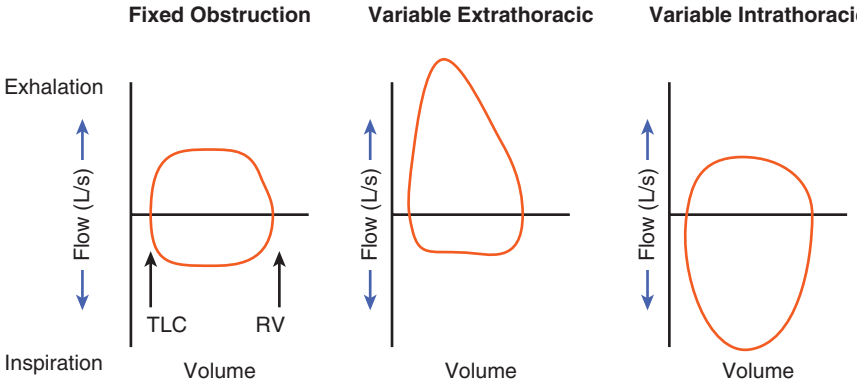

FIGURE 15-22 The flow-volume loops display different patterns of upper airway obstruction. With fixed obstruction, both inspiratory and expiratory flows are reduced (clipped). With variable extrathoracic obstruction, only the inspiratory flows are clipped. With variable intrathoracic obstruction, only the expiratory flows are clipped. RV, Residual volume; TLC, total lung capacity.

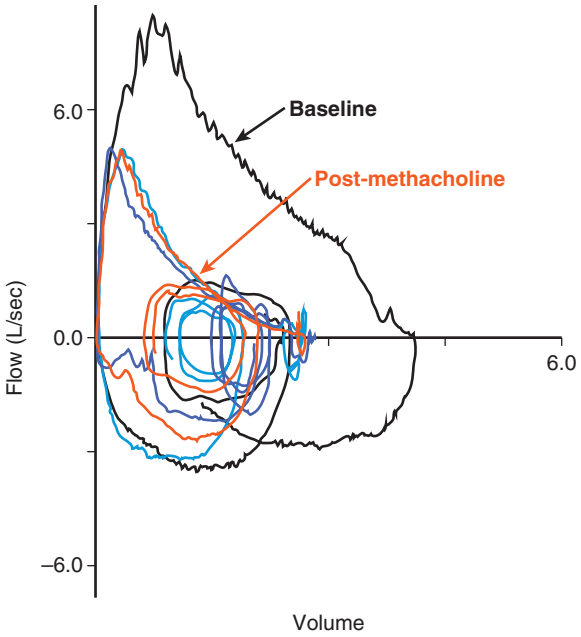

FIGURE 15-23 In bronchoprovocation challenge, patients are exposed to increasing concentrations of an inhaled challenge (e.g., methacholine, histamine), followed by evaluation of the forced expiratory volume in 1 second (percentage of baseline value) or airways conductance. The FEV_1 falls by more than 20% (compared to baseline), and airways conductance by more than 40%, at lower concentrations of the challenge drug in individuals with asthma.

increasing concentrations of methacholine. Measurements of FEV_1, FVC, and specific airways conductance are obtained after the inhalation of each concentration until the maximal dose of methacholine has been administered. If the FEV_1 is reduced by 20% or more or the specific airways conductance is reduced by 40% or more, a diagnosis of hyperreactive airways disease is established. Patients with asthma demonstrate a fall in FEV_1 at considerably smaller doses than in normal individuals (Fig. 15-23).

Lung Diffusion Capacity

The diffusion of oxygen from the alveolus into the capillary can be assessed by measuring the diffusion capacity for carbon monoxide (DLCO). To calculate the diffusion capacity for oxygen, one would need to know the alveolar volume and the partial pressures of oxygen in the alveolus and in the pulmonary capillary. Because it is not practical to measure the oxygen tension of pulmonary capillary blood, carbon monoxide is used rather than oxygen to assess diffusion capacity. Carbon monoxide diffuses across the alveolar capillary membranes much as oxygen does. However, carbon monoxide has the advantage of binding completely to hemoglobin. Therefore, the partial pressure of carbon monoxide in the pulmonary venous blood is negligible. The DLCO is then measured as the rate of disappearance of carbon monoxide from the alveolus and is used as a surrogate for oxygen diffusion capacity.

The DLCO measurement provides an overall assessment of gas exchange and depends on factors such as the surface area of the lung, the physical properties of the gas, perfusion of ventilated areas, hemoglobin concentration, and the thickness of the alveolar-capillary membrane. Therefore, an abnormal value may not only signify disruption of the alveolar-capillary membrane but may also be related to a reduction in surface area of the lung (pneumonectomy), poor perfusion (pulmonary embolus), or poor ventilation of alveolar units (COPD). A low DLCO may be seen in interstitial lung diseases that alter the alveolar-capillary membrane or in diseases such as emphysema that destroy both alveolar septa and capillaries (E-Fig. 15-3). Anemia lowers the DLCO. Most laboratories provide a hemoglobin correction for diffusion capacity. An increased DLCO may be associated with engorgement of the pulmonary circulation by red blood cells or polycythemia.

TABLE 15-2 NORMAL VALUES FOR ARTERIAL BLOOD GASES

Partial pressure of oxygen (Pao_2): $104 - (0.27 \times age)$
Partial pressure of carbon dioxide ($Paco_2$): 36-44
pH: 7.35-7.45
Alveolar-arterial O_2 difference $= 2.5 + (0.21 \times age)$

Arterial Blood Gases

The measurement of Pao_2 and $Paco_2$ provides information about the adequacy of oxygenation and ventilation. This requires arterial blood sampling through arterial puncture or indwelling cannula (Table 15-2). Oxygenation also can be measured through noninvasive devices such as the pulse oximeter, which measures hemoglobin oxygen saturation, and through transcutaneous devices that measure Pao_2 and $Paco_2$. These devices are particularly useful for measuring oxygenation during exertion or sleep. Often, alterations in oxygenation are not detected at rest but are unveiled during exertion. The 6-minute walk