstriction of respiratory passages (reducing the volume of inspired air)
 - e) cause an increase in secretion of the mucous glands in the respiratory passages (mucus keeps the respiratory surfaces moist and traps small particles in the inspired air)
 - f) conduct general sensations (pain, touch) from the epithelial lining of the respiratory passages (cough reflex)
 - g) conduct information from stretch receptors in the walls of the respiratory passages (monitors the degree of expansion of the respiratory passages)
- 2) Sympathetics
 - a) derived from lower cervical and upper thoracic ganglia of the sympathetic trunks
 - b) mildly constrict pulmonary arteries and arterioles in order to increase arterial pressure
 - c) indirectly cause bronchodilation by sympathetic system's stimulatory effect on the adrenal medulla to secrete epinephrine, which causes bronchodilation

Pleurae and Pleural Cavities

Serous Membranes

- 1) definition - a mesothelium (mesodermally-derived simple squamous epithelium) that sits on a framework of loose connective tissue
- 2) a continuous, uninterrupted membrane that is subdivided into visceral and parietal parts
 - a) visceral part - intimately attached to the outer surface of an organ
 - b) parietal part - not in direct contact with an organ but rather lines inner body walls or non-visceral structures adjacent to viscera
- 4) visceral and parietal parts of a serous membrane are apposed to each other
 - a) serous cavity - the very narrow gap (18 to 20 μm wide) between apposing parts of a serous membrane
- 5) serous fluid
 - a) a small amount of liquid in a serous cavity - serves as a lubricant, allowing apposing parts of a serous membrane and the structures they cover to move (e.g. change size and shape) in a frictionless environment
 - b) continuously produced and re-absorbed
 - c) formation and removal of serous fluid
 - i) formation - derived from the underlying interstitial fluid; continuously traverses the mesothelium into the serous cavity.
 - (1) serous pressure - the pressure within a serous cavity; less than the interstitial pressure of the serous membrane itself which creates a gradient for fluid movement into the serous cavity
 - ii) removal - continuously transported out of the serous cavity into the lymphatic system via stoma
- 6) stoma - 8 to 10 μm diameter channels in the parietal part of a serous membrane that are sites of continuity between mesothelial cells of the serous membrane and endothelial cells of the underlying lymphatic vessels.

Pleurae (syn. Pleural Membranes) and Pleural Cavities

- 1) left and right pleurae – the two serous membranes associated with the lungs
- 2) visceral pleura - intimately attached to the outer surface of a lung
- 3) parietal pleura - not in direct contact with a lung but rather lines the inner walls and structures of the thoracic cavity that a lung abuts.

- a) named for the region that it lies against
 - i) cervical - root of the neck
 - ii) costal - ribs and intercostal spaces
 - iii) mediastinal - lateral extremes of the mediastinum
 - iv) diaphragmatic - upper surface of the diaphragm
- 4) parietal and visceral pleurae are continuous with each other around the root of a lung near the hilum
 - a) pulmonary ligament – an inferior extension of the continuity between visceral and parietal pleurae; provides “slack” in the pleurae to accommodate changes in lung size
- 5) pleural cavity (syn. pleural space) - the serous cavity of a pleura
 - a) two separate pleural cavities, one for the left lung and one for the right lung
 - b) a lung is surrounded by a pleural cavity, it is not in a pleural cavity.
 - c) pleural fluid – fluid of a pleural cavity
 - d) pleural (syn. intrapleural) pressure – pressure in the pleural cavity; is constantly negative under normal physiologic conditions and with the very small volume of pleural fluid plays a vital role in mechanically coupling the lungs (visceral pleurae) and thoracic wall (parietal pleurae).

Pleural Recesses & Reflections

- 1) pleural recesses - regions of the pleural cavities where parietal pleura is apposed not to visceral pleura but rather to other parietal pleura; functions as the physical space that accommodates changes in the size of a lung during respiration.
 - a) costodiaphragmatic recesses - costal pleurae apposed to diaphragmatic pleurae
 - b) costomediastinal recesses - costal pleurae apposed to mediastinal pleurae
- 2) pleural reflections – the sites of continuity between the two apposing layers of parietal pleurae that create a pleural recess
 - a) costal pleural reflections
 - i) continuity at costodiaphragmatic recesses - parallel the inferior borders of the lungs
 - ii) lower limits of the costal pleural reflections are near the 8th, 10th, and 12th ribs at the midclavicular, midaxillary, and scapular lines respectively.
 - b) sternal pleural reflections
 - i) continuity at costomediastinal recesses - parallel the anterior borders of the lungs
 - ii) run from sternoclavicular joints to sternal angle near the midline and then descend vertically behind the body of the sternum - gradually deviate laterally to become continuous with costal pleural reflections.
 - iii) left sternal pleural reflection begins its lateral deviation more superiorly than the right, reflecting the lateral deviation of the anterior border of the left lung at the cardiac notch.

