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Predictors of Weaning Failure from Mechanical Ventilation in Pediatric Intensive Care Unit

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Abstract

Prior to initiating HFNC support, the doctor will ascertain the gas temperature, FiO2 percentage, and flow rate. Gas temperature is usually adjusted 1oC to 2oC below body temperature for comfort, while patient physiology should guide the selection of FiO2 and its modification to reach the aim of peripheral capillary oxygen saturation (SpO2). The ideal starting gas flow rate is not universally agreed upon, however a flow dosage depending on weight is favored. For newborns to get respiratory support, the recommended flow rates range from 0.5 to 1 L/kg/min. Flow rates of up to 2 L/kg/min effectively reduce intrathoracic pressure fluctuations induced by effort of breathing and are considered optimal. Clinical results are not improved by flows greater than 2 L/kg/min. Efficacious but noninvasive Individuals suffering from neuromuscular weakness, extrathoracic airway blockage, obstructive or restrictive lung disease, and other conditions have greatly benefited from the use of noninvasive positive pressure ventilation (NIPPV) techniques including CPAP and BiPAP.

Keywords: Predictor variables, weaning failure, mechanical ventilation, pediatric obstetric intensive care units (PICUs)

Introduction

Individuals suffering from neuromuscular weakness, extrathoracic airway blockage, obstructive or restrictive lung disease, and other conditions have greatly benefited from the use of noninvasive positive pressure ventilation (NIPPV) techniques including CPAP and BiPAP [1]**.**

Continuous positive airway pressure (CPAP) allows the patient to breathe naturally by maintaining a consistent pressure on the airway throughout the breathing cycle. Depending on the equipment utilized, flow might be either fixed or variable. Sedation may be necessary for some children to alleviate anxiety or pain caused by the device-patient interface, even though CPAP is often well-tolerated. [2] .

While using BiPAP, the user may adjust the expiratory pressure, inspiratory pressure, and FiO2 levels. For BiPAP modes that need breaths, additional settings like inspiratory time and necessary respiratory rate are required. Both the IPAP and the EPAP work to increase the tidal volume (VT) during inspiration, but the EPAP keeps the airway open during expiration, stops the derecruitment of alveoli, lowers the intrathoracic pressure fluctuations, and maybe improves the triggering synchronization. [3].

Both CPAP and BiPAP work best when administered via an interface that is both snug and airtight, such as a nasal or full-face mask. Air leakage around an improperly fitted interface might cause the patient pain and make it difficult to maintain the required airway pressures. On the flip side, skin breakdown and pressure ulcers may result from an interface that is overly tight, particularly when used for an extended period of time. Nasal pillows, oro-nasal masks, full-face masks, helmets, and mouthpieces are some of the patient interfaces that may be used to administer CPAP or BiPAP (Fig. I). Wearing a nasal, oro-nasal, or full-face mask is the norm in the pediatric intensive care unit. [4].

Treatment failure has been linked to hypoxemia and tachypnea that last more than 1 to 6 hours after starting NIPPV. So, if reducing FiO2 takes more than a few hours after starting NIPPV, intubation may be necessary. Complications, including mortality, may rise when NIPPV delays intubation and masks the progression of respiratory insufficiency (Box III). As a result, identifying NIPPVV failure requires a high index of suspicion and proper patient selection. [5].

Invasive mechanical ventilation

While invasive mechanical ventilation aims to promote tissue viability until acceptable lung function is restored, it does not aim to normalize gas exchange. Rather, it aims to provide enough oxygenation and ventilation while reducing problems and unnecessary strain of breathing. It is crucial to prevent ventilator-induced lung injury (VILI) while using invasive mechanical ventilation, even if it may save lives when used correctly. [6].

Table (1) Complications of Noninvasive Positive Pressure Ventilation.

- Poor exchange of gases
- Aspiration of air into the lungs, gastric distention or perforation, skin injuries (nose, face), irritation or conjunctivitis of the eyes, air leaks
- (pneumothorax, pneumomediastinum), agitation, and intubation delays are all possible complications.

Reasons to Use Invasive Mechanical Ventilation on Patients

Patients with acute respiratory failure are often decided to undergo invasive mechanical ventilation in order to support native pulmonary function. Possible causes include weak or fatigued respiratory muscles or an inability to maintain gas exchange at an acceptable level. [7] .

