

Non-Invasive Average Volume Assured Pressure Support for Acute Hypercapnic Respiratory Failure: A Case Study and Novel Approach

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Key Words

AVAPS, acute hypercapnia, average volume assured pressure support, noninvasive positive pressure ventilation

Abbreviations

ABG: Arterial blood gas

AVAPS: Average volume assured pressure support

BiPAP: Bilevel positive airway pressure

COPD: Chronic obstructive pulmonary disease

CPAP: Continuous positive airway pressure

EIP: Effective inspiratory pressure

IBW: Ideal body weight

ICU: Intensive care unit

IPAP: Inspiratory positive airway pressure

IPAPmin: Minimum inspiratory pressure

NIPPV: Non-invasive positive pressure ventilation

Vt: Tidal volume

Introduction

Non-invasive positive pressure ventilation (NIPPV), delivered via a facemask, has been shown to reduce morbidity and mortality in acute hypercapnic respiratory failure.¹⁻³ Traditionally, non-invasive ventilatory support is provided using continuous positive airway pressure (CPAP) or bilevel positive airway pressure (BiPAP) modes. Average volume assured pressure support (AVAPS) has been studied extensively in the treatment of chronic hypercapnic respiratory failure, yet there is limited data regarding its use in the acute setting.³ We present a case followed by a novel approach to the treatment of acute hypercapnic respiratory failure utilizing AVAPS mode.



Case

A 54-year-old female with a past medical history significant for chronic hypercapnic respiratory failure, tobacco abuse and chronic obstructive pulmonary disease (COPD) presented with increasing shortness of breath and somnolence. She was found obtunded by her family and brought via ambulance to the emergency department for evaluation. An arterial blood gas (ABG) was obtained on 6 Lpm via nasal cannula: pH 7.29, PaCO₂ 82 mmHg, PaO₂ 74 mmHg, HCO₃ 39 mEq/L. The patient was placed on BiPAP 14/6 mm H₂O and admitted to the telemetry floor. While on the medical floor, a rapid response was called for persistent hypersomnolence. During the rapid response, a second ABG was performed and was unchanged at pH 7.29, PaCO₂ 84 mmHg, PaO₂ 75 mmHg, HCO₃ 40 mEq/L. Her BiPAP was titrated to 20/6 mm H₂O and she was moved to the intensive care unit (ICU). Despite titration of her inspiratory pressures, she remained somnolent and a third ABG revealed continued hypercapnia with a pH 7.24 and a PaCO₂ of 84 mmHg. Discussion with the family included a recommendation to proceed with endotracheal intubation. Due to the patient's underlying COPD, the family expressed concern regarding intubation and the possibility of failure to wean and subsequent need for tracheostomy. The decision was therefore made to trial her on AVAPS before proceeding with endotracheal intubation. She was placed on AVAPS with a goal tidal volume (Vt) of 400 ml. Within one hour, her encephalopathy and hypersomnolence resolved. Repeat ABG showed improvement with a pH of 7.37 and a PaCO₂ 67 mmHg. She was transitioned to nasal cannula several hours later and had an uneventful stay upon downgrade from the ICU.

Discussion

NIPPV administered via a face mask has been shown to significantly reduce the need for intubation, the duration of mechanical ventilation, and ICU length of stay in patients with acute hypercapnic respiratory failure.¹⁻⁴ Over the past decade, utilization of NIPPV in the inpatient setting has become the standard of care for patients with acute COPD exacerbation and acute hypercapnic respiratory failure. Several factors have been shown as indicators for NIPPV success, including a skilled and motivated clinical team, comfortable patient-ventilator interface, careful monitoring, and continued support and coaching of the patient.^{4,5} Despite the proven efficacy of NIPPV, it is not uncommon for patients to fail a trial of BiPAP and ultimately require mechanical intubation. Elevated PaCO₂ and low pH levels at the time of BiPAP initiation and failure to correct PaCO₂ and pH within 30-60 minutes have been shown to be predictors of failure.^{6,7}



Clinician inexperience likely contributes to failure of NIPPV, particularly in training institutions, where inexperienced medical staff have to select the initial ventilator settings.⁸ Frequently, improper inspiratory or expiratory pressure selection can be identified as the etiology of NIPPV failure resulting in persistent obstruction and/or decreased minute ventilation.⁹ Selection of a “one size fits all” ventilation strategy or a reluctance to select a high initial inspiratory pressure will directly result in worsening hypercapnia and clinical deterioration.⁹ Therefore, it is imperative to confirm that initial inspiratory pressures yield adequate tidal volumes and subsequent minute ventilation.¹⁰

Advances in NIPPV technology over the past decade give clinicians the ability to benefit from a non-invasive volume targeted approach to ventilation, potentially reducing the incidence of NIPPV failure secondary to inadequate initial settings. AVAPS has the unique ability to auto-titrate the delivered inspiratory support to maintain a goal Vt and thus maintain an adequate minimum minute ventilation. This ventilation mode has been studied extensively in the setting of chronic respiratory failure from chronic obstructive pulmonary disease, obstructive sleep apnea, and obesity hypoventilation syndrome. AVAPS was initially developed as a hybrid mode of ventilation allowing for a consistent tidal volume while delivering the comfort and advantages of pressure support ventilation.¹¹ AVAPS ventilators estimate the expiratory tidal volume and respond by titrating the inspiratory positive airway pressure (IPAP) to maintain user set Vt. From a physiologic perspective, as a volume targeted mode of ventilation, AVAPS’ advantages over traditional BiPAP include its ability to control minute ventilation and more efficiently decrease pCO₂.^{12,13} This would seem to make it a favorable choice in the acute setting, but there is a paucity of data supporting its use.^{12,14}