Clinical Notes: 1) Pleural effusion - the abnormal accumulation of fluid in a pleural cavity; a space-occupying liquid with the potential to reduce lung volume by compressing the lung. The most common disorder of the pleurae. Pleural effusions typically result from a) a breach in the structural integrity of a pleural membrane (e.g. gunshot wound), which allows fluid, cells, and other foreign materials to enter the pleural cavity or b) a change in the normal equilibrium between the passage of pleural fluid into the pleural cavity and its re-absorption from the pleural cavity (e.g. increased interstitial fluid in the lungs due to blockage of lymph flow from the lungs secondary to bronchogenic carcinoma [lung cancer] leads to increased interstitial fluid passage into the pleural cavity). Pleural effusion is a secondary symptom of an underlying disease process. 2) Hemothorax - a pleural effusion containing a large volume of blood. 3) Pneumothorax - air within the pleural cavity; typically the result of trauma (e.g. rupture of visceral pleura and underlying lung via a penetrating wound) or spontaneous (e.g. rupture of a disease-based [e.g. emphysema] bleb [a flaccid air-filled vesicle of abnormal lung tissue]). 4) Barotrauma - pneumothorax in mechanically-ventilated patients due to rupture of a small airway or alveolus. 5) Thoracentesis - procedure by which the fluid of a pleural effusion is extracted from the pleural cavity via the passage of a needle or cannula through an intercostal space into the pleural cavity; can be both a diagnostic (e.g. chemical/cytological analysis of the fluid) and therapeutic (e.g. reduction in the fluid volume) procedure.

Neurovascular Supply

- 1) Visceral pleura
 - a) insensitive to pain - only autonomic vasomotor innervation
 - b) vascular supply from the bronchial circulation of the underlying lung
- 2) Parietal pleura
 - a) sensitive to pain - a variety of innervations from the nerve supply of underlying structures, e.g. intercostal and phrenic nerves.
 - b) vascular supply derived from the blood supply of underlying structures, e.g. intercostal arteries, arterial supply to the diaphragm
 - c) a rich lymphatic network, including the stoma, that drains into the lymphatic system of underlying structures, e.g. diaphragm, intercostal muscles

Clinical Note: Pleurisy (syn. pleuritis) - inflammation of the pleura. While visceral pleura is not sensitive to pain, inflammatory processes in the periphery of a lung that involve the visceral pleura (e.g. pneumonia) often involve the adjacent parietal pleura which in turn invokes pain via its sensory innervation. Pleural pain emanating from costal pleura and the periphery of diaphragmatic pleura is typically referred to the region of the chest wall innervated by the affected intercostal nerves. Pleural pain emanating from parietal pleura that is innervated by the lower intercostal nerves may also be referred to the antero-lateral abdominal wall, which receives sensory innervation from lower intercostal nerves. Pleural pain elicited from mediastinal pleura and the central portion of diaphragmatic pleura is referred to the shoulder due to their phrenic nerve innervation (C3, 4, 5); C3 through C5 also provides sensory innervation to the shoulder.

Mechanics of Respiration

Underlying Principles

- 1) lung movements are entirely passive and the result of forces external to the lungs
- 2) lungs have a natural tendency to collapse and the thoracic wall and its adherent pleurae function in part to prevent the collapse
- 3) pressure is inversely related to volume, e.g. if volume increases then pressure decreases
- 3) air moves from areas of high pressure to areas of low pressure
- 4) a change in the volume of the thoracic cavity results in a change in the volume of the respiratory air spaces within the lungs
- 5) the lungs are intimately connected anatomically to visceral pleurae which is intimately connected mechanically to parietal pleurae which is intimately connected anatomically to the deep surface of the thoracic wall and the upper surface of the diaphragm
- 6) respiration reflects rhythmic fluctuations between alveolar pressure (within the respiratory alveoli) and the atmospheric pressure outside the body

Musculoskeletal Actions

- 1) diaphragm - changes the vertical dimension of the thoracic cavity
 - a) descends upon contraction - increases vertical dimension
 - b) ascends upon relaxation - decreases vertical dimension
 - c) during descent, concurrently relax the anterior abdominal wall so as not to change the intra-abdominal pressure
 - i) since movement of the abdominal wall is visible and that of the diaphragm is not, diaphragmatic breathing is often referred to as "abdominal breathing"
 - ii) increase intra-abdominal pressure via descent of the diaphragm and contraction of the antero-lateral abdominal wall, e.g. parturition, defecation

