

Electrical Impedance Tomography in Mechanically Ventilated Children: Will It Impact Clinical Care?

Modern-day ICUs are filled with the latest technological advancements in critical care, some supported with definitive data and some not. Incorporating electrical impedance tomography (EIT) into patient assessment of those being managed with mechanical ventilation is one of the more interesting approaches. EIT allows the clinician to assess lung function in an innovative and exciting way.^{1,2} This technology transforms raw data obtained from external chest electrodes into a digital image presented on the ventilator and/or an external monitor reflecting changes in gas distribution throughout the lung with each breath. EIT's noninvasive approach makes it a safe, dynamic, diagnostic tool that can provide cross-sectional views of the lung in a continuous fashion. The image produced by EIT is generally precise and reliable, but an unanswered question is whether it can truly impact clinical care and clinical outcomes in a meaningful way.

In the current issue, van Dijk and colleagues describe the use of EIT to determine the distribution of tidal volume/gas delivery during the recovery phase of pediatric subjects with acute respiratory failure in their article titled "Global and Regional Tidal Volume Distribution in Spontaneously Breathing Mechanically Ventilated Children."³ In this paper, the authors describe the use of EIT to evaluate and compare tidal volume distribution and end-expiratory lung volume during common weaning approaches to mechanical ventilation: CPAP + pressure support ventilation (PSV) and pressure control/ synchronized intermittent mandatory ventilation (SIMV) + PSV. Progressively reduced levels of pressure support were employed as subjects transitioned toward liberation from mechanical ventilation. As demonstrated in previous studies, EIT measurements can allow a clinician to visualize improvement or worsening of ventilation in dependent and nondependent lung regions during incremental weaning of ventilator support.¹ van Dijk and colleagues hypothesized that pediatric patients with resolving respiratory failure who were treated with CPAP-PSV would have greater global and regional lung aeration as

well as more homogenous tidal volume distribution as compared to those treated in a more traditional manner during weaning, such as SIMV-PSV. For that measure alone, EIT is well suited to provide this information. However, the

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citations provided by the authors, which illustrate the positive effects of spontaneous breathing in mechanically ventilated adults, did not use EIT as their measure. Instead, those studies relied on lung compliance measurements, dead space/ tidal volume ratio, spirometry, and computed tomography scans to evaluate changes in lung volume and tidal volume distribution. Thus, one might conclude that the use of EIT in the pursuit of these answers in children was novel and forward thinking. Conversely, another could argue the value of using EIT in this manner was limited and lacked prior validation.

Where the investigators may have fallen short, however, was not with the use of EIT as the sole measure of lung volume or tidal volume distribution. Rather, the time in which each mode of ventilation was used before EIT measurements were obtained was relatively brief. The investigators allowed just 4 minutes of stable breathing in each of the ventilator mode categories before recording the EIT measurements for one minute, allowing just 5 minutes of time in each category. Whereas in the cited studies of adult subjects, interventions occurred for as long as 4 hours before obtaining measurements.^{4,5} To gain a better understanding of this intriguing monitoring approach, future studies may need to use longer time intervals of each ventilation mode prior to EIT measurements to more accurately reflect stability with each change in mode and/or after each intervention.

During the authors' discussion, they highlight that this may be the first prospective pediatric study examining global and regional lung volume changes using EIT during liberation from mechanical ventilation, and this is clearly a key strength of the study. Of note, they open their discussion speculating that their "findings may contribute to a better understanding of ventilator liberation in pediatrics." These investigators may be adding a new element to an existing body of science surrounding successful liberation from mechanical ventilation and the prevention of

Mr Gallagher discloses relationships with Mallinckrodt Pharmaceuticals and Chiesi, USA. The remaining authors have disclosed no conflicts of interests.

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DOI: 10.4187/respcare.10077

extubation failure. Extubation failure of mechanically ventilated children, often defined by the need for renewed mechanical ventilation within 48 hours of extubation, has been identified in the literature ranging from 16–22%.^{6,7} With such failure comes a host of potential complications including increased stay in the ICU, increased hospital stay, higher costs, and potentially increased mortality.^{6,7} Thus, it is critically important that clinicians have the best information available to aid them in making the correct decision regarding the timing of extubation.

Like most decisions in pediatric care, there is not a one-size-fits-all approach to this solution. To obtain the necessary information, clinicians may utilize a series of validated tests prior to extubation. In a recent study, investigators identified 8 predictive measures for determining extubation readiness in children.⁸ Notably, none of those identified was EIT measurements. However, of those 8, the most commonly used methods are the spontaneous breathing test, the rapid shallow breathing index, and the maximum inspiratory pressure. This rigorous outline of extubation readiness testing defines the map for where EIT may need to go. For its successful entry into this field of testing, the focus will need to be on the clinician's consistency of application, interpretation of the EIT signal, and validation of related findings in a large sample of patients.

Beyond the potential implication for extubation readiness assessment, the current study assesses the relationship between mode of ventilation and tidal volume/gas delivery throughout regions of the lung as assessed by EIT. Whereas an intriguing approach, the investigators found no relationship between mode of ventilation and gas distribution. It remains unclear whether this lack of a pertinent finding is related to the ventilator approaches/modes used, the presumed relatively mild lung injury studied as the subjects enrolled were in the resolution phase of their illness, and/or whether EIT is not the optimal monitoring technology. Additionally, no attempt was made to assess the degree of inspiratory effort or patient-ventilator synchrony. Both of these factors may have been uncontrolled variables in this real-world study of resolving lung injury.⁹ Overall, whereas a negative study, the current report raises important questions and interesting thoughts that will, hopefully, serve as the basis for future investigation. van Dijk and colleagues may have

provided a glimpse into the future pediatric critical care environment where EIT may become a standard respiratory tool of patient assessment. While clearly intriguing, it remains unclear whether EIT in mechanically ventilated children will be proven to impact clinical care and outcomes in a meaningful way.

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