

AARC Clinical Practice Guideline

Selection of Device, Administration of Bronchodilator, and Evaluation of Response to Therapy in Mechanically Ventilated Patients

BDMV 1.0 PROCEDURE:

Device selection, bronchodilator administration, and evaluation of response to therapy during mechanical ventilation. The reader is referred to previously published Guidelines addressing aspects of aerosol administration and delivery.¹⁻⁴

BDMV 2.0 DESCRIPTION:

The selection of a device and strategy for administration, the administration, and the evaluation of response of patients to bronchodilator aerosol during mechanical ventilation.

2.1 Devices include metered dose inhaler (MDI) with adapter and chamber or inline elbow and catheter; pneumatic nebulizer; small volume nebulizer (SVN) large volume nebulizer (LVN); ultrasonic nebulizer. (Although experience suggests that inhalers that dispense dry powder are not suitable for use in ventilator circuits, a recent bench study reports positive results and suggests clinical trials.⁵ Such use cannot yet be recommended.)

2.2 Aerosolized bronchodilators have been shown to be effective in adults, children, and infants receiving mechanical ventilation.⁶⁻²¹ Inhaled beta-adrenergic⁷⁻¹⁷ and anticholinergic bronchodilators^{17,18} are effective in mechanically ventilated patients. Inhaled isoproterenol hydrochloride,^{15,16} isoetharine mesylate,¹⁷ metaproterenol sulfate,¹⁸ fenoterol,¹⁹ and albuterol^{7-12,14} can all produce clinically important bronchodilation. In ventilator-supported COPD patients, fenoterol in combination with ipratropium bromide was more effective than ipratropium alone.¹⁴ Inhaled beta adrenergic and anticholinergic drugs are effective in ventilated infants and neonates with acute, subacute, and chronic lung disease.¹⁸⁻²⁰

2.3 Aerosol deposition in the lung has, in general, been shown to be reduced in intubated,

mechanically ventilated adult patients (1.0-15.3%) compared to nonintubated, ambulatory adult subjects in ambulatory adult patients (10-14%).²²

2.3.1 In-vivo studies of aerosol deposition from nebulizers during mechanical ventilation report 1.2%,²³ 2.22%,²⁴ 2.9%,²⁵ and 15.3%²⁶ in adults, and 0.22% in infants.²⁷ Similar studies using MDI reported 6-11%^{23,28} in adults and 0.9 in infants.²⁷

2.3.2 Factors that affect lower respiratory tract deposition include: aerosol device selected,^{7,10,23,24,29} how it is operated,^{24,26,30-32} its placement in relation to the ventilator circuit/patient,³³ the ventilator selected,³⁴ the ventilator settings and mode of ventilation,³⁵ humidity,^{32,35} drug formulation, drug dose, and caliber of the airway.^{29,36-38}

2.3.3 Assessment is necessary to determine the appropriate dose, optimal frequency of administration, and overall response to therapy.^{7,39} An empirical trial of bronchodilator is recommended in any mechanically ventilated patient in whom a potential indication exists.⁴⁰

2.4 Because delivery is reduced, increased doses may be required to provide desired or optimal effect. Patients should be monitored to determine effect of dose and to support initial and continued treatment.^{7-10,32.}

BDMV3.0 SETTING:

Aerosolized bronchodilator therapy via mechanical ventilator can be provided in a number of settings including: hospital, home, and subacute or extended care facility.

BDMV 4.0 INDICATIONS:

Bronchodilator aerosol administration and evaluation of response are indicated whenever bronchoconstriction or increased airways resistance is

documented or suspected in patients during mechanical ventilation:

BDMV 5.0 CONTRAINDICATIONS:

5.1 Some assessment maneuvers may be contraindicated for patients in extremis (eg, prolonged inspiratory pause for patients with high auto-PEEP).

5.2 Certain medications may be contraindicated in some patients. Consult the package insert for product-specific contraindications.

