Identifying asynchronies: work shifting and double triggering

Víctor Perez, [1] Jamille Pasco [2]

DOI: https://doi.org/10.53097/JMV.10066

Cite: Perez V, Pasco J. Identifying asynchronies: work shifting and double triggering. J Mech Vent 2022; 3(4):190-194.

Abstract

Mechanical ventilation supports the work of breathing, improves gas exchange, and unloads the respiratory muscles, all of which require good synchronization between the patient and the ventilator. Asynchronies occur when the ventilator’s breath delivery does not match the patient’s neural ventilatory pattern or is inadequate to meet the patient’s flow demand.

Patient–ventilator asynchrony can be easily detected by observing the patients in those extreme situations in which they fight the ventilator; nevertheless, the vast majority of asynchronies occur without major clinical signs and go undetected or corrected without measuring patient's respiratory effort (either esophageal pressure or electrical activity of the diaphragm).

Synchrony problems are common, occurring in perhaps as many as 25% of patients receiving invasive ventilation and up to 80% of patients receiving noninvasive ventilation.

In this concise review, we describe work shifting and double triggering asynchronies.

Keywords: Patient-ventilator asynchronies, work shifting, double triggering

Authors

1. Víctor Pérez Cateriano MD. Intensive Care Medicine. Master in Health Services Management. Dos de Mayo National Hospital. Lima, Perú.
2. Jamille Pasco Ulloa MD. Intensive Care Medicine. Alberto Barton Hospital. Callao, Perú.

Corresponding author: Víctor Pérez Cateriano.
Email: vpc051@gmail.com

Conflict of interest/Disclosures: None
Funding: None

Mechanical ventilation supports the work of breathing, improves gas exchange, and unloads the respiratory muscles, all of which require good synchronization between the patient and the ventilator. [1]

Asynchronies occur when the ventilator's breath delivery does not match the patient's neural ventilatory pattern or is inadequate to meet the patient's flow demand. [2-4]

Patient–ventilator asynchrony can be easily detected by observing the patients in those extreme situations in which they fight the ventilator; nevertheless, the vast majority of asynchronies occur without major clinical signs and go undetected or corrected without measuring patient's respiratory effort (either esophageal pressure or electrical activity of the diaphragm). [5]

Synchrony problems are common, occurring in perhaps as many as 25% of patients receiving invasive ventilation and up to 80% of patients receiving noninvasive ventilation. [6]

Patient ventilator asynchronies are more prone to occur when patients start to wake up (directly correlated with sedation management) and spontaneous efforts start to appear, so a mismatch between patient's breathing pattern and that programmed on the ventilator may occur. [7]

Several classifications have been proposed, based on the beginning (trigger) and pressurization of the inspiratory phase, and the cycling to the expiratory phase. [3,8,9]

Patient ventilator asynchronies are often classified in two groups: 1) asynchronies occurring when the ventilator flow delivery is inadequate to match the patient's ventilatory flow demand, named "flow asynchrony" and 2) asynchronies occurring because neural breath is not in the same phase with the mechanical breath either during triggering phase or cycling phase, usually named "phase asynchrony". [3,10]

Classically named flow starvation occurs when the ventilator does not satisfy the patient's flow demand. [11,12]

Flow asynchrony is a common problem, and the flow setting may be the most frequently incorrectly set ventilator parameter. [12]

Although not clearly impacting major outcomes, flow asynchrony might contribute to dyspnea, a prevalent and distressing symptom in mechanically ventilated patients. [13]

It is more common in volume-controlled ventilation mode (fixed flow) when sedatives are removed and the patient increases his ventilatory demand. [7] A breath in pressure-control ventilation mode better matches the patient's ventilatory needs because the flow is the dependent variable during the delivery of inspiratory pressure, which means it reproduces the physiologic descendent flow profile better. [14] Nevertheless, the setting of pressure-rise time (i.e., the time taken to reach the pressure set on the ventilator) may determine the flow output and consequently the asynchrony due to gas delivery. [15,16] The clinician can also adjust the inspiratory pressure target up or down according to the level of ventilatory support desired. [17]

In volume-control ventilation, this asynchrony is detected in pressure airway tracing by a concave depression during inspiratory phase (figure 1).

