are characterized by a loss of surfactant (e.g., infant respiratory distress syndrome). Diseases such as pulmonary fibrosis, which are characterized by excessive collagen in the lung, can make the lung stiff and difficult to inflate, whereas those such as emphysema, characterized by a loss of elastin and collagen, reduce lung recoil and increase lung compliance (Fig. 15-8). Normally, at FRC, it takes about 1 cm of water pressure (1 cm H_2O) to inflate the lungs 200 mL or to inflate the chest wall 200 mL. The lung and chest wall both need to be inflated to the same volume during inspiration, so 2 cm H_2O of pressure is required to inflate both to 200 mL. Therefore, normal respiratory system compliance is roughly 200/2 or100 mL/cm H_2O and compliance of the lung or chest wall compliance is 200/1 or 200 mL/cm H_2O at volumes near FRC.

The second set of forces that the inspiratory muscles must overcome to inflate the lungs are flow-dependent forces; namely, tissue viscosity and airway flow resistance, the latter constituting the major component of the flow-dependent forces. Airway resistance during inspiration can be calculated by measuring inspiratory flow and the difference in pressure between the alveolus and the airway opening (ΔP_{A-ao}).

$$\text{Resistance} = \Delta P_{A-ao} / \dot{V}$$

The airflow velocity, the type of airflow (laminar or turbulent), and the physical attributes of the airway (radius and length) are the key determinants of airway resistance. Of the physical properties, the radius of the airways is the major factor. Resistance increases to the fourth power as the diameter decreases under conditions of laminar flow (streamline flow profile) and to the fifth power under conditions of turbulent flow (chaotic flow profile). Because airway diameter increases as lung volume increases, airway resistance decreases as lung volume increases (Fig. 15-9). Airway diameter also contributes to regional differences in airway resistance. Although the peripheral airways are narrower than the central airways, their total cross-sectional area is much greater than that of the central airways, as described earlier. Consequently, resistance to airflow of the peripheral airways is low relative to the central airways (see Fig. 15-3).

The type of airflow is another key determinant of airway resistance. Resistance is directly proportional to flow rate when flow is laminar. Resistance is much greater with turbulent flow because it is proportional to the square of the flow rate. The velocity of airflow determines, in part, whether the flow pattern is laminar or turbulent. Clinically, increased airway resistance can be seen in diseases associated with airway obstruction caused by an intrinsic mass, mucus within the airway, airway smooth muscle contraction, or extrinsic compression of the airways.

Lung elastic recoil also influences airway resistance and airflow. Decreased lung recoil increases resistance by promoting collapse of the small airways (E-Fig. 15-1). Normal resistance when breathing at FRC at low flow rates is in the range of 1 to 2 cm H_2O/L per second.

Distribution of Ventilation

The distribution of inhaled volume throughout the lung is unequal. In general, more of the inhaled volume goes to the bases of the lung than to the apex when the individual is inhaling while in an the upright body position. This pattern of volume distribution leads to greater ventilation of the bases than at the apices. This inhomogeneity of ventilation results largely from regional differences in lung compliance. The alveoli at the lung apex are relatively more inflated at FRC than the alveoli at the lung base. The difference in alveolar distention from apex to base is related to pleural pressure differences from apex to base. The weight of the lung causes pleural pressure to be more negative at the apex

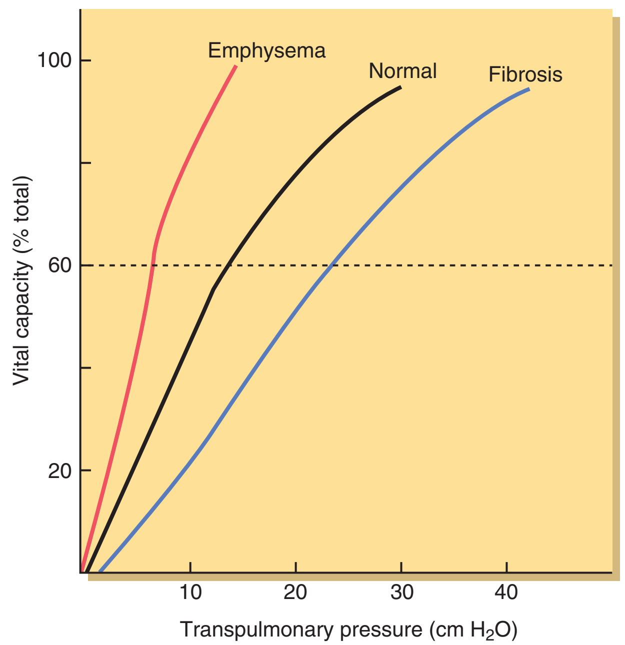

FIGURE 15-8 Compliance curves for normal individuals and for patients with emphysema or pulmonary fibrosis. The transpulmonary pressure required to achieve a given lung volume is greatest for the patient with pulmonary fibrosis (notice the horizontal dashed line at 60% of the vital capacity). This increases the work of breathing.

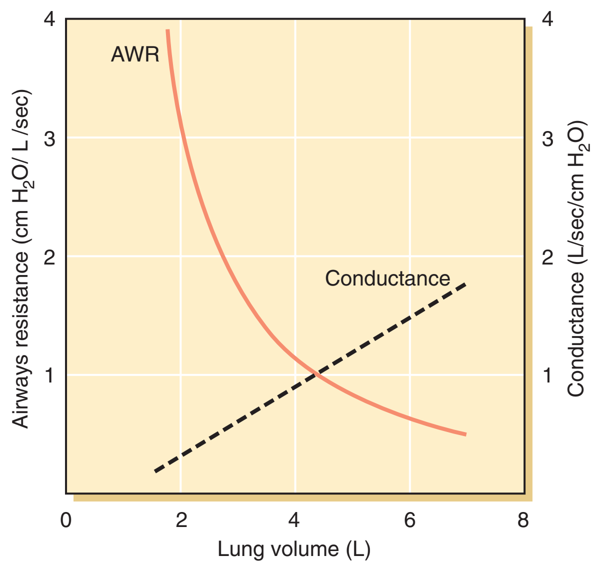

FIGURE 15-9 As lung volume increases, the airways are dilated, and airways resistance (AWR) decreases. The reciprocal of resistance (conductance) increases as lung volume increases.