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ARDS: Treatment or Prevention?

By Edwin Coombs, MA, RRT-NPS, ACCS, FAARC
Director of Marketing – Intensive Care North America, Dräger, Inc.

Background

Acute Respiratory Distress Syndrome (ARDS) is reported to have a mortality rate of approximately 40%.¹ The definition of ARDS has undergone several revisions based on research and a better understanding of the pathophysiology of the syndrome. In 1994, the American-European Consensus Conference (AECC) defined ARDS by establishing four key parameters which are: 1) acute onset, 2) P/F ratio of <300, 3) no demonstrable left heart failure, and 4) presence of bilateral infiltrates.² Then again in 2012, the Berlin definition included sub-stratifications to define the severity of ARDS; those being mild, moderate, and severe.³

Current practices

It is now known that improper mechanical ventilation can exacerbate ARDS-induced lung injury leading to a secondary ventilator induced lung injury (VILI), which can significantly increase mortality. In 2000 the standard of care changed dramatically when the ARMA trial demonstrated that when limited tidal volumes to 6cc/Kg-ibw, as compared to previous tidal volume standards, there was a marked improvement of 9% in survival rates.⁴ However, recent analysis suggests that the absolute size of the tidal volume is not the mechanism driving VILI but rather it has been shown that minimizing the driving pressure is the key to reducing ARDS mortality (Amato MBP NEJM 2016;372). Also we remain without a consensus regarding the methodology of defining the optimal level of PEEP necessary to maintain lung volume during expiration and prevent alveolar collapse and reopening with each breath. The current understanding of an optimal lung protective strategy necessary to minimize VILI is to open the lung and keep it open. A collaboration between Doctor Jesus Villar and Doctor Arthur Slutsky concluded that "ARDS is no longer a syndrome that must be treated, but is a syndrome that should be prevented".⁵

Airway pressure release ventilation (APRV)

APRV was first described in 1987 and defined as continuous positive airway pressure (CPAP) with a brief release period while allowing the patient to spontaneously breathe throughout the respiratory cycle. APRV may be an ideal mode for the "open lung" strategy; the extended time at inspiration (i.e. CPAP) would continually recruit the lung, while minimal release time would prevent lung collapse during expiration. Unfortunately, the settings that constitutes a APRV breath have been inconsistently defined and significant variations in both clinical practice and laboratory experiments render any conclusions of APRV efficacy difficult. Variations in APRV strategies revolves around modifying the CPAP and release time durations; however, the most significant evolution of APRV has been the development of the ability to personalize the expiratory duration to precisely meet the needs of the patient's changing lung physiology.⁶ This personalization is accomplished by analyzing the expiratory flow curve with each breath and adjusting expiratory duration accordingly (Jain S. Intensive Care Med Exp 2016;4:11). Since the initial concepts of APRV in 1987, there has been a major paradigm shift in the way in which APRV is set. Initially, settings that determined

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inspiratory and expiratory termination were fixed and not adjusted to an individual patient's lung compliance. In 2005, Dr. Habashi published a novel method of setting expiratory duration based on expiratory mechanics of the slope of the expiratory flow curve.⁷ In humans, Putensen et al. showed that APRV with spontaneous breathing increased oxygenation, cardiac index, and pulmonary compliance with reduced sedation requirements as compared with conventional positive pressure ventilation.⁸ Our understanding of ventilator induced lung injury is an evolution from a normal homogeneously ventilated lung to that of a heterogeneously ventilated lung that is characterized by collapse and edema-filled alveoli. This heterogeneity results in stress concentrators and recurrent alveolar collapse. Thus a ventilation strategy that restores or maintains homogeneity would minimize VILI and obstruct the progression of acute lung injury.^{9, 10, 11}

Personalized APRV: Alveolar stress and strain

As mentioned earlier, the most significant evolution of APRV is the understanding to personalize the mechanical breath which recruits alveoli resulting in homogenous inflation of the lung, coupled with a brief release phase based on lung mechanics (expiratory curve of the flow-time waveform). The prevention of alveolar collapse and cyclical opening and closing of the alveoli prevents dynamic tissue strain.^{12, 13} Kollish-Singule et al conducted three micro-anatomic studies that demonstrated reduced alveolar and conducting airway micro-strain as well as increased alveolar homogeneity using a personalized APRV approach where the Tlow was set to maintain an end-expiratory flow/peak expiratory flow (EEF/PEF) ratio of 75%. Extending the EEF/PEF ratio to 10% resulted in alveolar collapse and instability.¹⁴

Clinical implications of APRV and current state

In a meta-analysis, Andrews et al. demonstrated a tenfold decrease in the incidence of ARDS as well as a threefold decrease in mortality when compared to trauma patients with similar injuries that were treated with standard of care ventilation in fifteen trauma units.¹⁵ It is clear from the initial days of Dr. Stock and Dr. Downs and current reviews that the application and principle behind APRV have evolved over nearly thirty years. Although the acronym remains as "APRV" the mechanical properties of the breath are vastly different. The "personalized APRV breath approach" appears to be an exciting and novel approach to reduce the incidence of ARDS, morbidity and mortality of established ARDS.

Controversy remains

Despite recent animal laboratory studies and retrospective analysis of trauma sites, there is a lack of human trials that utilize a personalized APRV approach. This appropriately leads to questions which must be answered before a wide-spread change of clinical practice can be considered. A pro-con discussion had been conducted at a Respiratory Care Journal Conference discussing the role of APRV. The authors and the panel participants did not reference many of the contemporary research works that are enumerated in this whitepaper.¹⁶ The published pro-con discussion focused on the technical characteristics of "fixed-APRV" which as discussed can render a mechanical breath either protective or harmful based on current understandings of "personalizing" the mechanical breath. APRV cannot simply be considered inverse ratio ventilation, the brief release phase (Tlow) must be set appropriately to prevent alveolar collapse. The pro/con discussion added that different manufacturer's devices operate differently; to this there is no disagreement and that understanding these differences when using APRV clinically are of paramount importance. A White Paper from the AARC and UHC Respiratory Care Network provides guidance on best practices to define competency, training, and an interdisciplinary approach necessary for patient safety and improving outcomes.¹⁷

Lessons learned

The published pro/con debate also pointed out that for APRV to perform as intended and obtain the desired therapeutic goals, clinicians must set the device appropriately. However, optimal settings are critical for APRV to be lung protective and the ability to set these optimal settings vary amongst different manufacturer's devices.¹⁶ This is very true, initiating and maintaining both invasive and non-invasive mechanical ventilation is a complex process. The licensed clinician must differentiate among various manufacturers, ventilator models, available modes, and breath types to determine which is appropriate for each individual patient.¹⁷ The suggestion of an evidence-based protocol or management strategy is valid, as is potentially the need to have an established nomenclature.

More study and education efforts required

Generally speaking, the ventilator management of ARDS should take into consideration the patient's specific physiologic parameters with the objective of providing the greatest benefit with the least risk of complications. Although low tidal volume and high PEEP has led to improved outcome in ARDS, mortality remains high. To date, APRV remains a "tool in the toolbox" for clinicians. Further clinical trials will be required before it will be considered a main-stream line of treatment in the future. Promising animal studies and retrospective reviews will continue to advance our understanding of the mechanical breath profile. Additionally, clinicians must be educated in the personalized breath approach to APRV to ensure effectiveness when the clinical decision is made to utilize this mode.

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