reasons for mechanical ventilation in patients with acute respiratory failure.

Immediate complications of mechanical ventilation include barotrauma causing pneumothorax, pneumomediastinum, or subcutaneous emphysema. Atrophy of the diaphragm and impairment of mucociliary motility may also occur.

Noninvasive Mechanical Ventilation

Although intubation and mechanical ventilation are usually the preferred options in respiratory failure that is considered reversible, noninvasive positive-pressure ventilation (NPPV) is useful in selected patients. NPPV is ventilation delivered through a noninvasive interface (i.e., nasal mask, face mask, or nasal plugs), rather than through an endotracheal tube or tracheostomy. Selecting patients for NPPV requires careful consideration of its indications and contraindications. A trial of NPPV is worthwhile in patients with acute cardiogenic pulmonary edema or hypercapnic respiratory failure due to COPD who do not require emergent intubation and who do not have contraindications to NPPV.

Contraindications to NPPV include cardiac or respiratory arrest; inability to cooperate, protect the airway, or clear secretions; uncontrolled vomiting, hematemesis or hemoptysis; severely impaired consciousness; facial surgery, trauma, or deformity; anticipated prolonged duration of mechanical ventilation; and recent esophageal anastomosis. Early predictors of success include a significant correction in pH (i.e., respiratory acidosis) and a decrease in $Paco_2$ of more than 8 mm Hg.

Invasive Mechanical Ventilation

After the decision to intubate is made, an experienced operator should expeditiously perform intubation. Complications of intubation include prolonged hypoxemia due to delays in the procedure, vomiting and aspiration of gastric contents, trauma to the vocal cords, bleeding, pneumothorax, cardiac arrhythmias, and cardiac arrest. Immediately after insertion, endotracheal location should be confirmed by assessing exhaled carbon dioxide. The endotracheal tube should be secured and its position assessed by examining for breath sounds, followed by chest radiography for confirmation. Direct visualization, such as by bronchoscopy, is occasionally needed for successful intubation.

Initial ventilator settings may vary, but orders should include ventilator mode, fraction of inspired oxygen (Fio_2) of 1.0 (or 100%), respiratory rate set, and tidal volume (discussed later). The adequacy of the ventilator settings is determined with arterial blood gas measurement and clinical evaluation of the patient. After the settings are adjusted to maintain relatively normal levels of arterial blood gases (i.e., pH of 7.3 to 7.45, Pao_2 >60 mm Hg, and $Paco_2$ of 30 to 45 mm Hg), attention should be given to developing a maintenance plan to ensure adequate oxygenation and ventilation until the cause of the respiratory failure is treated and reversed. This plan should include assessment of the need for sedation, appropriate strategy of mechanical ventilation, supportive measures to achieve hemodynamic stability, nutritional assessment, and therapies targeting the initial injurious process that triggered the respiratory failure. Most patients require sedation to diminish discomfort and to decrease the work of breathing, but it should be administered carefully because sedation is often accompanied by a decrease in blood pressure.

Commonly used modes of ventilation are determined by the duration of inspiration, which can be limited by volume, pressure, flow, or time. During volume-limited ventilation, inspiration ends after delivery of a preset tidal volume. Airway pressure varies during volume-limited ventilation and is related to respiratory system compliance, airway resistance, and tubing resistance. Assist control ventilation (ACV), continuous mandatory ventilation (CMV), and synchronized intermittent mandatory ventilation (SIMV) are examples of volume-limited modes of ventilation. CMV has a set rate and set tidal volume that do not allow spontaneous breathing by the patient. Because patient-ventilator asynchrony is a serious problem, CMV is rarely used. ACV is similar to CMV in that there is a set rate and set tidal volume, but this mode allows the patient to initiate machine-delivered breaths. When the machine senses that the patient is attempting to take a breath, it delivers the selected tidal volume. SIMV is similar to ACV in that a set rate and set tidal volume are selected. The patient is also able to generate a spontaneous breath. However, this spontaneous breath may have a very small tidal volume and thereby increase work of breathing. Consequently, this mode of mechanical ventilation is seldom used except when weaning patients from mechanical ventilation.

The pressure control mode of ventilation (PCV) uses machine breaths that are pressure cycled, not volume cycled. With PCV, the pressure to be used for each breath is ordered. If the patient attempts a spontaneous breath, a machine breath at the designated pressure is delivered. This may be helpful in limiting airway pressures in patients with bronchospasm or stiff lungs because it limits the risk for pneumothorax (i.e., barotrauma). Because tidal volumes may vary, PCV must be titrated carefully at the bedside to determine the proper pressure settings. The physician should order the desired minimal tidal volume.

Pressure support ventilation (PSV) is used only for spontaneously breathing patients. The inspiratory and expiratory pressures are selected, and there are no mandatory machine-delivered breaths. Patients find this to be a more comfortable mode of mechanical ventilation. However, PSV should be used only for patients with a stable respiratory drive (i.e., not sedated heavily) and stable lung compliance. PSV is typically used for patients who are weaning from mechanical ventilator support.

Pressure-regulated volume control, airway pressure–release ventilation, and high-frequency ventilation are newer modalities. They are increasingly used in clinical practice.

Settings

Numerous settings need to be considered when mechanical ventilation is initiated. They include tidal volume, respiratory rate, trigger mode and sensitivity, fraction of inspired oxygen, positive end-expiratory pressure (PEEP), flow rate, and flow pattern.

The appropriate initial tidal volume depends on numerous factors, most notably the disease for which the patient requires mechanical ventilation. The tidal volume can then be increased or decreased incrementally to achieve the desired pH and $Paco_2$. Large tidal volumes can cause barotrauma or volutrauma, which