Proposed remedial action: increase tidal volume (under lung protective strategy), consider switching mode to pressure support, if possible, increase inspiratory time, consider more sedation, analgesia, or neuromuscular blocking agents. [7]

As mentioned, this asynchrony can also occur in pressure-control ventilation with variable flow which depends on various factors, including set target pressure, patient effort, and respiratory-system compliance and resistance. [12] The presence of muscle pressure (Pmus) is identified by deformations in the flow and in the pressure waveform (figure 2). Inspiratory Pmus will increase tidal volume and flow. [17]

During the inspiratory phase, a convex deflection in the airway pressure indicates a strong effort, the higher the effort, the higher the convexity. The effect on the flow is usually apparent on the decelerating or the descending flow but not the constant flow, with a concavity of the curve correlates to the patients' muscle pressure. [18]

Additionally, flow starvation results in an increasing load to the patients' respiratory muscles. [19] The maximum expression of flow asynchrony is when airway pressure is less than or equal to the programmed PEEP, indicating that there is no ventilator inspiratory support. [7]

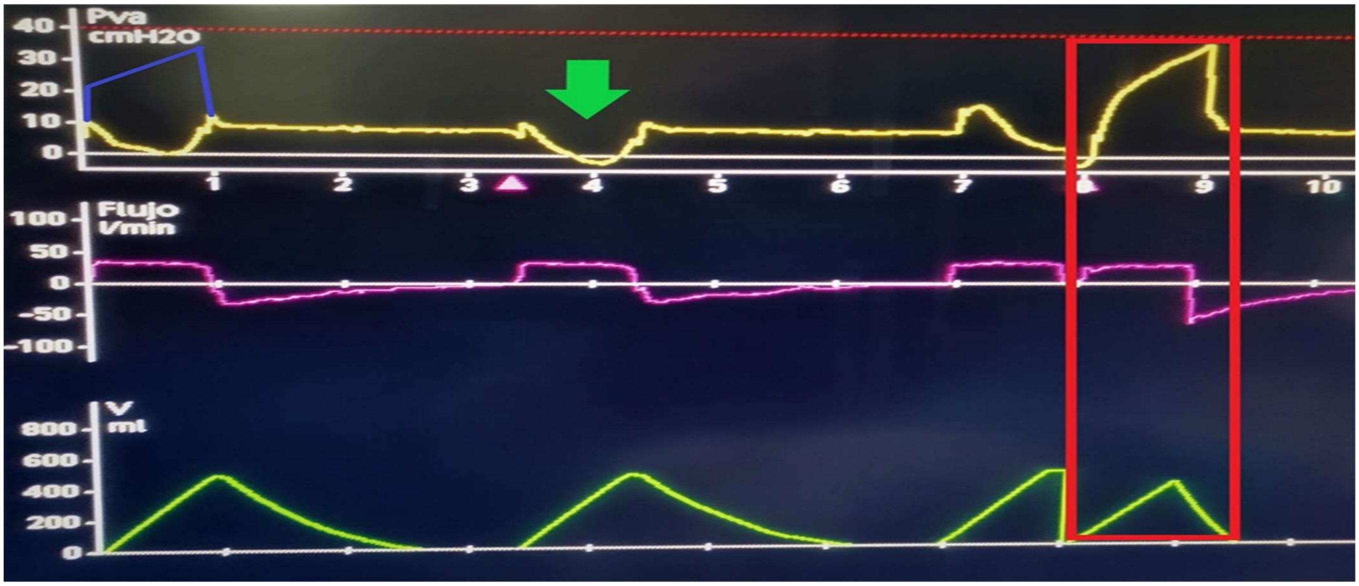

Figure 1. Severe work shifting in a patient undergoing volume-control ventilation recognized in the flow-time curve by the fixed rectangular flow. From top to bottom: pressure-time, flow-time and volume-time curves. Spontaneous respiratory efforts by the patient blunt the airway pressure (green arrow) from the theoretical tracing (blue line). The pressure waveform is deformed due to the presence of Pmus; the pressure crosses the baseline. The patient is doing work against the ventilator. It needs immediate clinician attention. In the third breath we can see a double triggering (red rectangle) when closing the inspiratory valve the patient persists with his inspiratory effort and occurs a pressure drop that can reshoot a inspiratory cycle.

