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Patient-Ventilator Asynchrony

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Patient-ventilator asynchrony is more frequent than previously considered and correlates with unfavourable outcomes. Different forms of asynchronies may depend on various causes. When detected, asynchronies may be often corrected.

Controlled mechanical ventilation, although necessary in many instances, has side effects and complications and is therefore interrupted as soon as possible in favour of forms of partial ventilatory assistance, where the ventilator is driven by the patient's spontaneous breathing activity. With these modes both the patient and ventilator contribute to generate the ventilator output and share the work of breathing. If, on the one hand, these modes offer clinical advantages such as reduced need for sedation, lower risk of respiratory muscles atrophy and dysfunction, and less haemodynamic impairment, on the other hand, a poor patientventilator interaction may lead to discomfort, agitation, increased work of breathing and worsening of gas exchange (Sassoon and Foster 2001).

Going to extremes, a poor interaction may result in asynchrony, which is when the patient and the ventilator do not work in unison. Chao et al. first suggested that patient-ventilator asynchrony could affect the outcome of weaning, the rate of failure being higher in patients with asynchrony (Chao et al. 1997). Later on, Thille et al. found that approximately one-fourth of patients receiving partial ventilatory assistance for more than 24 hours had a high incidence of asynchrony; notably, the patients with asynchronies had a prolonged duration of mechanical ventilation and, consequently, a high rate of tracheostomy (Thille et al. 2006). Recently de Wit et al. confirmed the worsened outcome of patients with asynchronies (de Wit et al. 2009). Whether asynchrony worsens a patient's outcome, or is rather a marker of severity, however, is still unclear (Sassoon 2011).

Classification and Detection

While, strictly speaking, asynchrony means absence of concurrence in time, the term is often used to indicate, in general, more a disturbance of coordination between two events normally occurring simultaneously. Relevant asynchronies are commonly considered: 1) ineffective (wasted) efforts, also named ineffective triggering and by far the most frequent, indicating that the effort exerted by the patient is not assisted by the ventilator; it may occur during both the inspiratory and expiratory mechanical phase, and is often consequent either to a weak effort, or to the presence of intrinsic positive endexpiratory pressure (PEEPi) (Leung et al. 1997; Parthasarathy et al. 1998); 2) auto-triggering, which means the ventilator delivers assistance without patient effort; as it occurs when variations in airway pressure and/or flow secondary to cardiac oscillations (Imanaka et al. 2000) or air-leaks (Vignaux et al. 2009) are unduly sensed as triggering efforts; 3) double-triggering, characterised by two mechanical cycles triggered by the patient separated by a very short expiratory time (<30% of the mean inspiratory time) (Thille et al. 2006); it occurs because the mechanical breath terminates before the completion of the patient's effort, which triggers, after a brief phase of exhalation, a second mechanical breath. Additional forms of asynchrony are: 4) premature (anticipated) cycling, indicating that the duration of the mechanical breath is shorter than the patient's own inspiration; and opposite 5) prolonged (delayed) cycling, i.e., the mechanical breath lasts longer than the patient's effort (Vignaux et al. 2009). It is generally considered that asynchronies assume clinical relevance when their rate exceeds 10% (Colombo et al. 2008; Thille et al. 2006).

Even though algorithms for automatic recognition have been proposed (Chen et al. 2008; Mulqueeny et al. 2009; Sinderby et al. 2013), in clinical practice, asynchronies are commonly detected by visual inspection of the ventilator waveforms. Colombo et al., however, recently showed that this approach provides a gross estimate, with a relatively small influence of physician's experience, suggesting that additional signals such as oesophageal pressure or diaphragm electrical activity are necessary for proper detection (Colombo et al. 2011).

Causes of Asynchrony

Asynchronies may be secondary to multiple factors related to either the patient (mechanical properties of the respiratory system, breathing pattern, respiratory drive and effort), and/or the ventilator (mode and settings).

Ineffective triggering and delayed cycling are frequently encountered in patients with airway obstruction, determining dynamic hyperinflation and PEEPi (Nava et al. 1995); while applying external PEEP may help to reduce ineffective efforts, delayed cycling may be eliminated, shortening ventilator insufflation by varying the inspiratory flow threshold to a higher value during Pressure Support (PS), or decreasing machine pre-set inspiratory time in Assist/Control (A/C). Patients with a very low respiratory system compliance undergoing PS may develop double triggering, because the inspiratory flow decays rapidly and the threshold for cycling from inspiration to expiration is reached when the patient's effort is still ongoing (Mauri et al. 2013). Decreasing the flow threshold to a lower value helps in some cases, but is ineffective in conditions of particular severity (Mauri et al. 2013).

