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CASE REPORT

New type of wasted effort during neurally adjusted ventilatory assist: a case report

J. Doorduin, L.H. Roesthuis, J.G. van der Hoeven, L.M.A. Heunks

Department of Critical Care Medicine, Radboud University Medical Center, Nijmegen, the Netherlands

Correspondence

J. Doorduin - jonne.doorduin@radboudumc.nl

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Abstract

In patients with dynamic hyperinflation, such as patients with chronic obstructive pulmonary disease (COPD), development of intrinsic positive end-expiratory pressure (PEEPi) complicates ventilator triggering in conventional assisted ventilation modes, such as pressure support, and causes wasted efforts. The use of extrinsic PEEP (PEEPe) can counterbalance PEEPi and as such facilitate triggering. With neurally adjusted ventilatory assist (NAVA) the ventilator is triggered by an increase in diaphragm electrical activity and does not depend on generation of inspiratory flow. Numerous studies report the absence of 'classical' wasted efforts with NAVA. Therefore, the widespread assumption among physicians is that wasted efforts cannot occur with NAVA. We present a 58-year-old male with an acute exacerbation of COPD in which we identify a new type of wasted effort unique to NAVA. We show that during NAVA in the presence of PEEPi it is as important to perform titration of PEEPe as with conventional modes, in order to prevent wasted efforts.

Introduction

Wasted or ineffective efforts refer to failed attempts of the patient to trigger the mechanical ventilator. Wasted efforts increase energy expenditure of the respiratory muscles and are associated with prolonged mechanical ventilation.[1,2] Approximately 25% of the mechanically ventilated patients exhibit wasted efforts, which are even more frequent in patients with chronic obstructive pulmonary disease (COPD).[2] In COPD patients, increased airway resistance and small airway collapse during expiration cause dynamic hyperinflation and a consequent increase in end-expiratory lung volume. Inspiratory muscles have to overcome intrinsic positive end-expiratory pressure (PEEPi) before inspiratory flow commences. In conventional assisted ventilation modes, such as pressure support ventilation (PSV), the ventilator is triggered by detection of a preset change of inspiratory flow or airway pressure (Paw) drop (trigger sensitivity). Accordingly, in the presence of increased end-expiratory lung volume the patient has to overcome both PEEPi and trigger sensitivity to trigger the ventilator. When the pressure generated by the inspiratory muscle is less than PEEPi plus trigger sensitivity, wasted effort occurs. The use of extrinsic PEEP (PEEPe) can counterbalance PEEPi and as such facilitate triggering. In neurally adjusted ventilatory assist (NAVA) mode the ventilator is triggered by electrical activity of the diaphragm (EAdi) and inspiratory support is delivered in proportion to EAdi.[3] Hence, triggering is not affected by PEEPi. Sensu stricto wasted efforts will not occur in NAVA as triggering of the ventilator does not depend on generation of inspiratory flow, but on EAdi. Indeed, numerous studies report the absence of wasted efforts with NAVA.[4-12] These studies generate the assumption that wasted efforts cannot occur with NAVA, regardless of the level of PEEPe to counterbalance PEEPi. To dispute this assumption and stress the importance of good PEEPe titration, we present a new type of wasted effort unique to NAVA.

Case report

A 58-year-old male with an acute exacerbation of COPD (GOLD stage IV) was admitted to our ICU. After an initial attempt of non-invasive ventilation, intubation was necessary due to persistent hypercapnia and hypoxaemia. Visual inspection of flow and Paw at 6 cmH_2O of PEEPe raised the suspicion of frequently occurring wasted efforts (*figure 1B*). An EAdi catheter with oesophageal balloon (Neurovent Research Inc., Toronto, Canada) was inserted into the oesophagus in order to calculate PEEPi, monitor wasted efforts, and allow support with NAVA. An atypical COPD breathing pattern with highly variable inspiratory efforts (i.e. low and high EAdi) was found. Dynamic PEEPi, measured as described previously,[13] was 10 cmH_2O, while ventilated in PSV with 0 cmH_2O of PEEPe. Wasted efforts were present at 0 and 6 cmH_2O PEEPe (± 9/min and 6/min,

respectively) and abolished at 10 cmH_2O (*figure 1A-C*). Next, the patient was switched from PSV to NAVA. Again PEEPe was modulated. As expected with NAVA, the patient triggered the ventilator regardless of the PEEPe level, as is evident from the rise in Paw at every inspiratory effort (*figure 1D-F*). However, despite the increase in Paw, inspiratory flow was often zero during the inspiratory phase at 0 and 6 cmH_2O of PEEPe (*figure 1D-E*).