Although respiratory failure can be caused by a wide variety of diseases affecting the CNS, PNS, cardiovascular system, and lungs, endotracheal intubation and mechanical ventilation are only used in intensive care units for a small subset of these cases. [8]

The kind of mechanical ventilatory assistance needed will vary across these groups due to the high variability in the degree of original lung damage. Actually, neuromuscular weakness or "...altered mental status" might cause even individuals with normal respiratory function to need artificial breathing and airway management. [9].

Basic Ventilator Function

Gas exchange between the lungs and the rest of the body is the foundation of ventilation. This process is typically sustained by the diaphragm and other muscles of the respiratory system. Air must first overcome airway resistance and then pass through the elastic tissues of the respiratory system in order to reach the lungs. When a patient need help breathing, whether from illness or weak muscles, a ventilator may supply partial or full pressure to provide the required tidal volume. [10].

Phases of a Breath

In a mechanical breath, the most important parts are the inspiratory duration, cycle, limit, flow pattern, and trigger (Fig. I). Initiating a mechanical breath is signaled by the trigger parameter, while the flow pattern specifies the manner in which air is introduced into the patient during inspiration. Pressure or volume limitations may apply to individual breaths. [11] .

As soon as the cycle parameter is satisfied, the breath is pressured to the predetermined pressure during pressure ventilation. In volume-limited ventilation, gas is continuously supplied during inspiration until either the target VT is attained or the high-pressure warning is triggered. There are a lot of terms for the many modes of mechanical breathing, but the fundamentals of every given breath include trigger, flow pattern, limit, and cycle. [12].

In conventional ventilation, there are three different modes: control, support, and mixed. In control, both the inspiratory duration and the limit are specified. In support, just the limit is preselected. For controlled breaths with a volume restriction, the mode's title will be volume control, and for supported breaths with a pressure limit, it will be pressure support. [13]

Unlike mixed modes, which allow for both patient-triggered breaths (supported breaths) and control breaths (as determined by the ventilator rate), pure control modes (like assist control) give each breath a predetermined inspiratory time. In each of these modes, the ventilator will administer a time-triggered control breath to ensure the patient receives at least the set ventilator rate if they do not start breathing on their own within the specified period. [14].

A patient's inspiratory time is the duration between the beginning of the flow into the patient and the beginning of expiration. Measured from the beginning of exhalation until the beginning of the subsequent breath, this duration is called expiratory time. Add the durations of inhalation and exhalation to get the total cycle time. [15], **(Fig. 1).**

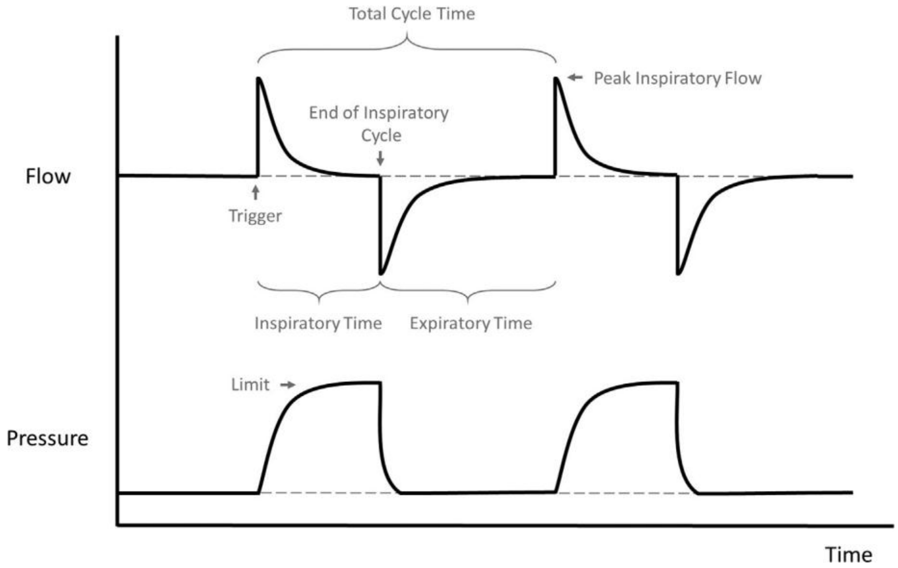


Fig. (1) Phases of a breath. [16]

on children who are chronically ventilated and need escalation of support for acute exacerbations, children who do not have lung pathology, children with heart conditions, and children without such conditions do not have any outcome data from which to draw recommendations on ventilatory or respiratory assist modes. It is important to evaluate the pathophysiology of the condition while deciding on the ventilator mode, which should be guided by clinical experience and theoretical reasoning. [16].

