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► **To cite this version:**

Audrey de Jong, Giuseppe Citerio, Samir Jaber. Focus on ventilation and airway management in the ICU. *Intensive Care Medicine*, 2017, 43 (12), pp.1912-1915. 10.1007/s00134-017-4982-y . hal-01743103

**HAL Id: hal-01743103**

**<https://hal.science/hal-01743103>**

Submitted on 3 Apr 2020

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# Focus on ventilation and airway management in the ICU

Audrey De Jong<sup>1,2,3\*</sup>, Giuseppe Citerio<sup>4,5</sup> and Samir Jaber<sup>1,2</sup>

Airway and ventilation management are particularly challenging in the intensive care unit (ICU), and are associated with high morbidity and mortality [1]. Figure 1 summarizes some of the more recent findings from the literature [1].

## Avoiding intubation: the role of noninvasive support strategies

In the ICU, the prevention and management of acute respiratory failure (ARF) most commonly involves the use of noninvasive ventilation (NIV). A recent prospective multicenter audit study by Demoule et al. [2] examined the use of NIV among 4132 patients receiving mechanical ventilation (51% required ventilatory support for ARF and 49% for non-respiratory conditions). The authors reported an increase in the overall use of NIV over time, as well as changes in the distribution of NIV indications. In particular, pre-ICU and post-extubation NIV increased substantially. NIV was less often used to treat de novo ARF, and NIV success rates increased over time [2]. While some indications of NIV are well recognized, such as hypercapnic respiratory failure and cardiogenic pulmonary edema, other indications, such as ARF in immunocompromised patients or after abdominal surgery, have been debated [2]. Recent large randomized controlled trials report new evidence for different indications in hypoxemic ARF for NIV compared to standard oxygen therapy or high-flow nasal cannula oxygen (HFNC). In immunocompromised patients with hypoxemic ARF, no significant difference was observed in intubation rates, duration of mechanical ventilation, hospital

stay, or mortality between NIV and standard oxygen therapy or HFNC [3]. In postoperative patients with hypoxemic ARF following abdominal surgery, NIV reduced the risk of tracheal reintubation as well as the incidence of nosocomial infection compared to standard oxygen therapy [4]. Similar to NIV, the use of HFNC is becoming increasingly common [5]. In the past, indication of HFNC in the post-extubation setting has been unclear. New evidence suggests that among high-risk adults who have undergone extubation, HFNC is not inferior to NIV for preventing reintubation and post-extubation ARF [6]. In patients at low risk of reintubation, post-extubation HFNC reduced reintubation rates compared with conventional oxygen therapy [7].

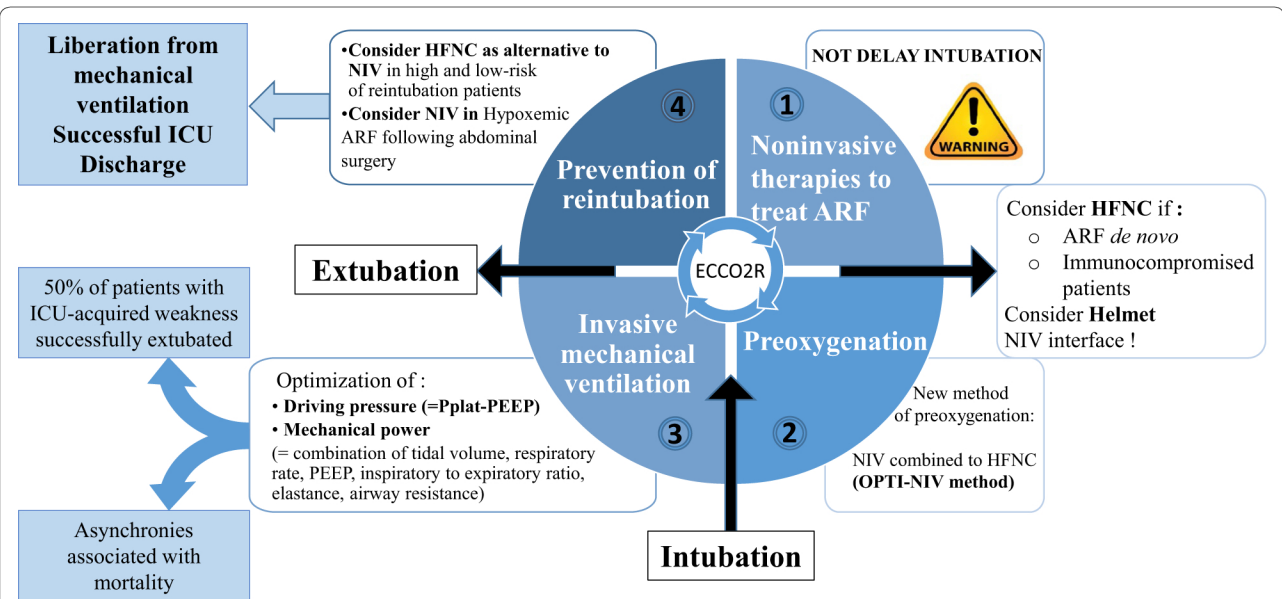
With NIV use, the choice of interface can be important. In a study of patients with acute respiratory distress syndrome (ARDS), treatment with helmet NIV versus face-mask NIV [8] was associated with a significant reduction in rates of intubation and mortality. However, this was a monocentric study [8], and large multicenter studies are needed to confirm these findings.