Managing the Acutely Hypercapnic Patient with AVAPS

When initiating AVAPS, the clinician must designate a minimum inspiratory pressure, maximum inspiratory pressure, expiratory pressure, Vt and respiratory rate. Utilizing a computer algorithm, the ventilator will begin delivering breaths at the set minimum inspiratory pressure and titrate every one to two minutes by 1 cm/H₂O until the goal Vt is achieved. The patient’s acid-base status must be carefully monitored during the inherent delay period in achieving the goal Vt. In patients with a preexisting respiratory acidosis, this delay could theoretically precipitate a life-threatening rise in carbon dioxide and subsequent drop in arterial pH. Because of this risk, AVAPS initiation in the acute setting requires a modified approach.

One small study by Claudett et al. evaluated the safety of AVAPS in the acute setting.¹⁵ In this study, 11 patients presenting to the emergency department with acute hypercapnic encephalopathy secondary to COPD were immediately placed on AVAPS. AVAPS with goal Vt of 8 to 12 ml/kg ideal body weight were initiated and serial blood gases obtained. The average inspiratory pressure requirement for patients in this study was 19 mm H₂O and it was shown that AVAPS facilitated a more rapid recovery of consciousness than traditional BiPAP. The small number of study participants must be noted; however, no larger-scale studies have been published to date. This study also failed to address the potential for clinical decompensation due to the delay in achieving adequate minute ventilation during the initial titration phase.

The case described above illustrates how early intervention and correction of the patient’s hypercapnic respiratory failure in the emergency department could have prevented a rapid response and ICU upgrade. Another small study by Canpolat demonstrated a significantly improved pH and patient compliance with therapy compared to BiPAP in acute respiratory failure.¹⁶ We argue that AVAPS should be the preferred NIPPV modality for any patient with acute hypercapnic respiratory failure especially in the acute setting. Based on the data provided by the publications above and the clinical practice of the authors, we recommend the following strategy. When initiating AVAPS in the setting of acute hypercapnia, we suggest the initial minimum inspiratory pressure be identified using a traditional BiPAP mode. (Figure 1) The patient should be placed on BiPAP with initial inspiratory pressures deemed appropriate by the initiating physician. The resulting Vt should be noted and the inspiratory pressure adjusted to produce a Vt of 8-12 ml/kg ideal body weight (IBW).

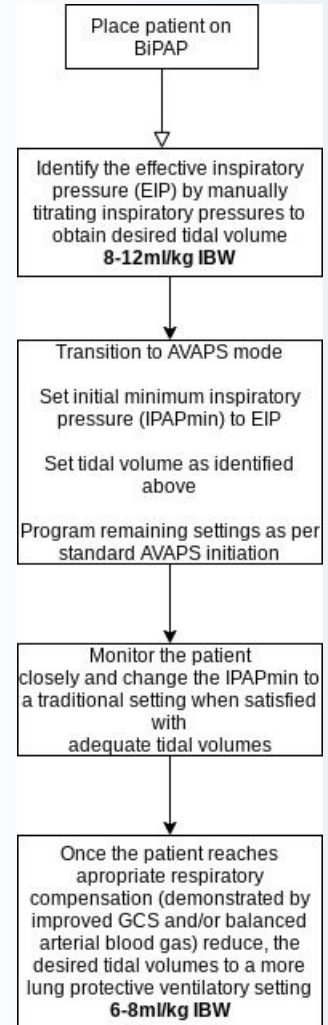


Figure 1.

Once an effective starting inspiratory pressure has been identified, the patient can safely be switched to AVAPS mode with initial minimum inspiratory pressure set at this newly identified level. The patient should be monitored for several minutes as the AVAPS ventilator continues to optimize the Vt. At this point, the minimum inspiratory pressure can be set to a lower value and the ventilator will titrate as needed in order to maintain consistent minute ventilation as compliance changes in the dynamic patient. Utilizing this approach, the AVAPS initial titration phase will not result in an acute worsening of the patient’s hypercapnia and will improve the time needed to reach the goal minute ventilation by up to 30 minutes. Once the patient’s



respiratory status has stabilized, with improvement in the patient's mental status or ABG, the Vt can be reduced to 6-8 mL/kg IBW.

Conclusion

The utilization of AVAPS in the setting of acute respiratory acidosis is promising; however, there has not been significant published research on the topic. Furthermore, there has been a failure of the literature to address the potential for worsening hypercapnia during the initial titration phase. After performing a literature review of the few existing publications using AVAPS in the inpatient setting for acute hypercapnic respiratory failure and our clinical practice we believe that this method of initiating AVAPS in this patient population to be effective in correcting the respiratory acidosis and decreasing the need for endotracheal intubation especially in the COVID era. Although, further randomized studies evaluating its efficacy are warranted to detect the potential degree of benefit, we believe this strategy to be simple yet effective and easily utilized by any emergency department physician with the assistance of a certified respiratory therapist especially for those patients who require rapid or large corrections in their CO₂, or those who are "do not intubate." ●

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