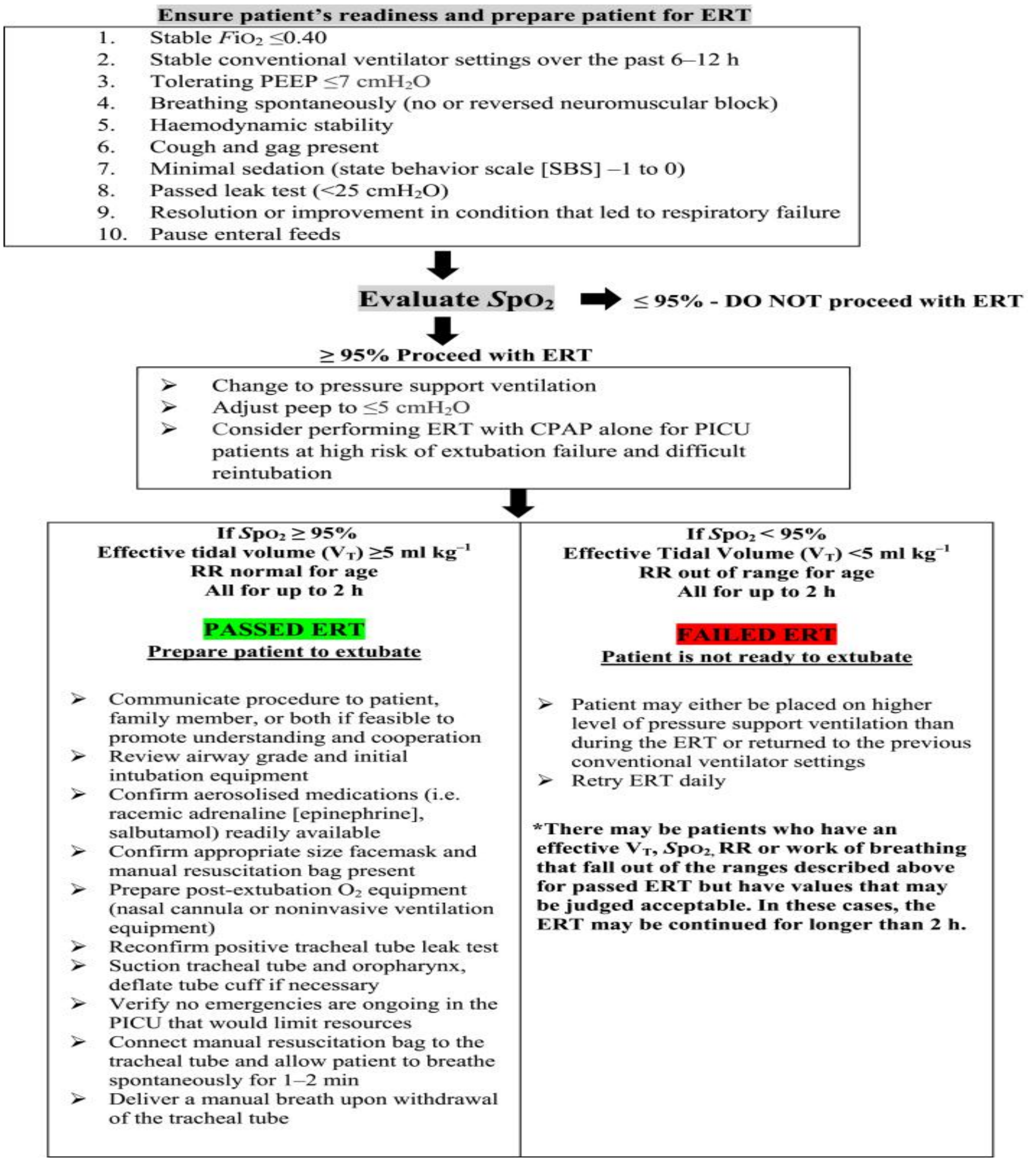
Initiating Breaths

Both the patient and the ventilator have the ability to start breathing. Electrical signals (such as electrical diaphragmatic activity), time, pressure, flow, minimum minute breathing, and apnea interval are all potential triggers. Pressure, flow, and time are the three most typical triggers. [17] .