Other therapeutics have recently been developed that may help to avoid or minimize the need for invasive ventilation. Extracorporeal membrane carbon dioxide removal (ECCO2R) may represent one such solution. Designed for the purpose of removing carbon dioxide from the blood, ECCO2R may be helpful in reducing the use of invasive ventilation for patients with chronic obstructive pulmonary disease (COPD) and hypercapnia [9].

Regardless of the support therapy used, however, avoiding a delay in tracheal intubation when invasive mechanical ventilation is needed remains a key message. It is worth noting that, as with NIV, failure of HFNC may delay intubation and increase the risk of mortality [10].

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**Fig. 1** Summary of the more recent findings from the literature. (1) Noninvasive ventilatory therapies for treating ARF. In immunocompromised patients with hypoxemic ARF, new evidence suggests that HFNC could be used in ARF de novo, including in immunocompromised patients [3]. In the case of NIV, the helmet–NIV interface may be of particular interest [7]. However, the role of NIV in ARF has yet to be determined. The main challenge remains avoiding a delay in intubation, which is associated with increased mortality [9]. (2) Preoxygenation: a new preoxygenation strategy was recently reported, which features the coupling of NIV and HFNC (OPTINIV) to reduce respiratory complications of intubation [11]. It was found to be more effective in reducing oxygen desaturation in severely hypoxemic patients than the reference method of NIV alone [11]. (3) Invasive mechanical ventilation: new studies have suggested that high driving pressure (above 13 cmH<sub>2</sub>O) is associated with increased mortality in ARDS [1, 12]. Most of the ventilatory parameters might be summarized using the “mechanical power” concept [13]. For the first time, it was shown that patient–ventilator asynchrony was detected in all patients and in all ventilator modes, and was associated with mortality [14]. Reducing the incidence of asynchrony is crucial in optimizing the patient for extubation, which must be considered even in patients with ICU-acquired weakness: researchers reported that half of all patients with ICU-acquired weakness were successfully extubated [15]. The ability to identify such patients, however, remains elusive. (4) Avoidance of reintubation: NIV is advised in patients with hypoxemic ARF following abdominal surgery, as it reduces the risk of tracheal reintubation compared to standard oxygen therapy [4]. Recent studies suggest that in a preventive setting, HFNC could be considered in high- and low-risk intubated patients [5, 6]. The effect of alternating HFNC with NIV remains unclear. The extracorporeal membrane carbon dioxide removal (ECCO<sub>2</sub>R) system might be used to avoid or minimize the need for invasive ventilation, particularly in patients with hypercapnia and obstructive disorder [8]. ECCO<sub>2</sub>R is of potential interest and remains to be assessed at each stage of airway and ventilatory management of the ICU patient. ARDS acute respiratory distress syndrome, ARF acute respiratory failure, NIV noninvasive ventilation, HFNC high-flow nasal cannula oxygen, P<sub>plat</sub> plateau pressure, PEEP positive end-expiratory pressure, ICU intensive care unit, ECCO<sub>2</sub>R extracorporeal carbon dioxide removal

