Detecting and correcting patient-ventilator asynchronies

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AIMS: *To learn about the difficulties in recognising patient-ventilator asynchronies and the steps needed to eliminate them.*

TARGET AUDIENCE: *Anaesthesiologist, Clinician, Emergency medicine doctor, Intensivist/critical care physician, Junior member, Neonatologist, Physiologist, Physiotherapist, Pulmonologist, Resident, Respiratory physician, Respiratory therapist*

SUMMARY

Mechanical ventilation (MV) is a life supporting treatment that, unfortunately, can be associated with several complications such as ventilator-induced lung injury, ventilator associated pneumonia or ventilation induced diaphragm dysfunction (VIDD)[1]. Clinicians generally try to provide assisted/supported ventilation instead of fully controlled ventilation in critically ill patients [2]. This strategy aims at avoiding diaphragmatic atrophy [3]. This requires harmonious synchronization and matching with patient's demands in terms of ventilator needs. Asynchrony between the patient and the ventilator occurs when there is a mismatch between the patient and ventilator in terms of breath delivery timing. Some asynchrony is inevitable because of the mechanical and electrical delays existing within the complex patient-ventilator loop. Gross asynchronies as those where the mismatch between the breath delivery and the patient effort is huge, such as auto-triggering or missing effort. Some asynchronies can cause or be associated with discomfort and dyspnea and/or increased need for sedative and paralytic agents but this is not the case for all of them [4] and asynchronies may even be caused by deeper levels of sedation [5]. This is why a classification based on their mechanism appears useful. A high incidence of asynchrony is associated with prolonged MV and intensive care unit (ICU) length of stay [6,7] and with mortality [8]. Thus, it seems intuitively important to enhance the detection of asynchronies and to adapt the ventilator assistance, although we have no direct evidence that reducing asynchrony improve outcome.

Definitions

During assisted ventilation, many problems of poor patient-ventilator interactions are related to phase (matching between the neural inspiration and expiration times of the patient on the one hand and the ventilator insufflation and expiration times on the other hand). These asynchronies can happen when the patient's respiratory drive is relatively high (acute respiratory failure). In such a case, the clinician need to decide whether the high drive to breathe and the asynchronies are caused by an insufficient level of ventilator assistance, creating dyspnea and unmatched needs, or whether it is intrinsic to the patient's acute disease and solely requires additional sedation. At the opposite, other asynchronies will happen when the respiratory drive is low (sedation, hyperventilation): here, the clinician must detect that an excess of sedation or of ventilation is present. We will classify asynchronies based on these circumstances.

Low respiratory drive and excessive ventilator assistance

1) Pressure support-induced apneas

During sleep, the apneic threshold for $PaCO_2$ increases, and lowering $PaCO_2$ level below this threshold caused by excessive ventilation rapidly lead to a specific form of poor patient ventilator interaction, characterized by central apneas that negatively influence sleep in the absence of backup ventilation. High levels of pressure support ventilation (PSV) may cause sleep disruption from periodic breathing [9]. If PSV delivers a higher-than-needed alveolar minute ventilation, hyperventilation and hypocapnia will occur that will be followed by apnea causing continuous sleep fragmentation [10]. Avoiding excessive levels of assistance is very important with PSV, especially during sleep. The use of modes with backup ventilation such as assist-control mode or synchronized intermittent mandatory ventilation may also prevent periodic breathing but they may have other downside effects if they put the respiratory muscles excessively at rest. Apneas during PSV may be worsened in patients with heart failure [11].

2) Ineffective efforts

Excessive ventilator assistance may also promote dynamic hyperinflation that itself generates intrinsic positive end expiratory pressure (PEEP), and reduces respiratory drive. This is favored by airway obstruction. The higher is the PSV level, the longer is the insufflation time and its termination beyond the end of patient's neural inspiratory time. Patient's effort arrives too soon, and becomes insufficient to overcome intrinsic PEEP before to trigger the ventilator. The result is that no breath is delivered following the effort (table and Figure 1). Whatever the mode, the higher is the level of assistance, the higher are the numbers of ineffective efforts [11]. Deep sedation with propofol can induce ineffective effort during pressure support ventilation [12].

3) Auto-triggering

Auto-triggering occurs when the ventilator delivers an assisted breath that was not initiated by the patient. Since a drop in airway pressure or a flow signal is used to trigger the ventilator, airways leaks or strong cardiac oscillations can reach the triggering threshold of the ventilator in the absence of patient's effort and provoke the insufflation of repeated extra breaths, sometimes causing profound hyperventilation.

