Using waveforms to identify asynchronies - Step 1

14.06.2022
Author: Branka Cupic, Caroline Brown, Reviewer: Giorgio Iotti, Süha Demirakca

The first step to identifying asynchronies using standard ventilator waveforms is knowing what a synchronous breath looks like during pressure-support ventilation.

A recent study showed that clinicians can use the analysis of standard ventilator waveforms to detect respiratory activity and asynchronies between the patient and ventilator with high sensitivity and specificity (1). The authors applied a systematic method that was based on the following principles.

- In a patient with a normal breathing pattern, inspiration is active and expiration is passive
- Exponential decay of flow indicates a passive condition (for both inspiratory and expiratory flow)
- In the case of synchronous pressure-support ventilation, passive conditions should only be observed during the ventilator’s expiratory phase
- Passive conditions during the ventilator’s inspiratory phase indicate auto-triggering or delayed cycling
- Deviations from passive conditions during the ventilator’s expiratory phase indicate trigger delay, ineffective efforts, early cycling or respiratory muscle activation

Around these principles, the authors created a set of pre-defined rules that they applied systematically to detect the patient’s respiratory activity and identify asynchronies from the airway pressure and flow waveforms. Esophageal pressure (Pes) was used as a reference.

In this bedside tip, we start with a normal breath and how to recognize good synchrony between the patient and ventilator. In future Bedside tips, we will show you how to identify the most common minor and major asynchronies.

What is exponential decay?

An important part of being able to identify the beginning and end of the patient’s inspiratory effort is recognizing exponential decay of flow. An exponential change describes the process whereby an amount decreases or increases by a consistent percentage rate over a
period of time (i.e., the rate of change is proportional to its current value). It occurs in many physical situations.

Figure 1: Two examples of exponential change

As described in the principles above, exponential decay of flow suggests a passive condition. The shape on the waveform will be different, depending on whether, after the initial peak flow, it is a decrease in inspiratory flow (left panel) or expiratory flow (right panel).

Figure 2: Exponential decay of flow
(Image modified from Mojoli et al. Critical Care (2022) 26:32)

Figure 2 shows two instances of exponential decay:
a) During inspiration: This is not normal during pressure-support ventilation, as inspiration should be active.
b) During expiration: This is as expected, as expiration is passive.
N.B.: The inspiration shown above is initially active and then becomes passive. The change between the two phases is evident from the change of slope on the waveform.

Identifying the start of an inspiratory effort
Figure 3: On the pressure and flow waveforms, the start of the patient’s inspiratory effort is indicated by:

a) a sudden negative deflection of Paw interrupting a phase of stable airway pressure
b) a sudden positive deflection of Flow interrupting a phase of exponential decay

Identifying a well-synchronized end of inspiration
Figure 4: The inspiratory flow profile shows an upwards convexity after the peak, with flow dropping more and more quickly. When the inspiratory effort is close to its end, flow crosses the zero line and moves straight towards its expiratory peak. This is then followed by exponential decay.

**The Pes waveform**

As shown above, it is possible to identify the start and end of an inspiratory effort without needing the Pes waveform. In the above-mentioned study, it was used as a reference to assess the accuracy of the waveform analysis. Below you can see the beginning and end of inspiration on the Pes waveform and the excellent agreement between Pes and the flow and pressure waveforms.
Figure 5: On the **Pes** reference waveform (shown here in green), the start of the patient’s inspiratory effort is indicated by a sudden negative deflection on the Pes curve.

The steep rise in both **pressure** and **flow** soon after indicates the start of the mechanical breath.

If the time gap between the two is very short, patient and ventilator are in synchrony. A longer gap (e.g., > 250 milliseconds) is considered a trigger delay.
Figure 6: The end of inspiration on the Pes waveform (Image modified from Mojoli et al. Critical Care (2022) 26:32)

Figure 6: The fast increase in Pes after its nadir corresponds to the relaxation of the inspiratory muscles, and its midpoint is the reference for the end of inspiration.

References