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EDITORIAL

Focus on ventilation management

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In this article, we summarize ten important developments in the field of mechanical ventilation. Recommendations have been made through the past decades for optimizing the ventilation of intensive care unit (ICU) patients [1], and in particular in 2017 in acute respiratory distress syndrome (ARDS) patients [2], including low tidal volume, positive end-expiratory pressure (PEEP), and early extubation. Asehnoune et al. [3] found that adherence to these recommendations in the specific population of brain-injured patients increased the number of ventilator-free days. However, inconsistent adoption limited their impact [3]: implementation of this nationwide quality project promoting lung-protective ventilation and systemic approach to early extubation did not result in a significant improvement in liberating brain-injured patients from mechanical ventilation. This point underlines the need for monitoring the implementation of the multifaceted approach and of promoting application. In these ventilated brain injury patients, advances have been made in the comprehension of pulmonary modifications. Brain-injured patients are particularly prone to lung impairment, in part because of a poorly understood but fundamental concept: lung–brain cross talk [4]. Acquired sepsis and respiratory failure are more frequent in brain-injured ICU patients than in other ICU patients without brain injury. On the one hand, injury from brain to lung involves increase in intracranial pressure, catecholamine release, neuroinflammation (humoral, neural, cellular), failure of cholinergic anti-inflammatory pathway, hyper-dopaminergic states, and hyperosmolar therapy [4]. On the other hand, injury from lung to brain also involves the release of mediators, and ventilatory disturbances such as hyper/hypocapnia and hypoxemia [4].

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In brain-injured and non-brain-injured patients [1], an adequate ventilatory management should begin by optimization of preoxygenation and intubation procedures [5]. The main objective of improved preoxygenation is to avoid oxygen desaturation during the intubation procedure. Arterial hypotension and severe hypoxemia are the main life-threatening complications related to intubation. The ultimate complication is cardiac arrest (2.7% of intubation procedures and associated with ICU mortality [6]). To predict intubation-related cardiac arrest, five independent risk factors were identified [6], with three potentially modifiable factors (absence of pre-oxygenation, hemodynamic failure prior to intubation, hypoxemia prior to intubation) that could respond to preventative approaches. Patient characteristics were also reported as associated with cardiac arrests: age > 75 years and body mass index > 25 kg/m^2.

Following the intubation procedure, ventilation management aims to reduce the duration of invasive mechanical ventilation in order to decrease ventilator-induced lung and muscle injuries. To achieve these objectives, and in particular to reduce asynchronies, sedation analgesia management is one of the key elements. A recent study [7] demonstrated that immediate interruption of sedation in critically ill postoperative patients with organ dysfunction who were admitted to the ICU after abdominal surgery improved outcomes compared with usual sedation care. These findings support early interruption of sedation in critically ill postoperative patients.

Similarly, in a non-surgical population, immunocompromised patients, the need for limiting invasive mechanical ventilation as much as possible is also widely demonstrated. In the international multicenter EFRAIM study [8], Azoulay et al. reported that in immunocompromised patients, invasive mechanical ventilation was an independent predictor of mortality. The odds ratio of mortality was related to noninvasive mechanical ventilation status before onset of invasive mechanical ventilation: noninvasive ventilation (NIV) + high-flow nasal cannula (HFNC) failure (2.31, 1.09–4.91), first-line invasive mechanical ventilation (2.55, 1.94–3.29), NIV failure (3.65, 2.05–6.53), standard oxygen failure (4.16, 2.91–5.93), and HFNC failure (5.54, 3.27–9.38). Therefore, one might hypothesize that NIV may be used with caution in cancer patients with hypoxemic respiratory failure, and even more in case of severe hypoxemia [9]. However, it is worth noting that the lowest odds ratio of mortality was associated with NIV + HFNC failure. In this context, it is crucial to predict NIV failure. For this purpose, the HACOR score [10] heart rate ($\leq 120 = 0, \geq 121 = 1$), acidosis ($pH \geq 7.35 = 0$, 7.30–7.34 = 2, 7.25–7.29 = 3, $< 7.25 = 4$), consciousness (Glasgow 15 = 0, 13–14 = 2, 11–12 = 5, $\leq 10 = 10$), oxygenation ($PaO2/FiO2 \geq 201 = 0$, 176–200 = 2, 151–175 = 3, 126–150 = 4, 101–125 = 5, $\leq 100 = 6$), and respiratory rate ($\leq 30 = 0$, 31–35 = 1, 36–40 = 2, 41–45 = 3, $\geq 46 = 4$) was developed. The total HACOR score ranges from 0 to 25 points. Patients with a HACOR score of > 5 had a very high risk of NIV failure. Applying NIV in hypoxemic respiratory failure patients might be still possible in well-selected patients and experienced centers, after selection of patients and optimization of ventilator settings [11].