4) Reverse triggering

Reverse triggering was firstly documented by Akoumianaki and colleagues who observed repetitive decrease in esophageal pressure occurring regularly near the end of each mechanical inspiration in heavily sedated patients (Figure 2) [13]. Inspiratory efforts were directly triggered by the mechanical insufflations. This was observed during both pressure or volume controlled ventilation. In the ICU, it might result in eccentric contractions of respiratory muscles, in extra-breaths going unrecognized (inducing "double cycling") and in unreliable plateau pressures. The use of neuromuscular blocking agents at the early phase of acute respiratory distress syndrome might avoid reverse triggering [14].

Increase in respiratory drive and/or insufficient ventilator assistance

Despite the delivery of a breath by the ventilator, when the patient's demand is high, the inspiratory effort may continue throughout the preset ventilator inspiratory time and remains present after ventilator inspiratory time has finished. This corresponds to a premature cycling resulting in increased work of breathing [15]. This phenomenon may lead to the consecutive delivery of two cycles for only one patient's effort (double triggering), also referred to as breath stacking (table 1 and Figure 3). A short inspiratory time, usually associated with a low tidal volume, and a high respiratory drive are risk factors for double triggering.

Prevalence

Until recently, studies assessing the prevalence of asynchrony were limited to relatively short evaluation periods of observation (from several minutes to 24 h). Therefore, the prevalence of asynchrony has probably been underestimated. The larger existing study reported that among 200 ventilator-dependent patients in a weaning center, ineffective efforts could be clinically detected in 10% [16]. Among 62 ICU patients, Thille et al. found that 15 exhibited a high asynchrony index (AI), defined as the ratio of the number of asynchrony events divided by the total respiratory rate, above 10% (mostly ineffective effort) [7]. In a recent study, Mellott et al. analysed 43,758 breaths and found that 24% of those breaths had asynchronies with mostly ineffective effort [17]. Blanch et al., using a device dedicated to continuous detection of asynchronies, found a median AI of 3.41 % during the entire course of MV [18].

Impact

Asynchronies could have crucial clinical implications in MV patients. Several studies reported an association between ineffective effort and a longer duration of MV [6,7]. Others showed that asynchronies induce sleep disorders [18] with a direct relationship between ineffective effort and a decrease in the proportion of REM (Rapid Eye Movement) sleep [19]. In addition, double triggering, by delivering a double tidal volume, could promote ventilator-induced lung injury and dynamic hyperinflation. Blanch et al. [8] found a significant relationship between an AI>10% and an increase in ICU and hospital mortality even after multiple adjustments [8]. Whether asynchronies increase mortality or are just a biomarker of severity and whether reducing asynchrony will change the outcome deserve further studies.

Bedside detection

Even if patient-ventilator asynchrony is very common, studying this phenomenon remains a challenge in daily clinical practice [20]. Accurate assessment of patient-ventilator interactions requires measurements of esophageal pressure and/or respiratory muscle electromyogram[21,22].

Airway pressure, volume and flow waveforms are displayed in real time on the screen of ventilator. Visual inspection of those waveforms has been shown to correlate well with esophageal-balloon readings, but is not without error [16]. There are limitations in the detection of asynchronies from ventilator waveforms. First, a study showed that the ability of ICU physicians, even experts, to detect asynchrony can be quite poor and does not enable a simple, reliable and sensitive detection of asynchronies [20]. Second, because asynchronies are susceptible to happen at any time, it is not possible to continuously track for asynchronies except when clinicians are examining the screen of the ventilator. Third, some asynchronies such as reverse triggering are hardly detected by waveforms only.

Monitoring esophageal pressure (Peso) enables to detect inspiratory effort and hence understand the interaction between patient and ventilator [23]. The electromyogram of the diaphragm can be now easily obtained through a special catheter equipped with multiple electrodes and can detect asynchronies, inspiratory effort or neuro-mechanical coupling in adult and pediatric settings [24-27]. An asynchrony index can be calculated as the number of flow-, pressure and diaphragm-based asynchrony events divided by patients' diaphragm-based respiratory rate[28].

Automatic dedicated software

An approach based on the equation of motion using V_T, Paw, flow and Peso signals on one hand, and estimated values of elastance and resistance on the other, has been developed[29]. This method provides a real-time trace that reflects respiratory muscle pressure output along with Paw and flow [29]. In 2012, Blanch et al. validated a software (Better Care™) designed to detect ineffective effort during expiration [30]. The software captures digital output from different ventilators and associates each acquired waveform with the parameter it represents (flow, Paw, or V_T). Others investigators have proposed automatic detection of asynchronies. Sinderby and colleagues designed a new index of patient-ventilator interaction [31]. There was a significant correlation between the number of wasted efforts and the NeuroSync index [32]. Inspiratory efforts can also be detected by looking at the thickening of the diaphragm [33], diaphragmatic ultrasound could become an interesting approach in the detection of asynchronies. This requires synchronizing ventilator waveforms with the ultrasound signal of the diaphragm breath by breath [34].

