

Chapter 03: How a Breath Is Delivered

Cairo: Pilbeam's Mechanical Ventilation: Physiological and Clinical Applications, 6th Edition

MULTIPLE CHOICE

1. The equation of motion describes the relationships between which of the following?
 - a. Pressure and flow during a mechanical breath
 - b. Pressure and volume during a spontaneous breath
 - c. Flow and volume during a mechanical or spontaneous breath
 - d. Flow, volume, and pressure during a spontaneous or mechanical breath

ANS: D

The mathematical model that relates pressure, volume, and flow during ventilation is known as the equation of motion for the respiratory system. This means that: Muscle pressure + Ventilator pressure = (Elastance \times Volume) + (Resistance \times Flow).

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2. The equation of motion is represented by which of the following?
 - a. $P_{TA} = P_A \times R_{aw}$
 - b. $P_{TR} = P_{aw} + P_A$
 - c. $P_{vent} + P_{mus} = R_{aw} + P_{TA}$
 - d. $P_{vent} + P_{mus} = R_{aw} \times P_A$

ANS: B

The transrespiratory pressure (P_{TR}) is the pressure generated by either the patient contracting the respiratory muscles or by the ventilator pushing the volume into the patient. This pressure is opposed by the elastic recoil pressure (P_E) and the flow resistance pressure (P_R). The transairway pressure (P_{TA}) is the pressure gradient between the airway opening and the alveolus. This produces airway movement in the conductive airways. It represents only part of the equation of motion, the pressure needed to overcome the airway resistance. The equation of motion may be represented, on one side, by $P_{vent} +$ muscle pressure (P_{mus}). However, this is equal to the elastic recoil pressure (V/C) plus the flow resistance pressure ($R_{aw} \times \dot{V}$) or $P_{vent} + P_{mus} = V/C + (R_{aw} \times \dot{V})$.

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3. How many variables can a ventilator control at one time?
 - a. One
 - b. Two
 - c. Three
 - d. Four

ANS: A

As the equation of motion shows, the ventilator can control four variables: pressure, volume, flow, and time. It is important to recognize that the ventilator can control only one variable at a time.

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4. Calculate the transrespiratory pressure given the following information: volume 0.6 L; compliance 1 L/cm H₂O; airway resistance 3 cm H₂O/L/sec; flow 1 L/sec.
- 0.9 cm H₂O
 - 1.8 cm H₂O
 - 3.6 cm H₂O
 - 4.6 cm H₂O

ANS: C

Transrespiratory pressure (P_{TR}) = $P_{vent} + P_{mus} = V/C + (R_{aw} \times \dot{V})$.

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5. An increase in airway resistance during volume-controlled ventilation will have which of the following effects?
- Volume increase
 - Flow decrease
 - Pressure increase
 - Rate decrease

ANS: C

When a ventilator is volume-controlled the ventilator will maintain the volume, which will remain unchanged, along with the flow, but the pressure will vary with changes in lung characteristics. An increase in airway resistance will require more pressure to deliver the set volume. The set rate is independent of the changes in pressure.

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6. An increase in airway resistance during pressure-targeted ventilation will have which of the following effects?
- Volume decrease
 - Flow increase
 - Pressure increase
 - Rate decrease

ANS: A

During pressure-targeted (pressure-controlled) ventilation, pressure is unaffected by changes in lung characteristics. However, an increase in airway resistance will cause less volume to be delivered and will change the flow waveform. The set pressure will not be able to overcome the increased resistance, resulting in less volume delivery and a decrease in flow (V/T_I).

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7. A patient who has a decrease in lung compliance due to acute respiratory distress syndrome during volume-limited ventilation will cause which of the following?
- Increased volume delivery
 - Increased peak pressure
 - Decreased flow delivery
 - Decreased peak pressure

ANS: B

When a patient is being ventilated in a volume-limited mode the ventilator will maintain the volume, which will remain unchanged, along with the flow, but the pressure will vary with changes in lung characteristics. A decrease in lung compliance will cause the amount of pressure needed to overcome elastance to increase. This will increase the peak pressure needed to deliver the set volume. Flow and volume will remain constant.

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8. During pressure-targeted ventilation the patient's airway resistance decreases to normal due to medication delivery. The ventilator will respond with which of the following changes?
1. Altered flow waveform
 2. Increased pressure
 3. Increased volume
 4. Decrease volume
- a. 1 and 3 only
 - b. 2 and 4 only
 - c. 1 and 4 only
 - d. 1, 2, and 3 only

ANS: A

During pressure-targeted ventilation the pressure remains constant and the flow and volume will respond to changes in the patient lung and airway characteristics. An improvement in airway resistance will make it easier to put more volume into the lungs with the same pressure setting as compared to volume delivery with increased airway resistance. Since volume and flow waveform will vary with changes in airway resistance, the volume will increase and the flow waveform will change with improvements in airway resistance. In pressure-targeted ventilation the pressure does not change. A decreased volume would be the result of worsening airway resistance.

