Mechanical Ventilation: Waveform Interpretation (Respiratory Therapy)

ALERT

If a mechanical ventilator malfunction is suspected, remove the patient from the ventilator immediately and begin manual ventilation with a resuscitation bag.

OVERVIEW

Mechanical ventilators include waveform graphics, which are graphic representations of changes in pressure, flow, and volume within a ventilator circuit. Acquiring an understanding of these graphics takes time and practice. Respiratory therapists (RTs) caring for patients who are critically ill need to monitor patient–ventilator interactions at the bedside. RTs must be able to assess waveform graphics to determine patient–ventilator synchrony. The challenge for RTs is to provide ventilatory support that is synchronized with the patient's effort and drive.

The use of ventilator flow and pressure waveforms allows detection of asynchrony. Asynchrony, which occurs frequently, is associated with significant patient discomfort and distress and poor clinical outcomes (e.g., duration of mechanical ventilation, intensive care unit, and hospital stay). It can occur during all phases of ventilated breaths and all modes of ventilation.[2]

Common waveform graphics include pressure-time, flow-time, and volume-time waveforms. Pressure-volume and flow-volume loops are also commonly used. A ventilator-assisted or ventilator-controlled breath can be divided into these parts: breath initiation, commonly termed triggering; breath delivery; breath termination, commonly termed cycling; and mechanical exhalation, which occurs when the patient is not receiving any assistance from the ventilator.

Understanding ventilator-derived waveforms requires a basic knowledge of pulmonary physiology. The RT should be able to interpret the waveforms that reflect how the pulmonary system is responding to changes in the ventilator prescription. Application of common therapeutics is implementable and traceable using graphic analysis.[3] Patient–ventilator asynchrony can occur in both volume and pressure modes of ventilation, and the inspiratory time is critical to establishing the correct mean airway pressure waveforms. The range of inspiratory time should be between 0.6 and 1 second, depending on the patient's pulmonary mechanics.[1] Excessive inspiratory times lead to excessive overdistention of the alveoli and air trapping.

Waveform graphics are often used to determine if a patient is being overventilated or underventilated and if he or she has inadvertent or intrinsic positive end-expiratory pressure (PEEP). The graphic for auto-PEEP would show the breath not returning to baseline before the subsequent breath is given. Waveform interpretation can help RTs determine if the patient has increased or decreased lung compliance and airway resistance. Waveform interpretation has also been used to determine if a patient has lung function improvement after the administration of a bronchodilator.

Waveform graphics also assist the RT in determining if the inspiratory time is set appropriately for the patient, which is important in improving patient–ventilator synchrony. The flow and volume graphic should represent a smooth transition from inspiration to expiration. If the flow graphic shows a drop-off that does not go smoothly to baseline, it indicates an inspiratory time that is too short. If the volume graphic is flat at the top instead of rising to a peak and then declining, this indicates that the inspiratory time is too long for the patient. A beak appearance at the top of the pressure-volume loop indicates pressure in excess of volume benefit.

EDUCATION

- Explain the procedure to the patient and family.
- Discuss the potential benefits of mechanical ventilation waveform interpretation.
- Explain what to expect while the patient is ventilated.
- Encourage questions and answer them as they arise.

ASSESSMENT AND PREPARATION

Assessment

1. Perform hand hygiene before patient contact.
2. Introduce yourself to the patient.
3. Verify the correct patient using two identifiers.
4. Assess the need for mechanical ventilation before initiating ventilator support.

a. Acid-base imbalance
b. Adventitious breath sounds
c. Altered level of consciousness
d. Cyanosis
e. Decreased oxygen saturation
f. Hemodynamic stability
g. Hypotension or hypertension
h. Patient's inability to maintain his or her airway
i. Increased work of breathing
j. Signs and symptoms of respiratory insufficiency or failure (e.g., hypercapnia secondary to hypoventilation, hypoxia)

5. Assess the waveforms for signs of ventilator asynchrony.
6. Assess the patient's comfort level.

Preparation

1. Perform a ventilator precheck and circuit leak test before use. Make sure that the patient has been removed from mechanical ventilation and is being supported with manual ventilation and oxygen before performing these procedures.
2. Ensure that the ventilator graphic interface is functioning properly using a test lung.
3. Ensure that a resuscitation bag with mask is at the bedside.
4. Ensure that suction is set properly and functioning at the bedside.

