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Detection of patient-ventilator asynchrony should be improved: and then what?

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Invasive mechanical ventilation often saves the lives of patients suffering from acute respiratory distress. Placement and maintenance of an endotracheal airway usually requires sedation and analgesia, which generally results in cessation of spontaneous breathing and the need for controlled mechanical ventilation. Today, modern intensive care medicine concepts aim at early reduction of the level of sedation (1) to promote spontaneous breathing efforts (2,3) and early mobilization (4), in order to avoid negative effects of deep and prolonged sedation and (respiratory) muscle weakness (5). Epidemiological data suggest an increase in the use of partial ventilator support modes (6).

Spontaneous breathing activity during time-cycled, volume preset assist control (AC) ventilation allows triggering of mandatory breaths, but the patients' ability to interact with the ventilator is otherwise limited. In patients with a high rate of spontaneous breathing activity, inspiratory efforts outside the trigger intervals may result in a second preset breath, which immediately follows the first breath before (complete) expiration was possible (7). In volume-preset AC, such breath stacking asynchrony may not only cause discomfort for the patient, but can result in uncontrolled delivery of tidal volumes (V_T) that are up to twice as high as intended (7). These high V_T may promote ventilator-induced lung injury (VILI) in patients with and without acute respiratory distress syndrome (ARDS) (8). Stacked breaths often remain undetected leaving the treating physicians unaware of this potential risk.

Detection of patient ventilator asynchrony

In a recent issue of *Intensive Care Medicine*, Dr. Beitler and colleagues (9) describe objective criteria for quantifying breath stacking asynchrony (BREATHE criteria). They are based on an automated analysis of flow curves performed for up to 72 hours counting the following events: consecutive inspiratory ventilator cycles, expiratory volume threshold [≥ 2 mL/kg predicted body weight (PBW) less than prior inspiratory volume], cumulative inspiratory volume threshold (≥ 2 mL/kg PBW above intended V_T), expiratory time threshold (< 1 s), and inspiratory time threshold ($\geq 120\%$ of preset inspiratory time). The authors compared their new definition with a method previously described by Thille (10), which defines breath stacking asynchrony as “two [inspiratory] cycles separated by a very short expiratory time, defined as less than one-half the mean inspiratory time, the first cycle being patient-triggered” (10). In addition, Beitler and colleagues used visual inspection, performed by two experienced intensivists, for comparison. Semi-automated application of the BREATHE criteria detected more high V_T breaths as compared with the Thille method (10), whereas the latter method found more desynchronized breaths. Agreement of the BREATHE method and visual inspection was at least 97%. Breath stacking occurred in about three fourth of hours during the observation time, presuming no use of neuromuscular blockade (NMB). With NMB use, breath stacking asynchrony was eliminated (9).

Although the occurrence of breath stacking had been

reported previously (7,11), a major contribution of Dr. Beitler's study is that it discusses patient-ventilator asynchrony as a phenomenon that often goes clinically undetected or underestimated and shows how to improve its detection by the BREATHE criteria.

Once detected, however, a crucial question is, how to improve patient-ventilator interaction. Two basic approaches are available for decreasing patient-ventilator asynchrony:

- (I) Adaptation of the patient to the ventilator by increasing sedation/analgesia with or without muscle paralysis;
- (II) Adaptation of the ventilator to the patient (ventilator adjustment or change in ventilator mode).

Adapting the patient to the ventilator

In the study by Beitler *et al.*, the use of NMB was shown to abolish breath stacking asynchrony effectively (9). The somewhat outdated concept of NMB use in patients with early ARDS was rediscovered by recent data showing improved 90 days in-hospital survival during time-cycled, volume preset AC with constant inspiratory flow (12). The study by Papazian *et al.* (12), however, was criticized for being underpowered (13) and did not provide a physiological mechanism for improved survival with NMB. Patients in both groups were deeply sedated and breathing pattern and lung mechanics [provided in Supplementary Appendix, page 11 (12)] at days 1, 2, and 7 did not differ appreciably. It is conceivable that patient-ventilator asynchrony might have occurred outside the data acquisition periods and that this may explain the higher rate of barotrauma and pneumothorax in the control group. Another possible mechanism includes a direct anti-inflammatory action of cis-atracurium by blocking the nicotinic acetylcholine receptor $\alpha 1$ of isolated human lung epithelial, endothelial, and CD14+ cells, that were challenged with mechanical stretch and in a rat model with acid aspiration lung injury (14).