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9. High-frequency oscillators control which of the following variables?
- a. Flow
 - b. Time
 - c. Volume
 - d. Pressure

ANS: B

High-frequency oscillators control both inspiratory and expiratory time.

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10. The ventilator variable that begins inspiration is which of the following?
- a. Cycle
 - b. Limit
 - c. Trigger
 - d. Baseline

ANS: C

The trigger mechanism ends the expiratory phase and begins the inspiratory phase. Limit is the maximum value that a variable may reach during inspiration. Cycle terminates the inspiratory phase. The baseline variable is applied during exhalation and is the pressure level from which a ventilator breath begins.

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11. The trigger variable in the controlled mode is which of the following?
- Flow
 - Time
 - Pressure
 - Volume

ANS: B

In the controlled mode the ventilator initiates all the breathing because the patient cannot. All ventilator initiated breaths are time triggered. Flow, pressure, and volume triggers are patient initiated.

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12. A patient who has been sedated and paralyzed by medications is being controlled by the ventilator. The set rate is 15 breaths/min. How many seconds does it take for inspiration and expiration to occur?
- 2 seconds
 - 4 seconds
 - 6 seconds
 - 8 seconds

ANS: B

$60 \text{ sec/min} \div 15 \text{ breaths/min} = 4 \text{ seconds}$

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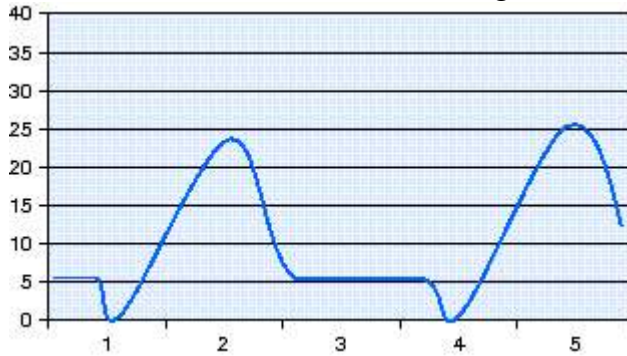
13. The most commonly used patient-trigger variables include which of the following?
- Flow
 - Time
 - Pressure
 - Volume
- 1 and 3 only
 - 2 and 4 only
 - 1 and 4 only
 - 2 and 3 only

ANS: A

The patient trigger variables are flow, pressure, and volume. Time is the ventilator trigger variable. The most common of the three patient triggers are flow and pressure. Very few ventilators use volume as a patient trigger.

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14. A patient is receiving volume-controlled ventilation. The respiratory therapist notes the pressure-time scalar on the ventilator screen, shown in the figure. The most appropriate action to take includes which of the following?



- Increase the rate setting.
- Increase the baseline setting.
- Decrease the volume setting.
- Increase the sensitivity setting.

ANS: D

What is being shown in the figure is a trigger pressure of 5 cm H₂O below the baseline setting of 5 cm H₂O. This is seen during the pressure trigger dropping down to 0 cm H₂O during the trigger. In this situation the machine is not sensitive enough to the patient's effort. The patient is working too hard to trigger the ventilator breath. The respiratory therapist needs to increase the ventilator sensitivity control. Changing any of the other parameters will not decrease the work that the patient is doing to trigger inspiration.

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15. The inspiratory and expiratory flow sensors are reading a base flow of 5 L/min. The flow trigger is set to 2 L/min. The expiratory flow sensor must read what flow to trigger inspiration?
- 1 L/min
 - 2 L/min
 - 3 L/min
 - 4 L/min

ANS: C

Base flow minus flow trigger setting is equal to the flow needed to be sensed at the expiratory flow sensor to trigger inspiration.

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16. The patient trigger that requires the least amount of work of breathing for the patient is which of the following?
- Time
 - Flow
 - Pressure
 - Volume

ANS: B

When set properly, flow triggering has been shown to require less work of breathing than pressure triggering.

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17. The limit variable set on a mechanical ventilator will do which of the following?
- End inspiration
 - Begin inspiration
 - Control the maximum value allowed
 - Control the minimum value allowed

ANS: C

A limit variable is the maximum value a variable can attain. It limits the variable during inspiration but does not end the inspiratory phase. The cycle setting ends inspiration. The trigger variable begins inspiration, and there is no control over the minimum value.

