Ventilator Waveforms

Explanations for questions 1-8 please refer to tables on next page

Table 1: from Hamilton Medical

Table 2: A Taxonomy for Patient-Ventilator Interactions and a Method to Read. Respir Care 2022;67(1):129–148.

1) C

2) C

3) B

4) B

5) A

6) B

7) A

8) A

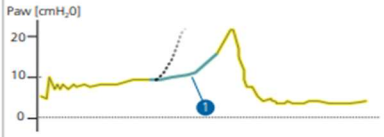
9) A

The inspiratory pause shows loss of pressure, the P-V and the F-V curves shows loss of volume, all secondary to airleak (from ETT, Ventilator circuit, Broncho-pleural fistula)

10) B

The oscillations seen both during inspiration and expiration are usually secondary to fluids in the airways secondary to secretions or fluid condensation in the ventilator circuit

Patient-ventilator asynchrony reference card

Asynchrony	Description	On the waveform	Waveform example	Common possible causes
Trigger asynchronies - during the beginning of inspiration				
Delayed triggering	The time interval between the patient's inspiratory effort and the delivery of a mechanical breath is increased	**Flow** waveform: Look for a longer-than-normal time interval between the positive deflection in flow ❶ and the delivery of ventilatory support ❷		Trigger threshold set too high Ventilator pneumatics Presence of AutoPEEP Low respiratory drive Weak inspiratory effort
Ineffective effort	The patient's inspiratory effort fails to trigger the delivery of a mechanical breath	**Flow** waveform: Look for an abrupt change in the steepness of the waveform ❶ (decrease in expiratory flow or increase in inspiratory flow) that is not followed by ventilatory support ❷		Trigger threshold set too high Pressure support too high Set frequency and/or inspiratory time too high (in controlled modes) Tidal volume set too high Presence of AutoPEEP Low respiratory drive Weak inspiratory effort Sedation
Auto triggering	A mechanical breath delivered without an inspiratory effort	**Pressure** waveform: Look for a delivered mechanical breath showing no drop in airway pressure ❶ at the beginning of the inspiratory phase		Trigger threshold set too low Air leaks in the endotracheal tube cuff, ventilator circuit, or chest tube Flow oscillations (water or secretion in the circuit, cardiac oscillations)
Flow asynchronies - during the gas delivery				
Flow asynchrony	The delivered flow does not meet the patient's inspiratory flow demands	**Pressure** waveform: Look for an upward concavity ❶ preceding the end of the mechanical breath		Inappropriate selection of ventilation mode (more frequent in volume-controlled modes) High inspiratory effort In volume-controlled modes: Inappropriate flow settings In pressure-controlled modes: Inappropriate **P-ramp** settings

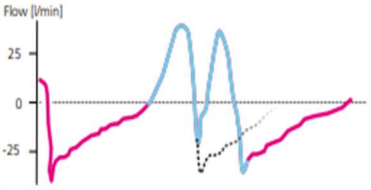
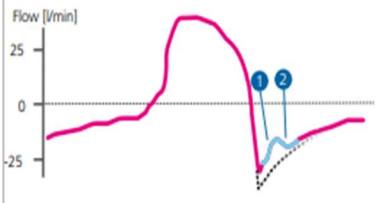
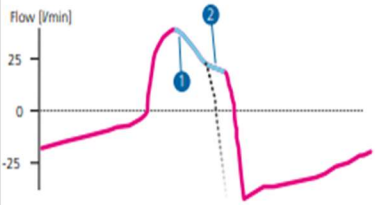
Asynchrony	Description	On the waveform	Waveform example	Common possible causes
Termination asynchronies - during the end of inspiration				
Double triggering	Two (or more) mechanical breaths are delivered during one single inspiratory effort	**Flow** waveform: Look for two assisted breaths without expiration between them or with an expiration interval of less than half of the mean inspiratory time (often visually displayed as a waveform with two inspiratory peaks)		Cycling criteria (**ETS**) set too high Pressure support too low **P-ramp** too short Flow starvation High respiratory drive Time constant too short Double triggering can be an effect of and/or promoted by reverse triggering or early cycling
Early cycling	The duration of the mechanical breath is shorter than the duration of the patient's inspiratory effort	**Flow** waveform: Look for a small bump ❶ at the beginning of expiration (after peak expiratory flow) followed by an abrupt initial reversal in the expiratory flow ❷		In pressure support ventilation: Cycling criteria (**ETS**) set too high Low levels of ventilator pressure support Time constant too short In time-cycled ventilation: Short inspiratory time
Delayed cycling	The duration of the mechanical breath is longer than the duration of the patient's inspiratory effort	**Flow** waveform: Look for a change in the slope of the inspiratory flow: a fast decrease ❶ followed by an exponential (less steep) decline ❷		In pressure support ventilation: Cycling criteria (**ETS**) set too low Pressure support too high **P-ramp** too long In pressure control ventilation: Cycling criteria (**ETS**) set too low Inspiratory time too long In volume control ventilation: Low flow Long inspiratory time High tidal volume