Any condition reducing the respiratory drive and/or altering the timing of breathing may determine asynchronies. When the respiratory drive is entirely suppressed and trigger sensitivity is set at a very low threshold, auto-triggering frequently occurs, consequent to activation of the mechanical assistance by non-respiratory events, such as cardiac oscillation (Imanaka et al. 2000) or air-leaks determining small fluctuations on the flow and airway pressure signals (Vignaux et al. 2009). When the drive is quite reduced, but not entirely suppressed, ineffective triggering, premature cycling and double triggering may all intervene.

Over-assistance is probably the most common determinant of asynchrony. High tidal volumes and respiratory alkalosis, secondary to excessive ventilator assistance, reduce the drive to breathe through feedback mechanisms mediated by chest wall and lung mechanoreceptors, and central and peripheral chemoreceptors, respectively. Optimising the ventilator settings to avoid over-assistance is often sufficient to reduce or even abolish patient-ventilator asynchrony. Thille et al. eliminated ineffective triggering in two-third of the cases by decreasing tidal volume and, accordingly, the preset inspiratory pressure, without observing clinically relevant increases in the patient's effort (Thille et al. 2008).

Sedatives affect the respiratory drive and/or timing through a direct effect on the brain. A pilot observational study by de Wit et al. first showed a correlation between the level of sedation and asynchrony (de Wit et al. 2009). More recently Vaschetto et al. confirmed and extended these findings in a study evaluating the effects of three levels (absent, light and deep) of sedation by propofol; they found that increasing the depth of sedation caused a reduction in respiratory drive, with minimal effects on timing, which affected breathing pattern, gas exchange, and, in the end, patient-ventilator interaction and synchrony (Vaschetto et al. 2014).

The conventional modes of partial assistance delivering a preset inspiratory pressure (PS) or volume (A/C) do not respond either breath-by-breath and intra-breath to changes in the patient's demand. New modes are now available that introduce a proportionality between patient demand and ventilator assistance and improve synchronisation between the patient's own inspiratory time and duration of ventilator applied assistance (Navalesi and Costa 2003). With Neurally Adjusted Ventilatory Assist (NAVA) and Proportional Assist Ventilatory Plus (PAV), the ventilator delivers assistance in proportion to diaphragm electrical activity and patient generated volume and flow, respectively; both modes have been shown to reduce asynchronies, irrespective of patient's respiratory mechanics, level of assistance and sedation (Colombo et al. 2008; Giannouli et al. 1999).

Non-Invasive Ventilation

Non-invasive ventilation (NIV) is increasingly used to treat patients with acute respiratory failure. Achieving a good patient-ventilator interaction is even more important during NIV, because the patient's tolerance is a crucial determinant of success and sedatives are preferentially avoided, or used at very low doses. Recent studies, however, have shown that, secondary to air-leaks and characteristics of the interface, the rate of asynchrony is quite high during NIV (Bertrand et al. 2013; Cammarota et al. 2011; Navalesi et al. 2007; Piquilloud et al. 2012; Vignaux et al. 2009). Use of ventilators specifically designed for NIV, with algorithms for airleaks detection and compensation (Carteaux et al. 2012), reduction of the overall applied pressure (Vignaux et al. 2009), choice of the proper interface (Navalesi et al. 2007), use of a leaks-insensitive ventilatory mode (Bertrand et al. 2013; Cammarota et al. 2011; Piquilloud et al. 2012) are all helpful strategies for decreasing asynchronies during NIV.

Summary

Patient-ventilator asynchrony occurs more frequently than previously considered in patients receiving partial ventilator assistance, during both invasive and non-invasive ventilation, and correlates with unfavourable outcomes. Asynchronies are generally detected by visual inspection of ventilator waveforms, but the use of an additional signal, such as oesophageal pressure or diaphragm electrical activity, may improve their recognition. There are several types of asynchronies, which depend on multiple factors related to either the patient (mechanical properties of the respiratory system, breathing pattern, respiratory drive and effort), and/or the ventilator (mode and settings). Identifying the determinants of asynchrony often allows finding solutions to reduce or even eliminate its occurrence.

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For full references, please send a request to editorial@icu-management.org

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