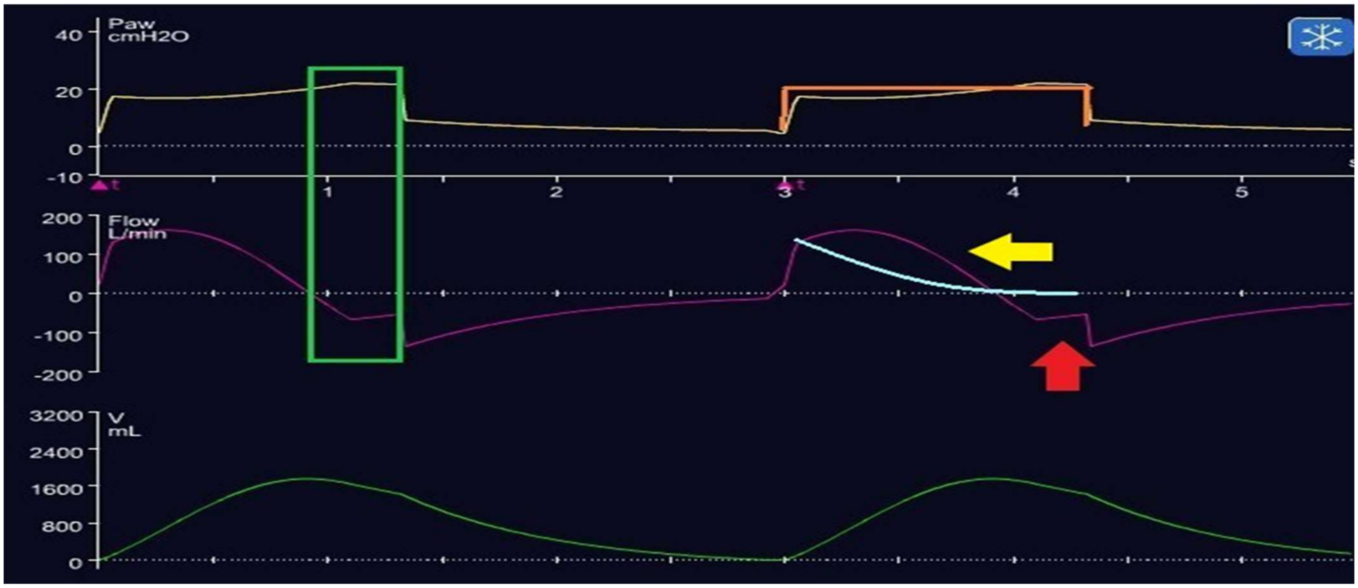

Figure 2. Work shifting in a patient undergoing pressure-control ventilation. From top to bottom: pressure-time, flow-time and volume-time curves. The pressure waveform is deformed toward baseline due to the presence of Pmus. Orange line demonstrates where the pressure waveform would be if there was not Pmus. Light blue line demonstrates the passive flow waveform. Additional flow above this line is due to Pmus (yellow arrow). We can aslo see: Delayed cycling (green rectangle). Expiratory flow during inspiratory phase: active exhalation valve allows expiration during inspiratory time (red arrow)

The nomenclature describing abnormal patient-ventilator synchrony is not consistent in the literature. Synchrony issues, by definition, have to do with timing. As such there are two defined timing points in a breath; for the patient, the beginning and end of the effort; and for the ventilator, the trigger and cycle of inspiration. [20]

During inspiration and expiration the main issues are not related to timing but to work of breathing. [20] Work of breathing refers to both the patient and ventilator work and their relation. This work relationship has been interpreted by some as need for more flow being delivered by the ventilator. In extreme cases, this is described as flow starvation. However, some authors think it is more accurate to use the term work shifting. [17]

Work shifting refers when pressure delivered by the ventilator (Pvent) and pressure generated by patient respiratory effort (Pmus) are active together, some portion of the total work is done by the ventilator and some by the patient. [20] It can occur in any phase of inspiration, as it will depend on when the Pmus is active, the ventilator settings (mode, inspiratory time, trigger sensitivity, cycle threshold), and patient-ventilator interaction. [17]

Notice that when work shifting becomes extreme (i.e., high ventilatory drive due to hypoxemia or metabolic acidosis), this can result in either diaphragm or lung injury (i.e., tidal volume overdose), and no mode or mode setting will ameliorate it. Sedation and paralysis may be required. [17]

Double triggering consists of a sustained inspiratory effort that persists beyond the ventilator's inspiratory time, triggering a second ventilator breath, which may or may not be followed by a short expiration, where all or part of the volume of the first breath is added to the second breath (figure 1). The resulting larger than expected tidal volume could cause ventilator-induced lung injury. [21]

It can occur due to early cycling of the inspiratory phase to expiration (short ventilator inspiratory time). If deep and long enough, the persistent inspiratory effort could produce a fall in airway pressure leading to double triggering and breath stacking. [7] However, passive insufflation by the ventilator in sedated patients may also trigger a contraction of the diaphragm causing a reverse triggering asynchrony (entrainment). [22]

An observational study in 67 patients showed that double triggering occurred in all patients, but was patient triggered (breath stacking) in 65% and reverse triggered in 35% of cases. [23]

Referencias

1. Epstein S. Optimizing Patient–Ventilator Synchrony. Seminars in Respiratory and Critical Care Medicine 2001; 22(2):137-152.

