Mechanical Ventilation: Airway Pressure Release Ventilation (Respiratory Therapy)

ALERT

Airway pressure release ventilation (APRV) is not recommended in patients who require deep sedation.

Ventilator failure or accidental disconnection can be catastrophic in patients undergoing neuromuscular blockade. Neuromuscular blockade can eliminate patient-ventilator asynchrony but not with a mode of ventilation requiring a spontaneously breathing patient.

OVERVIEW

APRV is a time-triggered, pressure-limited, time-cycled mode of ventilation that allows unrestricted spontaneous breathing throughout the entire ventilatory cycle. By allowing patients to spontaneously breathe during APRV, dependent lung regions may be preferentially recruited without the need to raise applied airway pressure. APRV is a lung-protective strategy that helps to meet the goals of acute respiratory distress syndrome (ARDS) management and to diffuse pneumonia and atelectasis by maximizing alveolar recruitment while limiting the transalveolar pressure gradient and barotrauma.

Conceptually, APRV applies a high continuous positive airway pressure (CPAP) (P high) identical to CPAP for a prolonged time (T high) to maintain adequate lung volume and promote alveolar recruitment. However, APRV adds a time-cycled release phase to a lower set CPAP (P low) for a short period of time (T low or release time) where most of the ventilation and carbon dioxide removal occurs. The goal is to maintain adequate oxygenation and ventilation without obvious lung distention during P high and to avoid lung derecruitment and intrinsic positive end-expiratory pressure (PEEP) during P low.

Very few randomized controlled trials have been conducted to study APRV, and consensus among practitioners regarding initial APRV settings is limited.[8] A time-controlled adaptive ventilation (TCAV) protocol should be used to establish appropriate APRV settings for each patient.[6]

Given the current focus on the deleterious side effects of sedation medication and neuromuscular blockade, including delirium,[5] APRV may begin to gain favor among practitioners, particularly when compared with high-frequency oscillatory ventilation (HFOV), which requires far deeper sedation levels and, in many cases, neuromuscular blockade.[7] APRV has been shown to improve oxygenation, achieve a better ventilation–perfusion match, and decrease dead space compared with conventional mechanical ventilation.[4]

In APRV, the extended inspiratory time allows for an increase in the mean airway pressure (MAP) and improvement in oxygenation. Increasing the T high and P high increases MAP and lengthens the time for gas mixing, thereby optimizing the gas exchange surface area to promote oxygenation.

When the measured arterial partial pressure of carbon dioxide ($Paco_2$) becomes extreme, shortening T high increases the frequency with which carbon dioxide is released. $Paco_2$ may increase if T high is increased, P high is decreased, or T low is decreased.

Mechanical Ventilation: Airway Pressure Release Ventilation (Respiratory Therapy)

Patients who have obstructive lung disease with airflow obstruction and who require a prolonged expiratory time may not benefit from APRV because of patient-ventilator asynchrony (i.e., auto-PEEP and inverse inspiratory-to-expiratory [I:E] ratios).

EDUCATION

- Provide developmentally and culturally appropriate education based on the desire for knowledge, readiness to learn, and overall neurologic and psychosocial state.
- Explain the need for ventilator changes to the patient and family.
- 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. Observe the patient for signs of ARDS.

a. Decreasing partial pressure of arterial oxygen/fraction of inspired oxygen (PaO_2/FIO_2) ratio
b. Increasing plateau pressures or peak airway pressures
c. Bilateral infiltrates on a chest radiograph

Preparation

1. Before initiating mechanical ventilation, check the system microprocessor or ventilation system. Perform a short self-test as appropriate.

a. Verify compliance of the heat-moisture exchanger (HME), humidifier, and filters (if needed).
b. Document the completed ventilation system test. Include pass or fail, date, and initials or signature and credentials of the respiratory therapist (RT).

2. Verify the authorized practitioner's order for the initiation of mechanical ventilation.
3. Use a TCAV protocol to guide ventilator settings and strategy when using APRV.