When the patient is actively participating, any contemporary ventilator can provide synchronized intermittent mandatory ventilation by detecting when the patient wants to breathe and then delivering a pressure-supported breath or a forced mechanical breath based on the patient's signal. If you're looking to increase synchronization, try using a flow or electrical trigger. These are especially helpful for newborns or individuals with poor respiratory muscular effort. [18].

Flow Pattern

Lung volume and airway pressure both rise during inspiration and continue to do so until the inspiratory flow stops. Both continuous and decelerating flow patterns are often utilized. Only when volume-limited ventilation is in place can constant flow be employed. The pressure and volume will rise linearly with constant flow, but they will rise rapidly at the start of an inspiration breath and then slow down as the breath comes to a close due to decelerating flow. Although other flow patterns may be advantageous for certain disease processes, the most prevalent is decelerating flow as it is more reminiscent of normal breathing and more likely to satisfy patient flow needs. [18].



Ensure patient's readiness and prepare patient for ERT

1. Stable $FiO_2 \leq 0.40$
2. Stable conventional ventilator settings over the past 6–12 h
3. Tolerating PEEP ≤ 7 cmH_2O
4. Breathing spontaneously (no or reversed neuromuscular block)
5. Haemodynamic stability
6. Cough and gag present
7. Minimal sedation (state behavior scale [SBS] –1 to 0)
8. Passed leak test (<25 cmH_2O)
9. Resolution or improvement in condition that led to respiratory failure
10. Pause enteral feeds

Evaluate SpO_2 ➡ $\leq 95\%$ - DO NOT proceed with ERT

$\geq 95\%$ Proceed with ERT

- Change to pressure support ventilation
- Adjust peep to ≤ 5 cmH_2O
- Consider performing ERT with CPAP alone for PICU patients at high risk of extubation failure and difficult reintubation

If $SpO_2 \geq 95\%$
Effective tidal volume (V_T) ≥ 5 ml kg^{-1}
RR normal for age
All for up to 2 h

PASSED ERT

Prepare patient to extubate

- Communicate procedure to patient, family member, or both if feasible to promote understanding and cooperation
- Review airway grade and initial intubation equipment
- Confirm aerosolised medications (i.e. racemic adrenaline [epinephrine], salbutamol) readily available
- Confirm appropriate size facemask and manual resuscitation bag present
- Prepare post-extubation O_2 equipment (nasal cannula or noninvasive ventilation equipment)
- Reconfirm positive tracheal tube leak test
- Suction tracheal tube and oropharynx, deflate tube cuff if necessary
- Verify no emergencies are ongoing in the PICU that would limit resources
- Connect manual resuscitation bag to the tracheal tube and allow patient to breathe spontaneously for 1–2 min
- Deliver a manual breath upon withdrawal of the tracheal tube

If $SpO_2 < 95\%$
Effective Tidal Volume (V_T) <5 ml kg^{-1}
RR out of range for age
All for up to 2 h

FAILED ERT

Patient is not ready to extubate

- Patient may either be placed on higher level of pressure support ventilation than during the ERT or returned to the previous conventional ventilator settings
- Retry ERT daily

***There may be patients who have an effective V_T, SpO_2, RR or work of breathing that fall out of the ranges described above for passed ERT but have values that may be judged acceptable. In these cases, the ERT may be continued for longer than 2 h.**

Fig. (2) Extubation Preparedness Model

Conclusion:

Major risk factors for weaning failure in children include chronic respiratory illnesses, neuromuscular diseases, heart issues, elevated initial ventilator settings, stunted growth, and prolonged mechanical ventilation. To improve weaning success and patient outcomes in the PICU, it is critical to identify and treat these issues early on. Improving the weaning process for this susceptible group should be the goal of future studies that design and evaluate specific therapies.

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