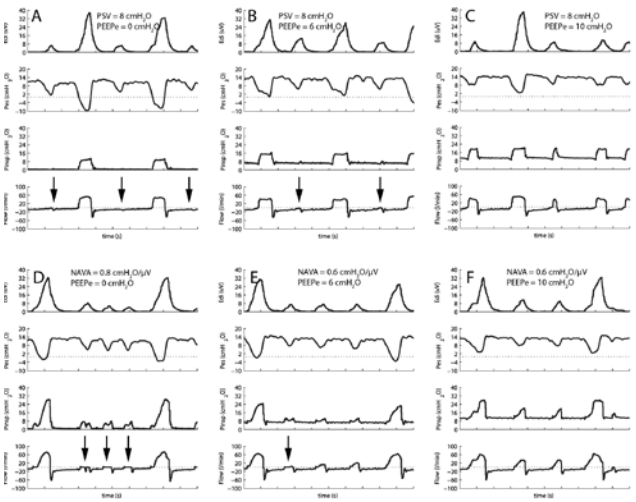

Figure 1. Recordings of electrical activity of the diaphragm (EAdi), esophageal pressure (Pes), airway pressure (Paw), and flow during pressure support ventilation (PSV; panel A-C) and neurally adjusted ventilator assist (NAVA; panel D-F) at 0 (panel A, D), 6 (panel B, E), and 10 cmH_2O (panel C,F) of extrinsic positive end-expiratory pressure (PEEPe). Arrows indicate classical wasted efforts (with PSV) and physiological wasted efforts (with NAVA). Note that during the inspiratory attempts indicated with an arrow with NAVA (panel D, E) the ventilator is triggered, as evidence by a rise in Paw, but inspiratory flow remains zero during the entire inspiratory phase.

Discussion

Our observation of zero flow during the inspiratory phase with NAVA can be explained as follows. With NAVA, triggering of the ventilator using EAdi is guaranteed with subsequent closing of the expiratory valve and opening of the inspiratory valve and generation of inspiratory pressure in proportion to EAdi. However, in the presence of PEEPi this does not guarantee the generation of inspiratory flow. Given that the pressure delivered by the ventilator (product of EAdi by NAVA level plus PEEPe) does not exceed PEEPi, the pressure gradient between the ventilator and the alveoli is directed towards the ventilator instead of the patient. In our understanding, this phenomenon does not only occur in COPD patients with variable EAdi, such as this exceptional case, but also holds true for all patients with substantial PEEPi. Whether it occurs and to which extent depends on the combination of the height of PEEPi and the chosen levels of NAVA and PEEPe. Blocking of inspiratory flow may occur during part of inspiration, causing a substantial trigger delay with NAVA, but in the worst case this may result in total absence of inspiratory flow during the entire inspiratory effort (arrows *figure 1D-E*). This type of patient-ventilator asynchrony is unique for ventilation in NAVA mode. It cannot be classified as 'classical' wasted effort because despite the absence of inspiratory flow the ventilator is triggered as evidenced by a rise in Paw. We propose the term physiological wasted effort for this type of asynchrony, which is defined as the absence of inspiratory flow, in the presence of ventilator triggering as evidenced by a rise in Paw.

In conclusion, our case clearly illustrates, for the first time, the occurrence of physiological wasted efforts during NAVA. This report underlines the complexity of patient-ventilator interaction and the need for appropriate monitoring with EAdi.[14] During NAVA in the presence of PEEPi it is as important to perform titration of PEEPe in order to prevent physiological wasted efforts as it is as during PSV.

Disclosures

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