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 the patient agrees to treatment.
4. Transition the patient to APRV from conventional ventilator settings.

a. Set P high by using the measured plateau pressure of the volume-controlled mode or the set peak airway pressure of the pressure-controlled mode to obtain an expired minute ventilation that is several liters per minute less than when on a conventional mode of ventilation. Typically, the maximum goal for P high is 30 cm H_2O.[9]

> Rationale: Limiting P high to 30 cm H_2O may minimize ventilator-associated lung injury.[9]

b. Set P low at 0 cm H_2O.[9]

Mechanical Ventilation: Airway Pressure Release Ventilation (Respiratory Therapy)

Rationale: P low of 0 produces minimal expiratory resistance and facilitates rapid pressure drops, thus accelerating unimpeded expiratory flow rates.[3]

c. Set T high from 3 to 6 seconds and adjust according to the patient's needs.[9]

Rationale: T high of less than 3 seconds begins to negatively impact mean airway pressure and recruitment. Extending the T high period may be required to enhance carbon dioxide clearance.[4]

d. Set T low from 0.5 to 0.8 seconds as determined by analysis of the expiratory gas flow curve.[9]

Rationale: The goal is to terminate expiratory gas flow at about 75% to 50% of the peak expiratory flow rate to prevent the peak expiratory flow from returning to a zero baseline.[3] T low should be short enough to prevent derecruitment and long enough to obtain a suitable tidal volume (V_T).[4]

5. Transition the patient who is newly intubated to APRV.

a. Set P high to a maximum of 30 cm H_2O (this higher transalveolar pressure recruits the lungs).[9]
b. Set P low at 0 cm H_2O.[3]
c. Set T high from 3 to 6 seconds and adjust according to the patient's needs.[9]
d. Set T low from 0.5 to 0.8 seconds.[9]
e. Set F_{IO_2} for the desired Pa_{O_2} or arterial oxygen saturation (Sa_{O_2}) level.

6. Transition the patient to APRV from HFOV.

a. Set P high with MAP on HFOV *plus* 2 to 4 cm H_2O.
b. Set P low at 0 cm H_2O.[9]
c. Set T high from 3 to 6 seconds and adjust according to the patient's needs.[9]
d. Set T low from 0.5 to 0.8 seconds (acute restrictive lung disease) or from 0.8 to 1.5 seconds (acute obstructive lung disease).[1]

7. Adjust settings based on the patient's arterial blood gas (ABG) values, expiratory gas flow pattern, and clinical status.

a. To decrease Pa_{CO_2}:

i. Decrease T high to no shorter than 3 seconds.[3]

Rationale: A shorter T high means more releases per minute.

ii. Increase P high to increase MAP and volume exchange in 2– to 3–cm H_2O increments.[9]

Monitor V_T and peak inspiratory pressure, which is best below 30 cm H_2O.[3]

Mechanical Ventilation: Airway Pressure Release Ventilation (Respiratory Therapy)

iii. Check T low. If possible, increase T low to allow more time for exhalation.

b. To increase $PaCO_2$:

i. Increase T high (fewer releases per minute) slowly.
ii. Decrease P high to lower MAP. Monitor oxygenation and avoid derecruitment. Accepting hypercapnia may be better than reducing P high so much that oxygenation decreases.

c. To increase PaO_2:

i. Increase FIO_2.
ii. Increase MAP by increasing P high in 2–cm H_2O increments.[2]
iii. Increase T high slowly (in 0.5-second increments).[9]
iv. Use recruitment maneuvers.
v. Consider shortening T low in 0.1-second increments (this may reduce V_T and affect $PaCO_2$).[2]

8. Evaluate the patient's scenario and follow these steps for weaning.

a. Wean FiO_2 to 40% first to rule out refractory hypoxemia.
b. Reduce the level of P high ("drop") and reduce the number of releases by increasing the T high ("stretch") until the mode is converted to a CPAP of 15 cm H_2O.[2]

> Rationale: The primary method to wean support in APRV is the "drop and stretch method." Increased P high and increased T high improves oxygenation. Manipulation of P low and T low regulates end-expiratory lung volume.

i. Decrease P high in 2– to 3–cm H_2O increments while simultaneously lengthening T high in 0.5- to 2-second increments.[1]
ii. Decrease P high until it meets P low.
iii. P high is typically 14 to 16 cm H_2O or less, and T high is approximately 12 to 15 seconds.[1]

c. Add pressure support as needed to augment spontaneous breathing efforts. The time interval between changes is patient dependent.

> Rationale: Too long a time interval lengthens stay in the intensive care unit; too short a time interval promotes alveolar collapse.

9. Remove gloves and perform hand hygiene.
10. Document the procedure in the patient's record.

MONITORING AND CARE

1. Monitor the patient's hemodynamic status.
2. Report any signs of increase in MAP.
3. Continuously monitor the patient's peripheral oxygen saturation (SpO_2).
4. Assess the patient's exhaled minute volume.
5. Assess the patient's end-tidal carbon dioxide ($ETCO_2$) level.

