Review article

Patient-Ventilator Asynchrony: The Power Struggle

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Abstract

Patient ventilator asynchrony (PVA) is a prevalent phenomenon seen in almost 25% of our intensive care unit patients. PVA can be trigger asynchrony, flow asynchrony, cycle asynchrony or mode asynchrony. Ineffective triggering is the most commonly occurring asynchrony. The best way to identify PVA is *via* the ventilator graphics. Corrective steps and manipulating the ventilator on the conventional mode to suit the patient's needs can help reduce the incidence of PVA. Recent advances have given rise to newer modes of ventilation such as Neurally Adjusted Ventilatory Assist and Proportional Assist Ventilation with the goal of reducing the frequency of PVA. Many new methods to reduce asynchronies are being studied; however additional large scale trials are needed to come to conclusive results. This article is an attempt to simplify the various asynchronies for better application to all healthcare professionals.

Keywords: Asynchrony, Neurally Adjusted Ventilatory Assist, Patient-ventilator, Proportional Assist Ventilation.

Introduction

The practice of mechanically ventilating a patient has been going on for a long time. The early 19th century saw the advent of negative pressure ventilation (NPV), with the iron lung as one of the early forms of ventilator. NPV then gained its popularity and reached its pinnacle during the polio epidemic in 1930-1970s.[1,2] However, the changing needs and the many drawbacks of NPV led to the development of positive pressure ventilation (PPV). Although the concept of PPV was first mentioned in the Bible, it was not until the 1780s when the first apparatus, the bag mask ventilator was introduced.[1] Ever since then we have seen a surge in technology and advancements in the various generations of mechanical ventilators. Today we use the fourth generation of smart and sophisticated ventilators.[1,2] These smart ventilators ideally share the work required to breathe with the patient, but in the clinical setting, substandard ventilatory management can lead to a struggle between the patient and the ventilator also known as patient-ventilator asynchrony (PVA).[3] Asynchronous episodes occur when the patient's breathing pattern does not match the ventilator's efforts. Asynchrony can also be seen when ventilator support is inadequate and does not meet the patient's demands.[3,4] Unfortunately, in reality, the prevalence of asynchronous events along with other factors has been found to be anywhere between 25%-80%, indicating the patient's discomfort.[3,4] Studies have also shown that significant asynchrony is associated with longer hospital stay and higher mortality.[4,5] Asynchrony, as common as it is, may occur due to patient-related factors or ventilator-related factors. They may be seen either at the beginning of the breath, during the breath or at the end of the breath.[3] Clinically we come across different types of asynchrony *(Table 1)*.[6]

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Table 1: Types of Asynchronies

- Trigger asynchrony
- Flow asynchrony
- Cycle asynchrony
- Mode asynchrony

Trigger asynchrony

Ineffective trigger is the most common PVA, where the ventilator fails to recognise the patient's efforts to breathe.[3] Ineffective triggers can be a result of improper trigger sensitivity settings or due to the added resistance of the artificial airway.[3,5] An inability to overcome the effects of auto positive end-expiratory pressure (autoPEEP), and a reduced respiratory neural response due to higher sedation levels are the most common patient-related factors leading to ineffective triggering.[3,6,7] Ineffective triggering is common in patients with COPD *(Figures 1 and 2)*.[7]