Table 3. Taxonomy of Patient-Ventilator Interactions

Phase	Patient-Ventilator Interactions Taxonomy	Other Names in Literature	Definition	What to Look for
Trigger	Normal		The beginning of a patient effort triggers inspiration within an acceptable timeframe (eg, 100 ms[15]).	Immediate elevation of pressure above baseline after patient trigger signal.
	Early	Reverse trigger, Early inflation	When a machine-triggered inspiration precedes patient effort. Patient effort may occur at any phase of inspiration or early expiration (to differentiate from failed trigger).	Machine breath followed by evidence of P_{mus}.
	Late	Trigger delay, Late inflation	The ventilator responds to the patient's effort after a clinically important delay in starting the ventilator inspiratory phase (eg, > 100 ms).	Airway pressure drops below baseline or flow crosses, > 100 ms before triggering breath.
	False	Auto trigger, Auto cycling	A nonpatient (eg, non-P_{mus}) signal triggers inspiration.	No evidence of patient muscle activity and presence of triggered patient breaths. Oscillations in the flow, pressure, or capnography waveform; these may be rhythmic or high frequency. Gain may need to be increased to detect it.
	Failed	Ineffective triggering, Ineffective effort, Missed trigger, Wasted efforts	When a patient signal (eg, P_{mus}) fails to trigger inspiration.	Airway pressure drops below baseline or flow moves toward baseline without triggering a machine breath.
Inspiration	Normal		Passive (no inspiratory effort)	No major evidence of P_{mus} during inspiration; breath may be patient triggered, but P_{mus} does not deform expected waveform.
	Work shifting	Flow starvation, Flow asynchrony, Flow limited, Insufficient flow	Some portion of the total work is done by the ventilator and some by the patient. Severe work shifting occurs when the inspiratory pressure drops below the baseline (PEEP).	Work shifting: flow or pressure waveform deformations consistent with P_{mus}. If airway pressure during inspiration drops below baseline, this is consistent with severe work shifting. When pressure is above baseline, it is likely clinically acceptable.
Cycle	Normal		Inspiration ends within an acceptable time after P_{mus} peaks.	Flow is deformed by presence of P_{mus}. Transition from inspiratory to expiratory flow occurs without evidence of end-inspiratory zero flow or evidence of inspiratory P_{mus} during early exhalation.
	Early	Premature cycling, Premature ventilator-terminated breath, Premature termination, Short cycling	When inspiration ends before the end of patient effort (P_{mus} peak).	Early expiratory flow demonstrates evidence of inspiratory effort (P_{mus}); flow waveform is deviated toward baseline.
	Late	Prolonged cycling, Delayed cycling, Runaway phenomena, Delayed termination	When the inspiration cycles after the end of patient effort (delay after the P_{mus} peak).	In a patient with inspiratory P_{mus}, the end-inspiratory flow demonstrates zero flow with or without concomitant increase in airway pressure.
Expiration	Normal		Passive (no expiratory effort)	Exponential decay of the flow waveform.
	Expiratory work	None	Evidence of increased expiratory flow compared to passive expiration.	The flow waveform moves away from baseline.