When invasive mechanical ventilation is finally needed, avoiding atelectrauma and volutrauma, and limiting asynchronies are one of the main objectives of a well-conducted mechanical ventilation. According to a recent study by Cressoni et al. [12] performed in ARDS patients, two alternatives are available to clinicians regarding the PEEP settings. The first one is to ventilate between 30 cmH_2O plateau pressure and PEEP 15 cmH_2O, keeping in mind that up to 30% of the lung will remain closed (atelectrauma). The second one is to use PEEP levels far higher those commonly applied, to allow optimal opening of the lungs, possibly leading to volutrauma. The benefit–risk ratio of each strategy has to be assessed, electing the best compromise between atelectrauma and volutrauma. Some tools exist and may be used for this purpose, such as esophageal pressure monitoring or electrical impedance tomography [1]. In mechanically ventilated patients with ARDS, neuromuscular blocking agents (NMBA) use may help reduce mortality [1]. Guervilly et al. [13] reported that the use of NMBA in ARDS patients was associated with alterations in inspiratory and expiratory transpulmonary pressures. The lower esophageal pressures measured in the NMBA group could reflect

Table 1 Ten new advances in ventilation management of ICU patients

1. Adherence to recommendations [2, 3] • Low tidal volume, moderate PEEP, and early extubation should be applied
2. Brain–lung cross talk [4] • Brain-injured patients are particularly prone to lung impairment: acquired sepsis and respiratory failure are more frequent in brain-injured ICU patients than in other ICU patients without brain injury
3. Intubation-related cardiac arrest [6] • Intubation-related cardiac arrest in ICU was reported in 49 of 1847 intubation procedures (2.7%) • Five independent risk factors of intubation-related cardiac arrest were identified, with three potentially actionable high-risk factors (hypoxemia prior to intubation, hemodynamic failure prior to intubation, absence of preoxygenation) that may respond to preventative approaches. Patient characteristics were also identified as associated with cardiac arrests: body mass index (BMI) > 25 kg/m^2 as a risk factor (being overweight or obese) and age > 75 years
4. Sedation–analgesia management [7] • Immediate interruption of sedation in critically ill postoperative patients with organ dysfunction who were admitted to the ICU after abdominal surgery improved outcomes compared with usual sedation care • These findings support interruption of sedation in these patients following transfer from the operating room
5. Prognosis of immunocompromised patients under invasive mechanical ventilation [8] • Invasive mechanical ventilation in immunocompromised patients was associated with increased mortality • NIV may be used with caution in cancer patients with hypoxemic ARF
6. Prediction of noninvasive ventilation failure [10] • The HACOR score [9] (heart rate, acidosis, consciousness, oxygenation, and respiratory rate) was developed • Patients with a HACOR score of > 5 had a very high risk of NIV failure. In these high-risk patients, early intubation may reduce hospital mortality
7. Optimal PEEP setting [12] • Two alternatives are available to clinicians: accepting atelectrauma or accepting volutrauma • The clinical question is whether the atelectrauma is less harmful than the possible volutrauma due to a further increase of PEEP
8. Mechanism of action of neuromuscular blockers [13, 14] • NMBA could exert beneficial effects, at least in part, by limiting expiratory efforts
9. Patient positioning during invasive mechanical ventilation [15] • Compared to semirecumbent position, lateral Trendelenburg position failed to prove any significant benefit
10. Reconnection to mechanical ventilation after spontaneous breathing trial [16] • Allowing patients to rest for 1 h after a successful spontaneous breathing trial reduces reintubation and postextubation respiratory failure in critically ill patients