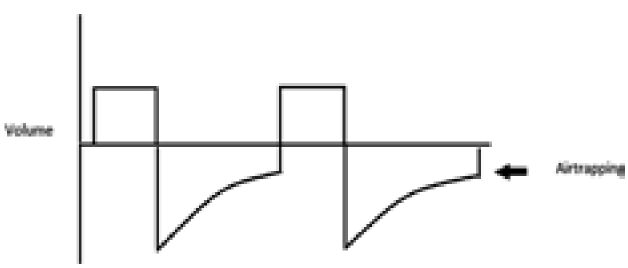

Figure 1: Air trapping

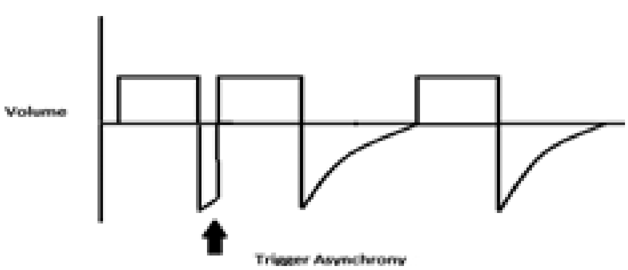

Figure 2: Trigger Asynchrony

Another form of trigger asynchrony is double-triggering (DT). Double triggering is defined as 2 breaths delivered by the ventilator within one patient effort separated by an expiratory time of less than half of the mean inspiratory time.[8,9] DT arises due to short inspiratory times and low PaO_2/FiO_2 ratios. It also occurs with high inspiratory pressure and high PEEP settings.[9] DT is associated with high tidal volume which in turn creates auto PEEP thereby increasing the patient's work of breathing.[9]

Auto-triggering (AT) is another commonly occurring phenomenon in the ICU setting. In AT, the ventilator delivers a breath without any trigger from the patient. It usually occurs if the trigger sensitivity is set too low, if there is water in the ventilator circuit or if there is a circuit leak.[8] AT is also associated with cardiogenic oscillations, and hiccups.[8] AT most commonly occurs in noninvasive ventilation due to leaks around masks and prongs.[6]
Recently, studies have described a new type of trigger asynchrony called reverse triggering. In reverse triggering, post a mandatory breath, the ventilator triggers an unwarranted subminimal contraction in the diaphragm muscles in heavily sedated critically ill patients,[6] This unique patient ventilator interaction, termed as respiratory entrainment is nothing but ventilator triggered muscle efforts.[10] These muscle contractions affect the plateau pressures that are measured, increase the oxygen consumption and lead to haemodynamic instability.[6] Reverse triggering may also lead to damage of muscle fibres and diaphragmatic dysfunction.[6,10]

Flow asynchrony

Flow asynchrony occurs when the flow delivered by the ventilator is not sufficient to meet the patient's ventilatory need.[3,6,8] This increases the work of breathing. Generally flow asynchrony can be corrected by either increasing the fixed flow to be delivered or allowing the ventilator to deliver variable flow. It can easily be identified on the ventilator's flow-volume or pressure-time graph *(Figure 3)*.[3,6,8]

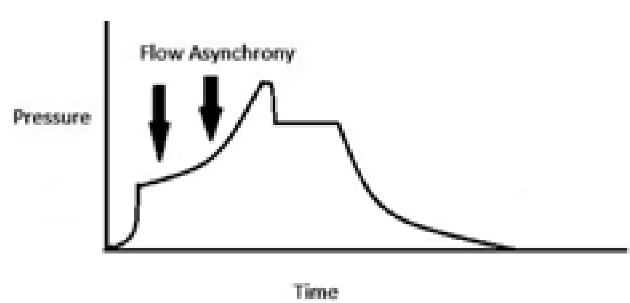

Figure 3: Flow Asynchrony

Cycle asynchrony

Asynchrony during the cycling phase of a breath occurs in two ways: Premature cycling or delayed cycling.[6] The basic problem lies in the poor coordination of the patient's expiration and the ventilator's response. Premature cycling occurs when patient's inspiratory time is longer than the ventilator's inspiratory time.[6,8] Delayed cycling occurs when the ventilator's inspiratory time is longer than the patient's inspiratory time *(Figure 4)*.[6,8]

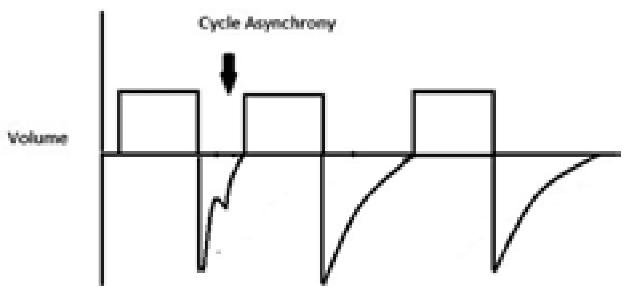

Figure 4: Cycle Asynchrony

Mode asynchrony

The phenomenon of mode asynchrony has been described in research studies dating back to the late 1980s.[6] These studies saw mode asynchrony during the synchronous intermittent mandatory ventilation, where there was an absence of adaptation to spontaneous and mandatory breaths.[6] Similar asynchrony was also seen by some in the volume support ventilation which led to an increase in dead space and work of breathing.[6]

