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# Extubations in the PICU – Where are We Now?

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In the future, utilization of mechanical ventilation will continue to rise. It is anticipated that mechanical ventilation may be required in up to 50% of critically ill and/or injured infants, children, and adolescents in the PICU. This is due to an expected increase in utilization of life sustaining therapies such as renal replacement therapy, extracorporeal membrane oxygenation, therapeutic hypothermia, and transplantation (bone marrow, stem cell and solid organ) [1]. The rise in the use of these modalities will come at a time when clinicians will be expected to limit expenditures and conserve valuable resources such as bed space, specialized equipment such as ventilators and personnel to support their use. These expectations highlight the need for early and accurate determination of extubation readiness. Both failure to recognize opportunities for extubation (extubation readiness) and unsuccessful attempts at extubation (extubation failure) lead to increased ICU and hospital mortality, prolonged length of stay, and higher hospital costs [1-19]. Extubation failure rates range from 3-30% and usually occur within 24-96 h of extubation [1,3-4,6-7,9,12-15]. Risk factors associated with extubation failure can be grouped into abnormal respiratory mechanics (impaired muscle strength, effort and gas exchange) [7,12,15]; prolonged duration of mechanical ventilation [1,4,6,13,14]; unfavorable cardiopulmonary interactions [3,6,9,13,15]; altered level of consciousness (delirium, residual sedation and/or ICU acquired weakness) [6,7,9,13]; inability to manage secretions [6,7,9,13]; anatomic abnormalities (upper airway obstruction) [6,7,9,12]; genetic abnormalities [4]; metabolic perturbations [9]; fluid overload [9,13]; and unresolved infection [4,6,9].

Current literature suggests daily assessment of extubation readiness testing (ERT) through the use of standardized guidelines and/or protocols, followed by the use of a spontaneous breathing trial (SBT) prior to extubation. [7,9,13,15,16] The use of standardized guidelines and protocols to determine extubation readiness has been reported to reduce time to extubation thereby facilitating early extubation. [1,5] These daily assessments of extubation readiness include the use of criteria such as vital signs (with goals of age related heart rate, respiratory rate, and systolic blood pressure); ventilator criteria (PEEP ≤ 5, pressure support ≤ 10 and $FiO_2$ ≤ 40%); calculated data ($PaO_2/FiO_2$); and presence of endotracheal tube cuff leak [6,7,9,12,13]. If ERT is successful, then a SBT is conducted through a pressure support/continuous positive airway pressure (≤ 5 cm $H_2O$) or T-piece trial up to 60 mints to assess spontaneous respiratory effort [8]. Unfortunately, ERT and SBT have limited ability to predict extubation outcome with 8-15% of patients who successfully met extubation criteria and pass a SBT will fail extubation [1,2,7,13,15]. Explanations reflect the challenge of performing ERT and SBT in pediatric patients due to underestimation of spontaneous respiratory capabilities (effort, muscle strength, generated tidal volume and associated work of breathing) [8,12]; capacity for airway maintenance and clearance of secretions [8,9,12,13] detection of residual central nervous system depression [8,9,12]; and left ventricular function to ensure adequate cardiac output [12,13,15]. In short, current ERT and SBT are pre-extubation assessments with limited ability to predict post-extubation physiology, complications and outcomes in the pediatric patient.

Four years ago, in the absence of evidenced based criteria to determine extubation readiness, we evaluated the use of similar pre-extubation data to predict extubation readiness and extubation outcome in a multi-disciplinary Pediatric Intensive Care Unit (PICU) [2]. This data included pre-extubation ventilator settings, blood gas analysis, and use of Spontaneous Breathing Trials (SBT) among other factors commonly associated with extubation outcome. We described the findings from 319 consecutive patients who underwent first planned extubation attempt with a 91% success rate. What we confirmed was that factors associated with extubation failure were length of ventilation ($p<0.0001$, OR 2.20), young age ($p=0.02$, OR 0.54), preextubation steroids ($p=0.04$, OR 2.40), and postextubation

stridor (p<0.01, OR 3.40); and that extubation failure was associated with prolonged length of stay (LOS) (p<0.0001) and cost (p<0.0001). What we learned was that neither pre-extubation ventilator settings, blood gas results nor use of SBT had any association with outcome. We concluded that attainment of specific numbers such as ventilator settings, blood gas results and use of a pre-extubation estimate of post-extubation status (SBT) may lead to unnecessary prolongation of Mechanical Ventilation (MV), thereby increasing PICU LOS and excess cost.

In the interim, recent literature has described use of several potential adjunctive measures to improve prediction of ERT and SBT. These include measures of respiratory muscle strength (maximal airway pressure during airway occlusion) [12], respiratory effort (pressure rate product, pressure time product and tension time index) [12], oxygenation (oxygenation index) [7] and cardiac output (near infrared spectroscopy to detect changes in regional and somatic oxygen saturation) [15]. Furthermore, methods to facilitate early removal of endotracheal tubes have also been investigated and include performance of early tracheostomy [9], extubation to non-invasive forms of positive pressure ventilation [6,9,14,17] and use of neurally adjusted ventilator assist modes of mechanical ventilation to assist in evaluation of diaphragmatic function [19]. In addition, application of recognized indices of extubation readiness in adults such as rapid shallow breathing index [4,15] and compliance, resistance, oxygenation and pressure index [4,15] have also been attempted. Unfortunately, lack of consistent reliability and benefit limit application in the pediatric population and will require further study before incorporation of these measures into widespread daily practice [4,6,7,9,12,14,15,17].

Overall, current recommendations for daily consideration of ERT and a SBT utilizing clinical practice guidelines and/or protocols in a standardized approach makes practical sense. However, it is important to recognize that the use of current pre-extubation criteria to determine extubation readiness and predict post-extubation outcome has limitations. As a result, future research efforts should focus on development of new criteria that include identification and subsequent resolution of common risk factors associated with extubation failure rather than maintain reliance on old criteria that result in an unacceptable failure rate of 8-15% in PICU patients undergoing mechanical ventilation.

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