**When intubation is needed: optimize preoxygenation!**

When intubation for invasive mechanical ventilation is required, achieving optimal preoxygenation to mitigate the risk of hypoxemia prior to intubation is challenging. The use of HFNC and NIV versus an oxygen facial mask for preoxygenation of patients with hypoxemic ARF has been associated with less hypoxemia during intubation procedures. However, although NIV can be safely applied for preoxygenation before intubation, the NIV facial mask must then be removed to allow the passage of the orotracheal tube through the mouth. HFNC (FiO<sub>2</sub> = 100% and a flow of 60 L/min) enables the continuous delivery of oxygen during the passage of the orotracheal tube through the mouth (apnoeic oxygenation) [5]. Until recently, the combined use of NIV and HFNC for

preoxygenation had never been evaluated. In a proof-of-concept study [11], preoxygenation incorporating both NIV and HFNC (OPTINIV), respectively—thereby combining the concepts of prevention of alveolar derecruitment and of apnoeic oxygenation—was found to be more effective in reducing oxygen desaturation than the reference method of NIV alone.

**New parameters for monitoring invasive mechanical ventilation**

Once invasive mechanical ventilation has been initiated in ARDS patients, ventilator-induced lung injury can lead to multiple-organ failure and death. The concept of “protective ventilation” was developed as a strategy to prevent worsening of lung injury and to minimize the effects of ventilation on the lungs through the use of low

tidal volume and plateau pressure of 30 cmH<sub>2</sub>O or less. New parameters have been developed in recent years. Studies have suggested that high driving pressure (above 13 cmH<sub>2</sub>O), defined as the difference between plateau pressure and positive end-expiratory pressure (PEEP), is associated with increased mortality in ARDS [1, 12]. These ventilatory parameters might all be summarized using the “mechanical power” concept, developed by Gattinoni et al. [13], which can be easily implemented in any ventilator software. The mechanical power is computed by multiplying each component of the equation of motion by the variation in volume and respiratory rate: the formula includes the tidal volume, respiratory rate, PEEP, elastance of the respiratory system, inspiratory-to-expiratory time ratio, and airway resistance [1, 13]. The mechanical power equation can be used to estimate the contribution of the different ventilator-related causes of lung injury and their variations. Considering mechanical power as a whole may provide better insight than considering its components, such as PEEP, tidal volume, or respiratory rate, separately.

Even after optimization of ventilatory settings, asynchrony can occur during ventilation, and the frequency of occurrence has been unknown in the literature. A recent study found that patient–ventilator asynchrony was detected in all patients and in all ventilator modes [14]. An observational study [14] comparing patients according to their asynchrony index (> 10 vs. ≤ 10%) revealed similar reintubation and tracheostomy rates, but higher ICU and hospital mortality and a trend toward longer duration of mechanical ventilation, in patients with an asynchrony index ≤ 10%. Limiting asynchrony seems mandatory for the clinician; however, asynchrony could be a marker as well as a cause of mortality.

### **Liberation from invasive mechanical ventilation: don't be shy!**

Removal of the tube and liberation from mechanical ventilation is the ultimate goal of airway and ventilation management. ICU-acquired weakness—both myopathy and neuropathy [15]—is associated with delayed weaning from mechanical ventilation [1]. One study [15] investigated whether ICU-acquired weakness was associated with diaphragm dysfunction, using a multimodal tool combining magnetic stimulation of the phrenic nerves, diaphragm ultrasound, and pulmonary function tests to evaluate diaphragmatic function at the bedside. Diaphragm dysfunction was frequent in patients with ICU-acquired weakness (80%), but correlated poorly with the ICU-acquired weakness Medical Research Council score. Half of the patients with ICU-acquired weakness were successfully extubated [15], which underscores the need

to better identify those who will fail weaning among this population of patients with ICU-acquired weakness.

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#### **Compliance with ethical standards**

#### **Conflicts of interest**

Dr. Jaber has received consulting fees from Dräger, Hamilton, and Fisher & Paykel. All other authors declare that they have no conflict of interest.

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