BDMV 6.0 HAZARDS/COMPLICATIONS:

6.1 Specific assessment procedures may have inherent hazards or complications: (eg, inspiratory pause, expiratory pause).⁴¹⁻⁴⁴

6.2 Inappropriate device selection or inappropriate use of device and/or technique variables may result in underdosing.⁷

6.3 Device malfunction may result in reduced drug delivery and may possibly compromise the integrity of the ventilator circuit.^{45,46}

6.4 Complications of specific pharmacologic agents. Higher doses of beta agonists delivered by an MDI or nebulizer may cause adverse effects secondary to systemic absorption of the drug or propellants. The potential for hypokalemia and atrial and ventricular dysrhythmias may exist with high doses in critically ill patients.⁴⁷⁻⁴⁹

6.5 Aerosol medication, propellants, or cold, dry gas that bypasses the natural upper respiratory tract may cause bronchospasm or irritation of the airway.⁴⁷⁻⁵⁰ Although the efficiency of aerosol delivery from an MDI can be increased by actuating the canister into a narrow gauge catheter with the catheter positioned at the end of the endotracheal tube. A study in rabbits²⁹ has shown that such introduction produces necrotizing inflammation and mucosal ulceration, probably from the topical effect of the oleic acid used for its surfactant property and the chlorofluorocarbons (CFCs). Such administration is not recommended. The results of further study are needed to support or condemn this practice.

6.6 The aerosol device or adapter used and technique of operation may affect ventilator performance characteristics and/or alter the sensitivity of the alarm systems.

6.6.1 Addition of gas to the ventilator circuit from a nebulizer may increase volumes, flows, and peak airway pressures, thus altering the intended pattern of ventilation. Ventilator setting adjustments made to accommodate the additional gas flow during nebulization must be reset at the end of the treatment.

6.6.2 Addition of gas from a nebulizer into the ventilator circuit may result in the patient's becoming unable to trigger the ventilator during nebulization,⁴⁷ leading to hypoventilation.

6.7 At least one early anecdotal report described cardiac toxicity due to CFCs used as propellants in MDIs.⁴⁸ Adverse cardiac effects are unlikely to occur with doses recommended in clinical practice because of the short half life of CFCs in the blood (< 40 s), particularly when at least a short interval is maintained between successive doses.⁴⁹

BDMV 7.0 LIMITATIONS OF PROCEDURE OR DEVICE:

7.1 During mechanical ventilation, the deposition of drug to the lower respiratory tract is reduced. Doses should be adjusted to compensate for reduced delivery. Variables should be optimized to enhance medication delivery.

7.2 Ventilator modes and settings can affect deposition. Lung-model studies suggest that low inspiratory flows, use of decelerating flow instead of square wave, tidal volume > 500 mL, and increased duty cycle (inspiratory phase) are all associated with improved aerosol deposition.^{24,26,30,31} Spontaneous inspiration through the ventilator circuit increased lung deposition compared to controlled, assist/control and pressure support ventilation.³⁵

7.3 Humidification of inspired gas during mechanical ventilation reduces aerosol deposition to the lower respiratory tract by approximately 40%.^{32,35} Because these in vitro studies suggest that humidity markedly decreases aerosol, the alternatives are to bypass the humidifier during aerosol therapy, which may dry the airway and offset the effect of the increased delivery, or to retain the humidifier and increase the dose of bronchodilator. It is probably better to retain the humidifier and increase the dose of bronchodilator.

7.4 Placement of the aerosol device in the ventilator circuit affects the amount of drug delivered to the lungs.³³ Placing the nebulizer 30 cm from the endotracheal tube is more efficient than placing it between the patient Y and the endotracheal tube because the tubing acts as a reservoir for accumulation of aerosol between inspirations.^{15,16,28} If an artificial nose is in use, it should be removed during aerosol administration.⁵¹

7.5 Coordination of aerosol generation with ventilator triggering (initiation of inspiratory gas flow) improves delivery of drug to the lung.³¹