On the other hand, even short term NMB treatment for 48 hours, as used in the study by Papazian *et al.* (12), may result in disuse atrophy of skeletal and respiratory muscles. In a landmark study in 14 brain dead organ donors, Levine and colleagues (15) demonstrated decreased cross-sectional areas of diaphragmatic slow-twitch and fast-twitch fibers by >50% following 18–69 hours of mechanical ventilation with total muscular inactivity. These ideas were consistent with increased diaphragmatic proteolysis during muscle

inactivity noted by other authors and reproduced with extensions to include physiological and histobiochemical signs of diaphragmatic injury and atrophy (5). A prospective multicenter cohort study in 251 ventilated patients showed that early sedation depth independently predicted delayed extubation and increased mortality (16). Overall, a strategy to adapt the patient to the ventilator obviously has serious defects and does not take into account modern ventilator modes which have the ability to avoid patients "fighting the ventilator".

Adapting the ventilator to the patient

In addition to previous data challenging the concept of deep sedation in ventilated patients (1,16,17), a study in patients with detected breath stacking asynchrony during volume-preset AC demonstrated that increasing the level of sedation was much less effective than adapting the ventilator to the patient by switching the mode to pressure support ventilation (18).

Modern ventilators are microprocessor controlled, equipped with demand flow valves, and offer a variety of different modes of augmentation for spontaneously breathing patients with respiratory failure. These include assisted pressure-controlled, volume controlled and pressure regulated settings, or switching between two levels of CPAP in a time-cycled manner (BIPAP/APRV). When using pressure regulated modes, V_T should be monitored and controlled. Recent data, however, suggest that it is even more crucial to adjust and minimize driving pressure carefully (19,20), which can be further increased by synchronized negative pleura pressure fluctuations due to spontaneous breathing. Thus, strong diaphragmatic activity should be avoided (21) and the use of non-synchronized modes of augmentation (BIPAP, APRV) may be preferable (22). Non-synchronized modes proved to preserve V_T variability and simultaneously provide effective prevention of potentially detrimental, very high V_T (21).

In contrast to AC, ventilator modes that offer high degree of freedom for interaction of a cooperative patient with the ventilator also allow sufficient augmentation of spontaneous breathing, precluding adequate analgesia and allowing for minimal sedation. This concept has several potential advantages: (I) the patient can be mobilized early, even in the acute phase of disease, and despite treatment of multiple organ failure (4,23,24); (II) since diaphragm muscle portions are located laterally and dorsally, spontaneous breathing activity redistributes regional ventilation to the dependent lungs (*Figure 1*) (25); (III) moderate spontaneous

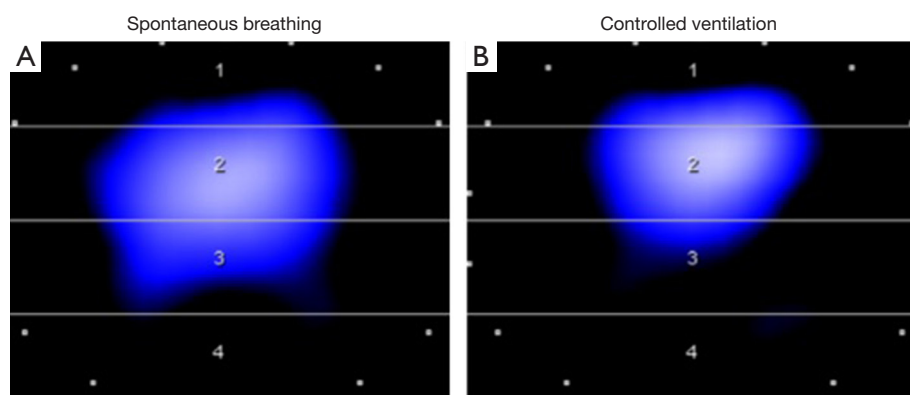


Figure 1 Electric impedance tomography images of an obese patient breathing spontaneously (A) and after intubation, neuro-muscular blockade and volume-controlled ventilation with positive end-expiratory pressure of 5 mbar (B). Note the shift of impedance changes representing regional ventilation to the non-dependent lung with institution of mechanical ventilation representing atelectasis in the dependent lung.

breathing activity may prevent ventilator induced diaphragm muscle atrophy and dysfunction (5,15); (IV) less sedation and spontaneous breathing activity may improve cardiorespiratory function (26).

In conclusion, we agree with Dr. Beitler and colleagues (9) that detecting and avoiding breath stacking is crucial. Instead of using early deep sedation and muscle relaxation, however, we suggest using ventilator modes that allow adaptation of the ventilator to the patient and not vice versa (27). This approach is compatible with the concept of early mobilization with no or early low-level sedation, which may decrease time in the intensive care unit, improve functional mobility at hospital discharge and may well improve outcome (28).

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Footnote

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