2. Branson RD, Blakeman TC, Robinson BR. Asynchrony and Dyspnea. Respir Care 2013; 58(6): 973–986.

3. Gilstrap D, MacIntyre N. Patient-ventilator interactions. Implications for clinical management. Am J Respir Crit Care Med 2013; 188:1058–1068.

4. Sassoon C. Triggering of the ventilator in patient-ventilator interactions. Respir Care 2011; 56:39–51.

5. Thille AW, Rodriguez P, Cabello B, et al. Patient-ventilator asynchrony during assisted mechanical ventilation. Intensive Care Med 2006; 32:1515-1522.

6. Bruni A, Garofalo E, Pelaia C, et al. Patient-ventilator asynchrony in adult critically ill patients. Minerva Anestesiol 2019; 85(6):676-688.

7. Damiani L, Bruhn A, Retamal J, et al. Patient-ventilator dyssynchronies: Are they all the same? A clinical classification to guide actions. Journal of Critical Care 2020; 60:50-57.

8. Kacmarek R, Villar J, Blanch L. Cycle asynchrony: always a concern during pressure ventilation. Minerva Anestesiol 2016; 82(7):728-730.

9. Tobin M, Jubran A, Laghi F, et al. Patient-ventilator interaction. Am J Respir Crit Care Med. 2001; 163(5): 1059-1063.

10. Gilstrap D, Davies J. Patient-ventilator interactions. Clin Chest Med 2016; 37(4):669-681.

11. Marini J, Rodriguez R, Lamb V. The inspiratory workload of patient-initiated mechanical ventilation. Am Rev Respir Dis 1986; 134(5):902-909.

12. Nilsestuen JO, Hargett KD. Using Ventilator Graphics to Identify Patient-Ventilator Asynchrony. Respir Care 2005; 50(2):202-234.

13. Branson R, Blakeman T, Robinson B. Asynchrony and dyspnea. Respir Care 2013; 58(6): 973-989.

14. Boysen P, McGough E. Pressure-control and pressure support ventilation: flow patterns, inspiratory time, and gas distribution. Respir Care 1988; 133: 126-134.

15. Kacmarek R, Chipman D. Basic principles of ventilator machinery. In Tobin M, editor. Principles and practice of mechanical ventilation, 2nd ed. New York: McGraw-Hill; 2006; 53-95.

16. Chatburn R. Classification of mechanical ventilators. In Tobin M, editor. Principles and practice of mechanical ventilation, 2nd ed. New York: McGraw-Hill; 2006; 37-52.

17. Mireles-Cabodevila E, Siuba M, Chatburn R. A taxonomy for patient-ventilator interactions and a method to read ventilator waveforms. Respir Care 2022; 67(1):129–148.

18. Shokry M, Yamasaki K. Patient effort at a glance. J Mech Vent 2021; 2(4):147-148.

19. MacIntyre N, McConnell R, Cheng K, et al. Patient-ventilator flow dyssynchrony: flow-limited versus pressure-limited breaths. Crit Care Med 1997; 25(10):1671-1677.

20. Chatburn R, Mireles-Cabodevila E. 2019 Year in Review: Patient-Ventilator Synchrony. Resp Care 2020; 65(4):558-572.

21. Beitler J, Sands S, Loring H, et al. Quantifying unintended exposure to high tidal volumes from breath stacking dyssynchrony in ARDS: The BREATHE criteria. Intensive Care Med. 2016; 42: 1427–1436.

22. Akoumianaki E, Lyazidi A, Rey N, et al. Mechanical ventilation-induced reverse-triggered breaths: a frequently unrecognized form of neuromechanical coupling. Chest 2013; 143:927–938.

23. de Haro C, Lopez-Aguilar J, Magrans R, et al. Double cycling during mechanical ventilation: frequency, mechanisms, and physiologic implications. Crit Care Med 2018; 46(9):1385-1392.