Mechanical Ventilation: Airway Pressure Release Ventilation (Respiratory Therapy)

6. Monitor the patient's ABG values as needed.
7. Assess the patient's overall level of comfort.
8. To minimize lung derecruitment, consider using a closed suction system to minimize the number of times the patient is disconnected from the ventilator.
9. Observe the patient for signs or symptoms of pain. If pain is suspected, report it to the authorized practitioner.

EXPECTED OUTCOMES

- Improved oxygenation
- Improved ventilation
- Improved patient comfort
- Lung recruitment
- Minimal ventilator-induced lung injury
- Liberation from mechanical ventilation

UNEXPECTED OUTCOMES

- Lung overdistention
- Worsening oxygenation
- Worsening ventilation
- Increase in lung infiltrates

DOCUMENTATION

- P high
- P low
- T high
- T low
- FIO_2
- Minute volume
- Spontaneously breathing at a reasonable rate (e.g., 10 to 25 breaths/min)
- Work of breathing
- Spontaneous exhaled volume
- MAP
- SpO_2
- $ETCO_2$
- Patient's tolerance of procedure
- Education
- Unexpected outcomes and related interventions

REFERENCES

1. Cairo, J.M. (Ed.). (2020). Chapter 5: Selecting the ventilator and the mode. In *Pilbeam's mechanical ventilation: Physiological and clinical applications* (7th ed., pp. 58-79). St. Louis: Elsevier.
2. Farkas, J. (2017). PulmCrit- APRV: Resurrection of the open-lung strategy? Retrieved March 20, 2020, from https://emcrit.org/pulmcrit/aprv/
3. Hess, D.R., Kacmarek, R.M. (Eds.). (2019). Chapter 8: Advanced modes of mechanical ventilation. In *Essentials of mechanical ventilation*. (4th ed., pp.73-86). New York: McGraw-Hill Education.

Mechanical Ventilation: Airway Pressure Release Ventilation (Respiratory Therapy)

4. Holt, G.A., Habib, S.A., Shelledy, D.C. (2020). Chapter 3: Principles of mechanical ventilation. In D.C. Shelledy, J.I. Peters (Eds.), *Mechanical ventilation* (3rd ed., pp. 95-154). Burlington, MA: Jones & Bartlett Learning.
5. Kenes, M. and others. (2015). The persistence of ICU delirium after cessation of sedatives and analgesics. *Critical Care Medicine, 43*(12), 151. doi:10.1097/01.ccm.0000474426.40750.09 (Level III)
6. Kollisch-Singule, M. and others. (2019). The time-controlled adaptive ventilation protocol: Mechanistic approach to reducing ventilator-induced lung injury. *European Respiratory Review, 28*(152). doi:10.1183/16000617.0126-2018 (Level III)
7. Mallory, P., Cheifetz, I. (2020). A comprehensive review of the use and understanding of airway pressure release ventilation. *Expert Review of Respiratory Medicine*, 14(3), 307-315. doi:10.1080/17476348.2020.1708719 (Level VII)
8. Miller, A.G. and others. (2017). Clinical management strategies for airway pressure release ventilation: A survey of clinical practice. *Respiratory Care, 62*(10), 1264-1268. doi:10.4187/respcare.05494 (Level III)
9. Shelledy, D.C., Peters, J.I. (2020). Chapter 6: Ventilation initiation. In D.C. Shelledy, J.I. Peters (Eds.), *Mechanical ventilation* (3rd ed., pp. 311-366). Burlington, MA: Jones & Bartlett Learning.

ADDITIONAL READINGS

Cairo, J.M. (Ed.). (2020). Chapter 17: Effects of positive pressure ventilation on the pulmonary system. In *Pilbeam's mechanical ventilation: Physiological and clinical applications* (7th ed., pp. 307-332). St. Louis: Elsevier.
Mireles-Cabodevila, E. (2016). Should airway pressure release ventilation be the primary mode in ARDS. *Respiratory Care, 61*(6), 761-773. doi:10.4187/respcare.04653
Nieman, G.F. and others. (2020). Prevention and treatment of acute lung injury with time-controlled adaptive ventilation: Physiologically informed modification of airway pressure release ventilation. *Annals of Intensive Care, 10*(1), 3. doi:10.1186/s13613-019-0619-3
Shelledy, D.C., Peters, J.I. (2020). Chapter 7: Patient stabilization: Adjusting ventilatory support. In D.C. Shelledy, J.I. Peters (Eds.), *Mechanical ventilation* (3rd ed., pp. 367-400). Burlington, MA: Jones & Bartlett Learning.

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 APRV mode of ventilation
- $ETCO_2$ monitor (optional)
- Pulse oximeter

Clinical Review: Alan Roth, MS, RRT-NPS, RPFT, FAARC, FCCP
Published: April 2020