Conclusion

There is growing evidence that asynchronies negatively correlate with clinical outcomes. This might encourage physicians to pay more attention to the interaction between patient and ventilator but tools allowing an easy recognition of asynchronies are necessary[35].

Table: Main asynchronies and their description.

Asynchronies	Description	Related to
Inspiratory effort	Patient inspiratory effort not followed by a ventilator-delivered pressurization.	Triggering
Double triggering	Two ventilator-delivered pressurizations during one single patient inspiratory effort.	Triggering
Auto triggering	Ventilator pressurization without inspiratory effort.	Triggering
Reverse triggering	Inspiratory efforts occurring near the end of each mechanical inspiration in a repetitive and consistent manner.	Entrainment
Premature cycling	Duration of pressurization shorter than the duration of patient inspiratory effort.	Cycling off
Delayed cycling	Duration of pressurization twice as long as patient inspiratory effort.	Cycling off

Figure 1. Ineffective efforts.

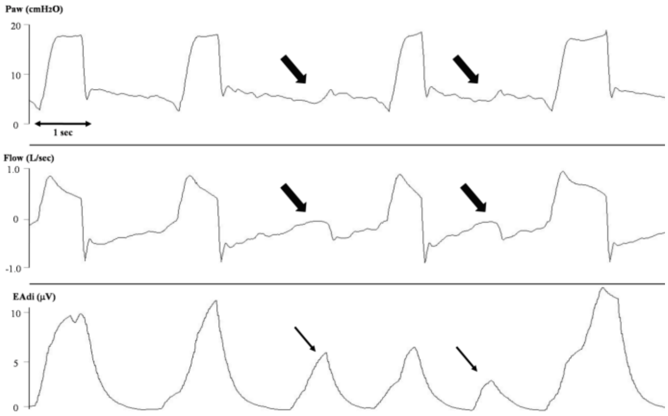


Figure 2. Reverse triggering.

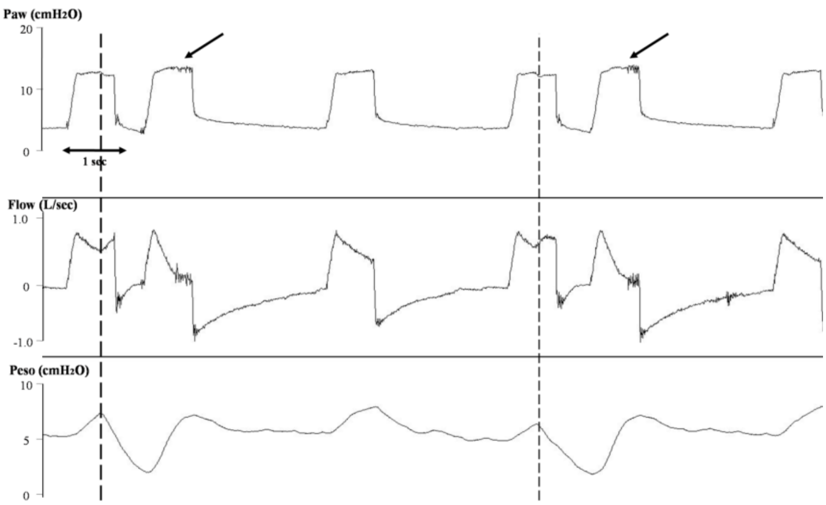
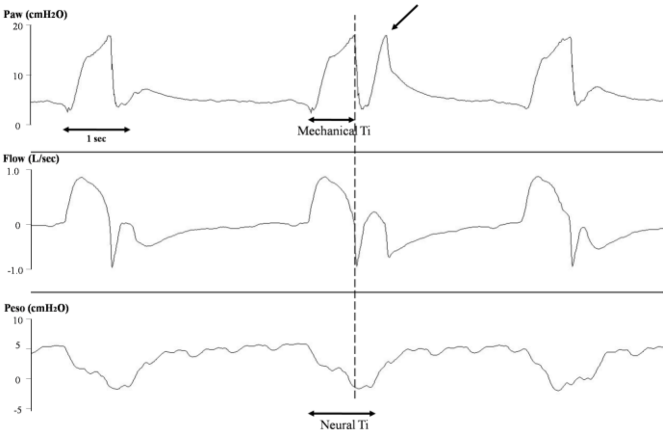


Figure 3. Premature cycling.



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FACULTY DISCLOSURE

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