PEEP positive end-expiratory pressure, *ICU* intensive care unit, *ARDS* acute respiratory distress syndrome, *NIV* noninvasive ventilation, *HFNC* high-flow nasal cannula, *ARF* acute respiratory failure, *NMBA* neuromuscular blocking agents the abolition of active expiratory muscle activity. These results suggest that NMBA could exert beneficial effects, at least in part, by limiting expiratory efforts, allowing a near-complete elimination of breath stacking dyssynchrony [14]. To further prevent complications associated with mechanical ventilation, and in particular ventilator-associated pneumonia, a semi-seated position may be used. In a large randomized controlled trial including 395 patients [15], in comparison to the classic semirecumbent position, the lateral Trendelenburg position failed to prove any significant benefit [15]. Finally, when the patient is ready for liberation from mechanical ventilation, following optimal ventilation management, allowing patients to rest for 1 h after the spontaneous breathing trial showed a reduction of reintubation and postextubation respiratory failure in critically ill patients [16].

These new advances in the field of mechanical ventilation are summarized in Table 1. Clinical practice guidelines are applicable for the majority of patients, but individualized ventilatory management should be followed taking into consideration physiological knowledge, clinical experience, literature, and closed monitoring [1].

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Compliance with ethical standards

Conflicts of interest

Dr. Jaber reports receiving consulting fees from Drager, Xenios, and Fisher & Paykel. A. De Jong reports personal fees from Baxter and Medtronic, and travel reimbursements from Fresenius-Kabi, MSD France, Astellas, Pfizer, and Fisher Paykel.