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18. The control variables most often used to ventilate infants are which of the following?
- Volume limited, time cycled ventilation
 - Pressure limited, time cycled ventilation
 - Pressure limited, pressure cycled ventilation
 - Volume limited, volume cycled ventilation

ANS: B

Infant ventilators most often limit the pressure delivered and end inspiration using inspiratory time. Volume limited, volume cycled ventilation is volume-controlled ventilation. Pressure limited, pressure cycled ventilation is the type of breath used during intermittent positive pressure breathing (IPPB).

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19. The respiratory therapist enters the room of a patient being mechanically ventilated with volume ventilation. The high pressure alarm is sounding and the measured exhaled tidal volume is significantly lower than what is set. The variable that is ending inspiration is which of the following?
- Time
 - Flow
 - Pressure
 - Volume

ANS: C

Volume ventilation is cycled by volume. However, to protect the patient's lungs from high pressures a maximum high pressure limit is set (usually 10 cm H₂O above the average peak inspiratory pressure). Inspiration ends prematurely when the high pressure limit is reached, independent of the set volume. This is the reason why the exhaled tidal volume reading is significantly lower than the set volume. Therefore, the variable ending inspiration in this instance is pressure.

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20. The variable that a ventilator uses to end inspiration is known as which of the following?

- a. Cycle
- b. Limit
- c. Trigger
- d. Baseline

ANS: B

Cycle is the term used to call the variable that is used to end inspiration. Limit is the maximum setting for a variable. Trigger is the term used to call the variable that is used to begin inspiration. Baseline is the pressure at the end of inspiration.

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21. When the maximum pressure limit is reached during volume ventilation, which of the following occurs?
- 1. Inspiratory time is decreased.
 - 2. Volume delivered is decreased.
 - 3. Inspiration continues until volume is delivered.
 - 4. Pressure is held and the breath is volume cycled.
- a. 3 only
 - b. 4 only
 - c. 1 and 2 only
 - d. 2 and 4 only

ANS: C

The maximum pressure limit is a safety mechanism used during volume ventilation to avoid excessive pressure in the lungs. When the pressure measured by the ventilator reaches the maximum pressure limit inspiration ends. This means that the inspiratory time will be decreased and the volume delivered will be less than the set volume. Therefore, reaching maximum pressure limit causes the delivered breath to be pressure cycled.

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22. The respiratory therapist is called to a patient's room because the "alarms are ringing." When the respiratory therapist arrives at the bedside, the high pressure limit, low exhaled tidal volume, and low exhaled minute volume alarms are active. The cause of these alarms is which of the following?
- a. Disconnection from the ventilator.
 - b. Critical leak in the ventilator circuit.
 - c. Lung compliance has improved.
 - d. Airway resistance has increased.

ANS: D

The low exhaled tidal volume and minute volume alarms are active when the high pressure limit alarm is active. This occurs because reaching the set high pressure limit setting will end inspiration immediately by pressure cycling and thereby will decrease the volume delivered to the patient. When the high pressure limit alarm is active for several breaths, the low exhaled tidal volume and then the minute ventilation alarms will become active. The high pressure alarm will sound when airway resistance is elevated (e.g., asthma). A disconnect from the ventilator or a critical leak would cause the low peak inspiratory pressure alarms to ring. Improved lung compliance will lower the peak inspiratory pressure and may trigger a low pressure alarm.

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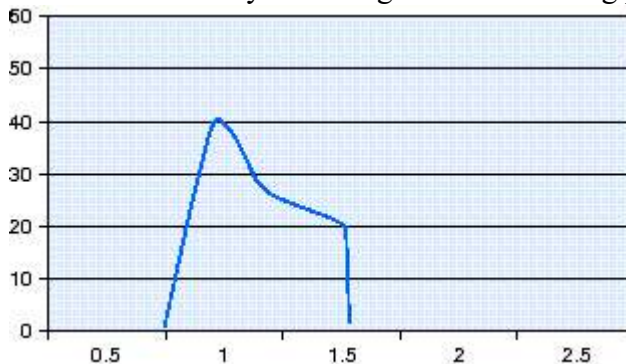
23. The most common method of terminating inspiration during pressure support ventilation is which of the following?
- Flow
 - Time
 - Pressure
 - Volume

ANS: A

During pressure support ventilation, when a breath is delivered, the flow will begin to taper down after a very short period of time. When flow drops to a certain percentage of the initial peak flow the ventilator flow cycles out of inspiration. A time cycled breath is usually a breath that is controlled by the ventilator during pressure control ventilation. Pressure cycling is used for intermittent positive pressure breathing (Bird Mark 7). Volume cycling is utilized during ventilator breaths on certain ventilators.