PROCEDURE

1. Perform hand hygiene and don gloves.
2. Verify the correct patient using two identifiers.
3. Explain the procedure to the patient and ensure that he or she agrees to treatment.
4. Turn on the ventilator graphics to the selected waveform measurement.
5. Interpret waveforms to detect:

a. Leaks in the system
b. Lung compliance issues

c. Correct inspiratory time
d. Possible airway obstruction
e. Lung overinflation or inadvertent PEEP
f. Trigger asynchrony
g. Flow asynchrony
h. Cycling asynchrony

6. Discard supplies, remove gloves, and perform hand hygiene.
7. Document the procedure in the patient's record.

MONITORING AND CARE

1. Monitor the patient's vital signs, including heart rate, respiratory rate (both mechanical and spontaneous), and blood pressure. Monitor oxygen saturation by pulse oximetry and end-tidal carbon dioxide ($ETCO_2$) levels.
2. Monitor the mechanical ventilator to ensure that it is performing properly and is receiving power from a source that has backup power.
3. Carefully monitor the patient's peak inspiratory pressure, mean airway pressure, and inspiratory and expiratory volumes.

    Rationale: Rising peak inspiratory pressure can indicate a change in compliance or the need for suctioning.

    Rationale: Patients receiving pressure ventilation can show an increase or decrease in exhaled volumes with a change in compliance. If compliance decreases, volumes decrease; if compliance increases, volumes increase.

    Rationale: Patients receiving volume ventilation can show an increase or decrease in pressure with changes in compliance. If compliance decreases, pressure increases; if compliance increases, pressure decreases.

4. Monitor the mechanical ventilator mode, set breath rate, volume or pressure settings, PEEP setting, flow settings, and fraction of inspired oxygen (FIO_2).
5. Monitor the waveform graphics for auto-PEEP.
6. Monitor the waveform graphics for appropriate inspiratory times.
7. Monitor the waveform graphics for patient–ventilator synchrony or asynchrony.
8. Monitor the waveform graphics for excessive moisture in the circuit. Waveform graphics are smooth lines, so a wavy graphic can signify water in the circuit.
9. Observe the patient for signs and symptoms of pain. If pain is suspected, report it to the authorized practitioner.

EXPECTED OUTCOMES

- Patient–ventilator synchrony
- Accurate interpretation of waveform graphics

UNEXPECTED OUTCOMES

- Patient–ventilator asynchrony
- Respiratory muscle fatigue
- Increased time spent on the ventilator
- Auto-PEEP or intrinsic PEEP

- Misinterpretation of waveform graphics

DOCUMENTATION

- Patient and family education
- Patient's vital signs
- Mechanical ventilator performing properly and receiving power from a source that has backup power
- Resuscitation bag with mask at the bedside
- Suction set properly and functioning at the bedside
- Peak inspiratory pressure, mean airway pressure and volumes (both inspiratory and expiratory)
- Mechanical ventilator mode, set breath rate, volume or pressure settings, PEEP setting, flow settings, and F_{IO_2}
- Waveform graphic abnormalities
- Unexpected outcomes and related interventions

HOME CARE CONSIDERATIONS

- Home health ventilators are available, but most do not have waveform graphics capabilities.

REFERENCES

1. Kacmarek, R.M. (2017). Chapter 47: Patient–ventilator interactions. In R.M. Kacmarek, J.K. Stoller, A.J. Heuer (Eds.), *Egan's fundamentals of respiratory care* (11th ed., pp. 1058-1077). St. Louis: Elsevier.
2. Mellott, K.G. and others. (2014). Patient ventilator asynchrony in critically ill adults: Frequency and types. *Heart & Lung, 43*(3), 231-243. doi:10.1016/j.hrtlng.2014.02.002 (Level IV)
3. Ramirez, I.I. and others. (2017). Ability of ICU health-care professionals to identify patient-ventilator asynchrony using waveform analysis. *Respiratory Care, 62*(2), 144-149. doi:10.4187/respcare.04750 (Level IV)

Elsevier Skills Levels of Evidence

- Level I - Systematic review of all relevant randomized controlled trials
- Level II - At least one well-designed randomized controlled trial
- Level III - Well-designed controlled trials without randomization
- Level IV - Well-designed case-controlled or cohort studies
- Level V - Descriptive or qualitative studies
- Level VI - Single descriptive or qualitative study
- Level VII - Authority opinion or expert committee reports

Supplies

- Gloves
- Mechanical ventilator with waveform graphic display
- Cuff pressure manometer
- Endotracheal tube holder
- Tracheostomy tube holder

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- ET_{CO_2} measuring device
- Pulse oximeter
- Resuscitation bag with mask
- Stethoscope
- Suction
- Ventilator circuit

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