increases the risk of ventilator-associated lung injury. The tidal volume should not be increased without considering its effects on airway pressure or the likelihood of ventilator-induced lung injury. In acute respiratory distress syndrome (ARDS), tidal volumes of about 6 mL/kg of ideal body weight are associated with improved mortality (level I evidence).

An optimal method for setting the respiratory rate has not been determined. After the tidal volume has been established, the respiratory rate can be incrementally increased or decreased to achieve the desired pH and $PaCO_2$ while monitoring auto-PEEP. Patients who are breathing spontaneously set their own respiratory rates in all modes of ventilation except CMV.

The lowest possible fraction of inspired oxygen (FIO_2) necessary to meet oxygenation goals should be used. This decreases the likelihood that adverse consequences of supplemental oxygen, such as absorption atelectasis, accentuation of hypercapnia, airway injury, and parenchymal lung injury, will develop.

PEEP usually is added to prevent end-expiratory alveolar collapse. This can improve $\dot{V}/\dot{Q}$ matching and arterial oxygenation, and it allows reduction in FIO_2, reducing the risk for oxygen toxicity. However, elevated levels of applied PEEP can have adverse consequences, such as reduced preload (i.e., decreased cardiac output), elevated plateau airway pressure (i.e., increased risk of barotrauma), and impaired cerebral venous outflow (i.e., increased intracranial pressure). The optimal PEEP value enhances oxygenation without lung hyperinflation and decreased blood pressure.

Respiratory therapists typically adjust the inspiratory flow rate, flow pattern, and amount of negative pressure required to trigger a mechanical ventilator breath. If these ventilator settings are not adjusted with due consideration of the patient's respiratory mechanics, two common problems can occur: asynchrony and auto-PEEP.

Patient-ventilator asynchrony occurs if the phases of breaths delivered by the ventilator do not match the breathing pattern of the patient. This can lead to dyspnea, increased work of breathing, and prolonged duration of mechanical ventilation. It is detected by careful observation of the patient and examination of the ventilator waveforms. The abnormality that is most readily apparent is failure of the ventilator to trigger a breath when the patient makes an inspiratory effort.

Auto-PEEP is usually seen when patients do not fully empty their lungs during expiration before the initiation of the next breath. This is called *stacking breaths* or *generating auto-PEEP*. It is particularly worrisome in patients who have exacerbations of COPD or status asthmaticus requiring mechanical ventilation. In ventilated patients, auto-PEEP may cause barotrauma or hemodynamic collapse because of high intrathoracic pressures that prevent blood return to the right ventricle.

Weaning from Mechanical Ventilation

The complications of endotracheal intubation and mechanical ventilation include barotrauma, volutrauma (i.e., acute lung injury caused by high tidal volumes), and ventilator-associated pneumonia. Weaning from mechanical ventilation should be considered on a daily basis, particularly when the original insult that caused respiratory failure has improved. Weaning is most likely to be successful in the awake and cooperative patient without respiratory or hemodynamic instability. Weaning is usually not attempted if requirements for oxygen supplementation remain high (FIO_2 >0.5).

Conventional parameters that determine whether weaning is possible include negative inspiratory force, vital capacity, tidal volume, respiratory rate, and minute ventilation (Table 22-1). However, the strength of these parameters lies in the ability to predict failure to wean rather than in the ability to predict successful spontaneous breathing. A better way to assess weaning capability is to engage the patient in a short weaning trial during which support from the ventilator is diminished. Another strategy is to decrease the pressure generated by the ventilator during a trial of continuous positive airway pressure (CPAP). The patient is monitored for signs of distress or hemodynamic instability, and arterial blood gas levels are measured to determine the effectiveness of spontaneous ventilation. If the patient tolerates the trial, extubation may be indicated, depending on the patient's clinical status, ability to protect the airway, and underlying medical condition.

If the patient fails the weaning trial, attempts should be made to identify the factors responsible for the failure to wean. For very sick patients, all obvious contributory factors might have been identified and corrected, but the patient still requires a more prolonged weaning trial before extubation. The first of two recommended weaning strategies is to engage the patient in spontaneous ventilation trials without positive pressure for 1 hour once or twice each day, with total ventilatory support between trials usually supplied by ACV or PCV. The length of the spontaneous breathing trials can be progressively increased until the patient no longer requires mechanical support. The second strategy uses PSV. The inspiratory pressure is progressively decreased until the patient can breathe spontaneously without ventilatory support.

Both strategies appear to be equally effective, although weaning through PSV may be preferred in patients with chronic lung disease who have been mechanically ventilated for prolonged periods. For patients with prolonged mechanical ventilation, studies have shown that early tracheostomy is beneficial for weaning purposes and facilitates trials of unassisted breathing exercises because it can be easily and repeatedly removed (level II-1 evidence).

For a deeper discussion on this topic, please see Chapter 105, "Mechanical Ventilation," in Goldman-Cecil Medicine, *25th Edition.*

TABLE 22-1 CONVENTIONAL WEANING PARAMETERS

PARAMETERS	WEANABLE VALUES	NORMAL VALUES
NIF (cm H_2O)	≤20	≤50
VC (mL/kg)	>10	>65-75
V_T (mL/kg)	<5	>5-7
RR (breaths/min)	<32	12-20
V_E (L/min)	>10	>10
RSBI (RR/V_T)	<105	<40

NIF, Negative inspiratory force; RR, respiratory rate; RSBI, rapid shallow breathing index; VC, vital capacity; V_E, minute ventilation; V_T, tidal volume.