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References

1. Jaber S, Bellani G, Blanch L, Demoule A, Esteban A, Gattinoni L, Guérin C, Hill N, Laffey JG, Maggiore SM, Mancebo J, Mayo PH, Mosier JM, Navalesi P, Quintel M, Vincent JL, Marini JJ (2017) The intensive care medicine research agenda for airways, invasive and noninvasive mechanical ventilation. Intensive Care Med 43:1352–1365
2. Del Sorbo L, Goligher EC, McAuley DF, Rubenfeld GD, Brochard LJ, Gattinoni L, Slutsky AS, Fan E (2017) Mechanical ventilation in adults with acute respiratory distress syndrome. Summary of the experimental evidence for the clinical practice guideline. Ann Am Thorac Soc 14:S261–S270
3. Asehnoune K, Mrozek S, Perrigault PF, Seguin P, Dahyot-Fizelier C, Lasocki S, Pujol A, Martin M, Chabanne R, Muller L, Hanouz JL, Hammad E, Rozec B, Kerforne T, Ichai C, Cinotti R, Geeraerts T, Elaroussi D, Pelosi P, Jaber S, Dalichampt M, Feuillet F, Sebille V, Roquilly A (2017) A multi-faceted strategy to reduce ventilation-associated mortality in brain-injured patients. The BI-VILI project: a nationwide quality improvement project. Intensive Care Med 43:957–970
4. Blanch L, Quintel M (2017) Lung-brain cross talk in the critically ill. Intensive Care Med 43:557–559
5. Mosier JM, Hypes CD, Sakles JC (2017) Understanding preoxygenation and apneic oxygenation during intubation in the critically ill. Intensive Care Med 43:226–228
6. De Jong A, Rolle A, Molinari N, Paugam-Burtz C, Constantin JM, Lefrant JY, Asehnoune K, Jung B, Futier E, Chanques G, Azoulay E, Jaber S (2018) Cardiac arrest and mortality related to intubation procedure in critically ill adult patients: a multicenter cohort study. Crit Care Med 46:532–539
7. Chanques G, Conseil M, Roger C, Constantin JM, Prades A, Carr J, Muller L, Jung B, Belafia F, Cisse M, Delay JM, de Jong A, Lefrant JY, Futier E, Mercier G, Molinari N, Jaber S (2017) Immediate interruption of sedation compared with usual sedation care in critically ill postoperative patients (SOS-Ventilation): a randomised, parallel-group clinical trial. Lancet Respir Med 5:795–805
8. Azoulay E, Pickkers P, Soares M, Perner A, Rello J, Bauer PR, van de Louw A, Hemelaar P, Lemiale V, Taccone FS, Martin Loeches I, Meyhoff TS, Salluh J, Schellongowski P, Rusinova K, Terzi N, Mehta S, Antonelli M, Kouatchet A, Barratt-Due A, Valkonen M, Landburg PP, Bruneel F, Bukan RB, Pene F, Metaxa V, Moreau AS, Souppart V, Burghi G, Girault C, Silva UVA, Montini L, Barbier F, Nielsen LB, Gaborit B, Mokart D, Chevret S (2017) Acute hypoxemic respiratory failure in immunocompromised patients: the Efraim multinational prospective cohort study. Intensive Care Med 43:1808–1819
9. Azoulay E, Schellongowski P, Darmon M, Bauer PR, Benoit D, Depuydt P, Divatia JV, Lemiale V, van Vliet M, Meert AP, Mokart D, Pastores SM, Perner A, Pene F, Pickkers P, Puxty KA, Vincent F, Salluh J, Soubani AO, Antonelli M, Staudinger T, von Bergwelt-Baildon M, Soares M (2017) The intensive care medicine research agenda on critically ill oncology and hematology patients. Intensive Care Med 43:1366–1382
10. Duan J, Han X, Bai L, Zhou L, Huang S (2017) Assessment of heart rate, acidosis, consciousness, oxygenation, and respiratory rate to predict noninvasive ventilation failure in hypoxemic patients. Intensive Care Med 43:192–199
11. Girault C, Ferrer M, Torres A (2017) Non-invasive ventilation in hypoxemic acute respiratory failure: is it still possible? Intensive Care Med 43:243–245
12. Cressoni M, Chiumello D, Algieri I, Brioni M, Chiurazzi C, Colombo A, Colombo A, Crimella F, Guanziroli M, Tomic I, Tonetti T, Luca Vergani G, Carlesso E, Gasparovic V, Gattinoni L (2017) Opening pressures and atelectrauma in acute respiratory distress syndrome. Intensive Care Med 43:603–611
13. Guervilly C, Bisbal M, Forel JM, Mechati M, Lehingue S, Bourenne J, Perrin G, Rambaud R, Adda M, Hraiech S, Marchi E, Roch A, Gainnier M, Papazian L (2017) Effects of neuromuscular blockers on transpulmonary pressures in moderate to severe acute respiratory distress syndrome. Intensive Care Med 43:408–418
14. Beitler JR, Sands SA, Loring SH, Owens RL, Malhotra A, Spragg RG, Matthay MA, Thompson BT, Talmor D (2016) Quantifying unintended exposure to high tidal volumes from breath stacking dyssynchrony in ARDS: the BREATHE criteria. Intensive Care Med 42:1427–1436
15. Li Bassi G, Panigada M, Ranzani OT, Zanella A, Berra L, Cressoni M, Parrini V, Kandil H, Salati G, Selvaggi P, Amatu A, Sanz-Moncosi M, Biagioni E, Tagliaferri F, Furia M, Mercurio G, Costa A, Manca T, Lindau S, Babel J, Cavana M, Chiurazzi C, Marti JD, Consonni D, Gattinoni L, Pesenti A, Wiener-Kronish J, Bruschi C, Ballotta A, Salsi P, Livigni S, Iotti G, Fernandez J, Girardis M, Barbagallo M, Moise G, Antonelli M, Caspani ML, Vezzani A, Meybohm P, Gasparovic V, Geat E, Amato M, Niederman M, Kolobow T, Torres A (2017) Randomized, multicenter trial of lateral Trendelenburg versus semirecumbent body position for the prevention of ventilator-associated pneumonia. Intensive Care Med 43:1572–1584
16. Fernandez MM, Gonzalez-Castro A, Magret M, Bouza MT, Ibanez M, Garcia C, Balerdi B, Mas A, Arauzo V, Anon JM, Ruiz F, Ferreres J, Tomas R, Alabert M, Tizon AI, Altaba S, Llamas N, Fernandez R (2017) Reconnection to mechanical ventilation for 1 h after a successful spontaneous breathing trial reduces reintubation in critically ill patients: a multicenter randomized controlled trial. Intensive Care Med 43:1660–1667