Abstract:
Early, goal-directed therapies, including effective oxygen delivery, are essential in providing good outcomes for the patient with sepsis. Understanding sepsis and the mechanisms that drive oxygen delivery is important in determining appropriate therapies to support oxygenation. Noninvasive modes of oxygen delivery, including noninvasive positive pressure ventilation, should be used early and escalated as determined by the patient's clinical signs and symptoms.

Keywords:
hypoxemic respiratory failure; oxygen delivery; oxygen consumption; high-flow nasal cannula; nasal CPAP

Respiratory Therapy Approaches to the Patient with Sepsis

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One of the greatest challenges in treating sepsis in children, regardless of age, is the consistent, effective delivery of oxygen. Maintaining sufficient oxygen delivery to the tissues along with maintaining adequate perfusion are the key elements of sepsis management. Oxygen delivery, as defined by the following formula, encompasses the complete cardiopulmonary system, with each segment vulnerable to compromise in the face of sepsis:[1]

Oxygen delivery = cardiac output (heart rate × stroke volume) × oxygen content (hemoglobin [Hgb] level × 1.34 × arterial oxygen saturation) + (Pa_{O_2} × 0.003).

Because of the many barriers to tissue oxygenation that the septic patient encounters, the respiratory therapist must be diligent in their task of providing optimal oxygen delivery, while closely monitoring patient response to such therapies. In addition to the delivery of oxygen, therapists must play close attention to laboratory values, specifically Pa_{O_2}, mixed venous oxygen saturation (Sv_{O_2}) and Hgb level, and the impact those values have on tissue oxygenation.

High oxygen delivery is a driver to better patient outcomes in certain populations; however, it is important to keep in mind that oxygen delivery does not guarantee oxygen uptake. Using the oxygen delivery formula as our reference, this review will consider the variety of oxygen delivery systems, oxygenation markers, and adjunct therapies to optimize efforts to provide adequate tissue oxygenation, thereby decreasing the opportunity for end-organ dysfunction.

RESPIRATORY ASSESSMENT OF THE SEPTIC CHILD

Early recognition of sepsis in conjunction with appropriate interventions provides first responders with the unique opportunity to change the course of a septic child. In the pediatric patient, some of the first signs of sepsis are tachypnea, tachycardia, and fever.[1,2] It is expected that the pediatric patient will be tachypneic in the early stages of sepsis, increasing their minute ventilation as a compensatory mechanism for their metabolic acidosis.[2] Early goal-directed therapy (EGDT), as recommended by the Surviving Sepsis Campaign suggest the immediate use of 1.0 fraction of inspired oxygen (Fi_{O_2}) via nasal cannula or facemask.[1,3] Concurrently, the patient should be assessed for airway patency, appropriate mental status, the ability to protect their airway, work of breathing, and gas exchange.[1] Oxygen saturations should be watched closely, and preferably, an arterial gas should be obtained. Results of the blood gas should be interpreted to determine the acid-base status, ventilation status, and evidence of tissue hypoxemia. These results will assist the respiratory therapist in determining the best options for oxygen delivery. Oxygen therapy is the first line of treatment for acute hypoxemic respiratory failure with the ultimate goal of adequate tissue oxygenation and perfusion. In response to the patient's work of breathing and level of hypoxemia, therapeutic respiratory support may be increased to include the use of noninvasive positive pressure ventilation as well as endotracheal intubation and mechanical ventilation.

OXYGEN DELIVERY

Oxygen should be delivered as an empirical therapy to the patient suspected of having sepsis. At minimum, a 2 L/min nasal cannula should be applied, after which the patient is assessed.[2] If it is determined that the patient requires more oxygen to maintain oxygen saturations, a nonrebreather mask at 15 L/min can be used. The patient supported with a nonrebreather, who continues to exhibit an increased work of breathing and suboptimal saturations, requires an increase in support.

Oxygen delivery devices vary, each with benefits and limitations. The optimal oxygen delivery device will be the one that the patient can tolerate, yet also meeting the patient's flow demands and delivering a consistent Fi_{O_2}. Facemask and standard nasal cannulas may not have the capacity to consistently meet the Fi_{O_2} requirement due to the inability to meet the patient's peak inspiratory flow demands, which will present the opportunity for the patient to entrain ambient air. High-flow nasal cannula (HFNC) is an appropriate first line of support for hypoxemic respiratory failure. Hypoxemic respiratory failure is defined a Pa_{O_2} less than or equal to 60 in the absence of hypercarbia.[4] Recommended treatment for hypoxemic respiratory failure is the administration of supplemental oxygen with the goal to achieve an arterial oxygen saturation of 94% with an Fi_{O_2} of less than 0.5.[4]

High-flow nasal cannula is often well tolerated due to the fact that it is able to deliver heated and humidified gas. More importantly, high flow diminishes air dilution, delivering a consistent Fi_{O_2} and decreases work of breathing by consistently meeting or exceeding the patient's flow demands.[5,6] High-flow nasal cannula reduces symptoms of respiratory distress and improves oxygenation by providing positive pressure and the opportunity for alveolar recruitment. Recent studies suggest that the high flow can generate mean airway pressures between 2.7 and 7.4 cm H_2O depending on the flow rates.[7] Eight liters per minute has been determined to deliver approximately 5 cm H_2O of continuous positive airway pressure (CPAP).[5] The high flows delivered to the nasopharynx promote a flushing out

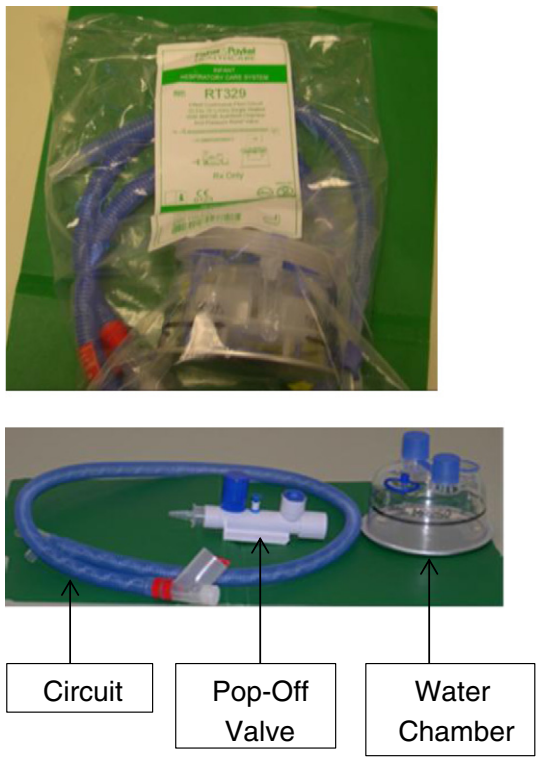

Figure 1. Fisher & Paykel infant respiratory care system (infant continuous flow circuit).