- 2) thoracic wall – due to the oblique axes of movement of the ribs, movements of the thoracic wall concurrently change the anteroposterior (AP) and transverse dimensions of the thoracic cavity
 - a) elevation - increase AP and transverse dimensions
 - b) depression - decrease AP and transverse dimensions

Types of Respiration

- 1) Quiet
 - a) normal resting state of activity; inspiration/expiration cycle occurs 12-20 times/minute, exchanging about 500 ml of gas per cycle
 - b) inspiration - primarily diaphragmatic activity
 - c) expiration - a passive process based on the inherent elastic recoil of the lungs
- 2) Forced
 - a) occurs during physical exertion or stress
 - b) maximum change in volume of the thoracic cavity to maximize volume of inspired air
 - c) employs accessory muscles of respiration (e.g. muscles of the anterolateral abdominal wall, sternocleidomastoids and scalenes of the neck, etc.)

Clinical Notes: 1) Eupnea refers to normal breathing. 2) Apnea means a lack of breathing. 3) Dyspnea means difficulty breathing. 4) Tension pneumothorax - a lung injury form of pneumothorax that is characterized by a ball-type valve mechanism where air enters the pleural cavity through the injured lung and, due to the anatomy of the injury, the air is unable to escape and accumulates in the pleural cavity over time. Each time a patient inspires air moves into the pleural cavity, increasing the volume of air that is trapped and in turn increasing the intrapleural pressure; a life threatening phenomenon due to the disruption of mediastinal anatomy over time, e.g. the accumulating air may push the heart to the opposite side, "kinking" some of the great vessels entering the heart.

Surface Anatomy of the Respiratory Tracts, Lungs, & Pleurae

Trachea and Primary Bronchi

- 1) trachea
 - a) palpable in the midline of the neck above the manubrium; best heard with a stethoscope at this location.
 - b) in the thorax confined largely to the midline superior mediastinum and thus deep to the manubrium.
- 7) two main bronchi descend infero-laterally from the level of the sternal angle

Clinical Note: Displacement of the trachea – the trachea may be displaced from its normal midline position in certain chest disorders, e.g. it is often displaced toward the same side as an absorption atelectasis (a collapsed lung due to bronchial obstruction) while it is displaced toward the opposite side in the case of a large pleural effusion or pneumothorax.

Lungs and Pleurae

- 1) apices of the lungs project above the 1st ribs into the root of the neck
 - a) 1st ribs are difficult to palpate due to the overlying clavicles; useful measurement for the tip of an apex is 2 to 4 cm above the medial third of the clavicle.
- 2) lung fissures and positioning of lobes
 - a) oblique fissures - follow a forward sloping course around the chest wall from the 2nd or 3rd thoracic vertebra to the 6th rib at the midclavicular line
 - b) horizontal fissure - intersects the oblique fissure in the midaxillary line near the 5th rib and projects forward to the 4th costal cartilage
 - c) positions of the lung lobes are dictated by the fissures

- i) anterior chest wall - mostly overlies upper lobe of left lung and upper and middle lobes of right lung
 - ii) posterior chest wall - mostly overlies lower lobes of both lungs
- 3) pleural cavities extend more inferiorly than the lungs
- a) the inferior borders of the lungs define their lower limits - cross the 6th, 8th, and 10th ribs at the midclavicular, midaxillary, and scapular lines respectively.
 - b) the costal pleural reflections define the lower limits of the pleural cavities - cross the 8th, 10th, and 12th ribs at the midclavicular, midaxillary, and scapular lines respectively.
 - c) thus a two rib difference between the lower limits of the lungs (6-8-10) and their adherent visceral pleura and the lower limits of the pleural cavities (8-10-12); difference is occupied by the costodiaphragmatic recesses.
- 4) pleural cavities and lungs reside posterior to the sternum
- a) sternal pleural reflections (which are the medial limits of the pleural cavities anteriorly) and the anterior borders of the lungs (which are the medial limits of the lungs anteriorly) closely parallel each other with narrow costomediastinal recesses between them
 - i) extend from the sternoclavicular joints to the sternal angle near the midline and then descend vertically behind the body of the sternum - gradually deviate laterally
 - ii) left sternal pleural reflection begins its lateral deviation more superiorly (around the 4th costal cartilage) than the right due to the cardiac notch of the left lung.

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