TABLE 323-1 CONTRAINDICATIONS FOR NONINVASIVE VENTILATION

Cardiac or respiratory arrest
Severe encephalopathy
Severe gastrointestinal bleed
Hemodynamic instability
Unstable angina and myocardial infarction
Facial surgery or trauma
Upper airway obstruction
High-risk aspiration and/or inability to protect airways
Inability to clear secretions

that time frame should alert the physician to the possible need for conventional MV.

Conventional Mechanical Ventilation Conventional MV is implemented once a cuffed tube is inserted into the trachea to allow conditioned gas (warmed, oxygenated, and humidified) to be delivered to the airways and lungs at pressures above atmospheric pressure. Care should be taken during intubation to avoid brain-damaging hypoxia. In most cases, the administration of mild sedation may facilitate the procedure. Opiates and benzodiazepines are good choices but can have a deleterious effect on hemodynamics in patients with depressed cardiac function or low systemic vascular resistance. Morphine can promote histamine release from tissue mast cells and may worsen bronchospasm in patients with asthma; fentanyl, sufentanil, and alfentanil are acceptable alternatives. Ketamine may increase systemic arterial pressure and has been associated with hallucinatory responses. The shorter-acting agents etomidate and propofol have been used for both induction and maintenance of anesthesia in ventilated patients because they have fewer adverse hemodynamic effects, but both are significantly more expensive than older agents. Great care must be taken to avoid the use of neuromuscular paralysis during intubation of patients with renal failure, tumor lysis syndrome, crush injuries, medical conditions associated with elevated serum potassium levels, and muscular dystrophy syndromes; in particular, the use of agents whose mechanism of action includes depolarization at the neuromuscular junction, such as succinylcholine chloride, must be avoided.

PRINCIPLES OF MECHANICAL VENTILATION

Once the patient has been intubated, the basic goals of MV are *to optimize oxygenation while avoiding ventilator-induced lung injury due to overstretch and collapse/re-recruitment*. This concept, known as the "protective ventilatory strategy" (see below and Fig. 323-1) is supported by evidence linking high airway pressures and volumes and overstretching of the lung as well as collapse/re-recruitment to poor clinical outcomes (barotrauma and volume trauma). Although normalization of pH through elimination of CO_2 is desirable, the risk of lung damage associated with the large volume and high pressures needed to achieve this goal has led to the acceptance of permissive hypercapnia. This condition is well tolerated when care is taken to avoid excess acidosis by pH buffering.

MODES OF VENTILATION

Mode refers to the manner in which ventilator breaths are triggered, cycled, and limited. The *trigger*, either an inspiratory effort or a time-based signal, defines what the ventilator senses to initiate an assisted breath. *Cycle* refers to the factors that determine the end of inspiration. For example, in volume-cycled ventilation, inspiration ends when a specific tidal volume is delivered. Other types of cycling include pressure cycling and time cycling. The *limiting factors* are operator-specified values, such as airway pressure, that are monitored by transducers internal to the ventilator circuit throughout the respiratory cycle; if the specified values are exceeded, inspiratory flow is terminated, and the ventilator circuit is vented to atmospheric pressure or the specified pressure at the end of expiration (positive end-expiratory pressure, or PEEP). Most patients are ventilated with assist-control ventilation, intermittent mandatory ventilation, or pressure-support ventilation, with the latter two modes often used simultaneously (Table 323-2).

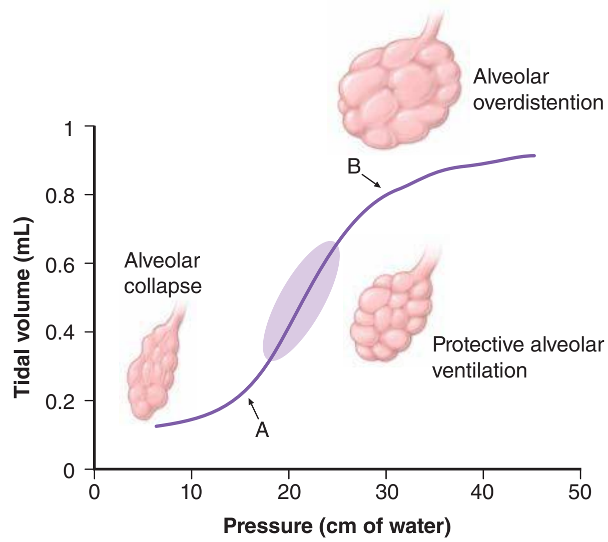

FIGURE 323-1 Hypothetical pressure-volume curve of the lung in a patient undergoing mechanical ventilation. Alveoli tend to close if the distending pressure falls below the lower inflection point (***A***), whereas they overstretch if the pressure within them is higher than that of the upper inflection point (***B***). Collapse and opening of ventilated alveoli are associated with poor outcomes in patients with acute respiratory failure. Protective ventilation (*purple shaded area*), using a lower tidal volume (6 mL/kg of ideal body weight) and maintaining positive end-expiratory pressure to prevent overstretching and collapse/opening of alveoli, has resulted in improved survival rates among patients receiving mechanical ventilatory support.

Assist-Control Ventilation (ACMV) ACMV is the most widely used mode of ventilation. In this mode, an inspiratory cycle is initiated either by the patient's inspiratory effort or, if none is detected within a specified time window, by a timer signal within the ventilator. Every breath delivered, whether patient- or timer-triggered, consists of the operator-specified tidal volume. Ventilatory rate is determined either by the patient or by the operator-specified backup rate, whichever is of higher frequency. ACMV is commonly used for initiation of mechanical ventilation because it ensures a backup minute ventilation in the absence of an intact respiratory drive and allows for synchronization of the ventilator cycle with the patient's inspiratory effort.

Problems can arise when ACMV is used in patients with tachypnea due to nonrespiratory or nonmetabolic factors, such as anxiety, pain, and airway irritation. Respiratory alkalemia may develop and trigger myoclonus or seizures. Dynamic hyperinflation leading to increased intrathoracic pressures (so-called auto-PEEP) may occur if the patient's respiratory mechanics are such that inadequate time is available for complete exhalation between inspiratory cycles. Auto-PEEP can limit venous return, decrease cardiac output, and increase airway pressures, predisposing to barotrauma.

Intermittent Mandatory Ventilation (IMV) With this mode, the operator sets the number of mandatory breaths of fixed volume to be delivered by the ventilator; between those breaths, the patient can breathe spontaneously. In the most frequently used synchronized mode (SIMV), mandatory breaths are delivered in synchrony with the patient's inspiratory efforts at a frequency determined by the operator. If the patient fails to initiate a breath, the ventilator delivers a fixed-tidal-volume breath and resets the internal timer for the next inspiratory cycle. SIMV differs from ACMV in that only a preset number of breaths are ventilator-assisted.

SIMV allows patients with an intact respiratory drive to exercise inspiratory muscles between assisted breaths; thus it is useful for both supporting and weaning intubated patients. SIMV may be difficult to