Newer modes of mechanical ventilation; neurally adjusted ventilator assist (NAVA) and proportional assist ventilation (PAV) have been developed to reduce the incidences of PVA.[11,12] Many research studies have reported the benefits of these modes.[11,12] In a recent study, the investigators compared NAVA and PAV with pressure support ventilation (PS) to gauge the patient ventilator interaction. They reported that both NAVA as well as PAV reduced the level of asynchrony considerably as compared to PS.[11,12]

Asynchrony in noninvasive ventilation (NIV)

Asynchrony in NIV has been seen in the form of inspiratory leaks around the mask which may look like an inspiratory effort to the ventilator. This mimicked effort leads to AT. Expiratory leaks simulate a continuous inspiration which leads to delayed cycling.[13] Studies have shown that high frequencies of asynchrony were linked to reduced tolerance of NIV.[14] To overcome this issue many ICU ventilator manufacturers devised an algorithm which compensated for the leak and improved gas delivery.[13] However, various studies that were conducted to evaluate how these algorithms worked in the ICU ventilators, showed mixed results probably due to the huge variety of mechanical ventilators available. Exclusive NIV has shown to have better synchronisation with the patient.[13,14]

PVA and sedation

An ICU patient who needs mechanical ventilation is typically sedated. Often this is done to encourage patient ventilator synchrony and to aid in mechanical ventilation.[7] However, there is negligible evidence supporting the same. A recent pilot study evaluated the correlation between the level of sedation and ventilator asynchrony.[7] They reported that deeper sedation levels gave rise to higher PVA.[7] Heavily sedated patients had higher rates of ineffective triggering as compared to the alert and awake patients.[7]

What can be done?

The ideal method to assess PVA is phrenic neurogram and oesophageal balloon catheter.[12] The neurogram gives us the diaphragm's functionality status and the balloon catheter measures the intrathoracic pressures.[12] However, both these methods are invasive and require special care during testing and hence are seldom used.[12] Studying and identifying discrepancies on ventilator graphics is the most common method to detect PVA.[15] Various types of graphs are available in the modern day ventilator, yet they are underutilised for the benefit of the patient.[15] Asynchronous trigger is the easiest anomaly that can be detected in ventilator graphics and occurs in most of the modes of ventilation. To overcome ineffective triggers or AT, the trigger sensitivity can be either increased to being more sensitive and reduce the patient's effort required to breathe or reduced to being less sensitive and avoid AT.[5,15] Similarly, flow asynchrony can be identified on a pressure time waveform. Evaluating and modifying the flow to be delivered helps improve asynchrony.

Setting the Rise time appropriately can help reduce work of breathing.[15] Delayed cycling can also be seen on the ventilator graph as a spike at the end of inspiration. Premature cycling can be identified on the pressure as well as the flow waveform.[15] Cycle asynchrony can be overcome by various techniques such as larger tidal volume in volume-cycled modes or adjusting flow-cycling in newer ventilators.[5]

Utilising conventional modes of ventilation to improve asynchrony is a viable option, if their features are used appropriately.[5] Airway pressure graphics and flow graphics are important identifiers of asynchrony.[5,15] Thorough patient assessment along with optimising trigger, flow, cycle and other variables can enhance synchrony in patients.[5,15]

Automated neural index

Due to the high prevalence of PVA, newer methods are often devised with the goal of better synchrony. One such new concept called neural index has come into picture where the automated neural index and standardised neural index helps quantify interaction between the patient and ventilator.[16,17] A research study validated this objective method where airway pressure waveforms and diaphragm electrical activity measurements detected, quantified and displayed patient-ventilator interaction. They also classified events as synchronous, dyssynchronous and asynchronous.[16,17] Although further large scale studies are warranted, this interesting new concept could improve the standard of care for our mechanically ventilated patients.

Conclusion

Patient ventilator asynchrony is a common occurrence and can be managed in various ways. Use of conventional modes using optimal parameters is the cornerstone of appropriate management. However, the use of newer methods such as NAVA or PAV has also shown to improve synchrony in our patients. Identifying the asynchrony correctly on the ventilator graphics and using the right management techniques to overcome them is the currently the best solution until further large scale studies offer better elucidations. There is still a lot of untapped information that can be a valuable stepping stone for respiratory therapists to manage their patients better.

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