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24. What is the flow-cycle setting for the following pressure supported breath?



- 20%
- 30%
- 40%
- 50%

ANS: D

The peak flow for this pressure supported breath is 40 L/min. The breath flow cycled at 20 L/min, which is 50% of the peak flow. Therefore, the flow-cycle setting is 50%.

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25. Which maneuver will maintain air in the lungs at the end of inspiration, before the exhalation valve opens?
- Pressure limit
 - Inspiratory hold
 - Expiratory hold
 - Expiratory resistance

ANS: B

The inspiratory hold, inspiratory pause, or end-inspiratory pause is the maneuver that will maintain air in the lungs and extend inspiration. Pressure limit allows pressure to rise but not exceed a pressure limit setting. Expiratory hold is the maneuver that will obtain the unintended positive end expiratory pressure (auto-PEEP) measurement. The ventilator pauses before delivering the next machine breath. Expiratory resistance is a resistance added to exhalation to mimic pursed-lip breathing.

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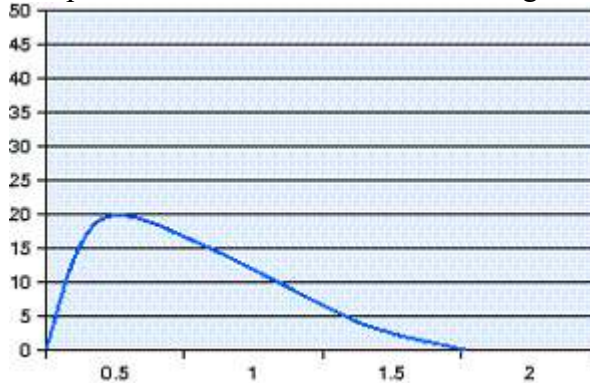
26. The ventilator that can provide a negative pressure during the very beginning of the exhalation phase is which of the following?
- Servoⁱ
 - VIASYS Avea
 - Puritan Bennett 840
 - Cardiopulmonary Venturi

ANS: D

The Cardiopulmonary Venturi applies a negative pressure to the airway only during the very beginning of the exhalation phase. This facilitates removal of air from the patient circuit and is intended to reduce the resistance to exhalation throughout the circuit at the start of exhalation.

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27. The pressure-time scalar shown in the figure could be caused by which of the following?



- Inspiratory hold
- Clogged expiratory filter
- Excessive secretions in the airway
- Negative end expiratory pressure

ANS: B

What is being shown in the figure is a peak pressure of 20 cm H₂O and then a very slow drop in the pressure over the course of approximately 1 second. Normally, as soon as the peak inspiratory pressure is reached, the pressure drops rapidly and remains at baseline until the next breath is given. A clogged expiratory filter will increase the resistance in the filter. This will cause there to be difficulty exhaling through this filter, showing up as a slow drop in pressure during the exhalation period. An inspiratory hold would cause there to be a plateau in the pressure-time scalar. Excessive secretions in the airway would elevate the peak inspiratory pressure to a point where the maximum safety pressure may be reached. The presence of negative end-expiratory pressure (NEEP) would pull the pressure down rapidly from the peak and drop it slightly below the baseline during that time.

REF: pg. 38

28. A ventilator is set to deliver a 600 mL tidal volume. The flow rate is set at 40 L/min and the frequency is set at 10 breaths/min. If the flow rate is doubled and the patient is not assisting, which of the following will occur?
- The frequency will decrease.
 - The tidal volume will increase.
 - The expiratory time will increase.
 - The inspiratory time will increase.

ANS: C

If you manipulate the formula: $\text{Flow} = \text{Volume change}/\text{Time}$ to $\text{Volume}/\text{Flow} = \text{Time}$, and use the numbers from this example, it can be shown that by increasing the flow rate the inspiratory time will decrease. Since the frequency remains constant, then the inspiratory time will decrease, thereby increasing expiratory time.

REF: pg. 38

29. The variable that controls exhalation is known as which of the following?
- Limit
 - Trigger
 - Pressure
 - Baseline

ANS: D

The baseline variable is the parameter that generally is controlled during exhalation. Although either volume or flow could serve as a baseline variable, pressure is the most practical choice and is used by all modern ventilators.

REF: pg. 29

30. In pressure targeted ventilation the trigger variable for a patient who is sedated is which of the following?
- Time
 - Flow
 - Volume
 - Pressure

ANS: A

When the patient is not triggering a breath, as with sedation, the set mechanical ventilator rate will be time-triggered based on the backup set rate.

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