Volume Guarantee: Neonatal Ventilation Advancement May Help Reduce Chronic Lung Disease

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ABSTRACT

This paper examines the technological advances in neonatal ventilation and focuses on advancements made in recent years, specifically volume-targeted modalities of conventional ventilation, which enable clinicians to effectively control tidal volume delivered to neonates.

The discussion focuses on Volume Guarantee (VG) in the NICU, a volume-targeted mode of ventilation that automatically adjusts the inspiratory pressure to achieve a set tidal volume according to changes in lung compliance or resistance, or the patient's respiratory drive. Because the benefits of this volume-targeted form of neonatal ventilation cannot be realized without ensuring that the tidal volume is distributed evenly throughout the lungs, the appropriate level of PEEP is essential.

BACKGROUND

When mechanical ventilation was introduced into neonatal care in the early 1970s, infant mortality dramatically declined. At that time, simple pressure-limited ventilation was the standard in the NICU.

The next few decades brought an increase in the clinical understanding of gestational development, technology advances, and the NICU care environment. This knowledge resulted in significant improvements in the quality of care—and ultimately created best practices that led to a healthy infant population post NICU discharge.

Today, neonatal ventilation has improved to the point where few newborns die due to acute respiratory failure. Mortality in the NICU is now predominantly caused by other complications of extreme prematurity—such as infection, necrotizing enterocolitis, intracranial hemorrhage, or congenital anomalies.

As the survival rate of extremely premature infants has increased in recent years, so too has the incidence of chronic lung disease. As a result, designers of neonatal ventilation systems such as Dräger have shifted their focus from reducing mortality to reducing the incidence of chronic lung disease.

Approaches to Neonatal Ventilation: Volume vs Pressure

One example of technology that improves neonatal respiratory support is volume-targeted modalities of conventional ventilation, which enable clinicians to effectively control tidal volume delivered to neonates.

For decades, exceedingly high inspiratory pressures have been thought to be a chief contributing factor of lung injury in the NICU. Pressure-limited, time-cycled, continuous flow ventilation has been the standard of care in neonatal ventilation for more than 30 years. One of the advantages cited for the preference for pressure-limited over volume-controlled ventilation has been the ability to directly control the inspiratory pressure. Over the past eight to ten years, a wealth of accumulating evidence confirms that volume, rather than pressure, is the critical determinant of ventilator-induced lung injury.¹
A microprocessor compares the tidal volume of the previous breath, using exhaled tidal volume to minimize possible artifact due to air leak, and adjusts the working pressure up or down to achieve the set tidal volume. To avoid overcorrection leading to excessive tidal volume, an algorithm limits the amount of pressure increase from one breath to the next. This means that very rapid changes in compliance or patient inspiratory effort require several breaths to reach target tidal volume.

To minimize the risk of excessively large tidal volume, the microprocessor opens the expiratory valve, terminating any additional pressure delivery if the delivered tidal volume exceeds 130% of the previous breath. By design, the Dräger algorithm is geared toward slower adjustment for low tidal volume and more rapid adjustment for excessive, potentially dangerous tidal volume.

As a result of the overwhelming evidence that excessive tidal volume is the primary determinant of lung injury rather than high inspiratory pressure, most clinicians now monitor the delivered tidal volume when using pressure-limited ventilation or volume-targeted ventilation.

The critical importance of distributing the tidal volume evenly into an optimally aerated lung has not been as widely studied and requires attention at the bedside. If extensive atelectasis is allowed to persist, the normal physiologic tidal volume entering the small proportion of open alveoli inevitably leads to overexpansion of the relatively healthy portion of the lung, with subsequent volutrauma and/or biotrauma. The collapsed portion of the lung is also damaged, which is known as atelectotrauma.

The Importance of Adequate PEEP

The benefits of volume-targeted ventilation in the NICU cannot be realized without ensuring that the tidal volume is distributed evenly throughout the lungs. In practical terms, optimization of lung inflation, referred to as the “open lung concept,” is achieved by applying adequate positive end-expiratory pressure (PEEP).

It is important to understand that there is no single “safe” PEEP level. Optimal end-expiratory pressure must be tailored to the degree of lung injury. For example, for infants who have no lung disease and thus have normal lung compliance, a PEEP of 3 cm H₂O is probably appropriate. A PEEP of 5 cm H₂O may result in overexpansion of the lungs, with impairment of venous return, elevated cerebral venous and systemic venous pressures, and decreased cardiac output.
Conversely, severely atelectatic, poorly compliant lungs may require PEEP levels as high as 8 to 10 cm H₂O or more to achieve adequate lung volume and improve the ventilation/perfusion ratio.  

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Future Technical Advancements

Volume Guarantee ventilation in the NICU has led to more stable tidal volumes, with a lower incidence of hypocarbia and excessively large tidal volumes. When combined with other lung-protective strategies aimed at optimizing lung volume and ensuring even distribution of tidal volume, Volume Guarantee appears to offer a significant impact on minimizing lung injury induced by neonatal ventilation.

However, the development of chronic lung disease in extremely preterm infants is multi-factorial. The degree of prematurity and presence of intrauterine inflammation have a very significant effect that may minimize the impact of a protective ventilation strategy. Thus, it will be difficult to demonstrate substantial differences in various ventilation strategies specific to long-term outcomes.

As technologies in breath delivery, non-invasive applications, patient synchrony, and developmental support in the NICU continue to advance, the next decade promises to bring further support for fragile neonates in their most critical time of life.

Questions?

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References