7.6 Limitation of specific devices

7.6.1 MDI

The MDI cannot be used for the mechanically ventilated patient with the actuator designed for use by the spontaneously breathing patient with a natural airway. An actuator designed specifically for mechanical ventilation is required for actuation of an MDI into the ventilator circuit. Accessory device adapter design affects aerosol delivery and the amount of drug available to the lung.^{28,52,53}

7.6.1.1 Chamber-style adapter. Both *in vitro* and *in vivo*^{28,52,53} have found that the combination of an MDI and a chamber device results in a four- to sixfold increase in delivery of aerosol over MDI actuation into an elbow connector (without chamber) attached directly to the endotracheal tube or into an inline adapter without chamber. This correlates with clinical response studies showing clinical response with as little as 4 puffs of albuterol¹⁰ whereas an elbow adapter demonstrated no response with 100 actuations of albuterol.⁷

7.6.1.2 Small-gauge adapters with closed suction devices. No published data support the use of these adapters.

7.6.1.3 Small-gauge tracheal catheter adapter. Although initial experiments suggest high-dose delivery to the lung (> 90% *in vitro*), *in*

vivo experiments have associated endothelial damage at the carina in response to temperature and ingredients (oleic acid) of the aerosol.⁵⁰ Insufficient data are available to support clinical use of such devices at this time.^{50,54}

7.6.1.4 MDI actuation is performed manually and should be synchronized with the beginning of inspiration.^{32,35} Actuating an MDI out of synchrony with the inspiratory airflow has been shown to result in negligible aerosol delivery to the lower airway.³²

7.6.2 Small volume nebulizer

7.6.2.1 Differences in placement of nebulizer in the ventilator circuit can result in large variances in drug delivered to the lung.³³

7.6.2.2 Mass median aerodynamic diameter (MMAD) and time required for treatment may vary with type of nebulizer, different models of the same type, and gas source, pressure, and flow.

7.6.2.3 Gas flow and the pressure driving a pneumatic nebulizer may change particle size characteristics and drug output.⁵⁵⁻⁵⁹ When gas flow driving the nebulizer is from a secondary gas source (other than the ventilator), the volumes, flows, and pressures delivered by the ventilator to the patient are altered.³⁴

7.6.2.4 Nebulizer output and efficiency are affected by fill volume and flow.⁵⁵⁻⁶⁰

7.6.2.5 Nebulizers in line with the ventilator circuit tend to collect condensate when not in use and should be removed from ventilator circuit between treatments.

7.6.2.6 Nebulizers are vulnerable to contamination, posing consequent increased risk for nosocomial infection.^{61,62}

7.6.2.7 Because of the relatively large amount of medication that is exhaled by the patient or that by-

passes the patient into the expiratory limb, placing a filter in the expiratory limb may reduce drug deposition on pneumotachographs or transducers and thus help maintain their accuracy.

7.6.4 LVN:

7.6.4.1 Concentration of medication delivered may vary during treatment due to changing dilution of medication.⁶³⁻⁶⁶

7.6.4.2 Close monitoring is required.

7.6.4.3 Few units meet MMAD of 1-3 microns.⁶⁷

7.6.4.4 Devices are vulnerable to contamination.

7.6.5 USN

Although it has been suggested that the use of the USN may lead to bronchodilator delivery greater than with a comparable dose by pneumatic nebulizer, evidence is lacking.⁶⁸⁻⁷⁰

BDMV 8.0 ASSESSMENT OF NEED:

8.1 The presence of one or more of the following in the mechanically ventilated patient suggests the need for bronchodilator administration:

8.1.1 previous demonstrated response to bronchodilator;

8.1.2 presence of auto-PEEP not eliminated with reduced rate, increased inspiratory flow, or decreased inspiratory to expiratory time ratio;

8.1.3 increased airway resistance as evidenced by

8.1.3.1 increased peak inspiratory pressure and plateau pressure difference;

8.1.3.2 wheezing or decreased breath sounds;

8.1.3.3 intercostal and/or sternal retractions;

8.1.3.4 patient-ventilator dyssynchrony.

8.2 Response to therapy should be evaluated in all patients receiving bronchodilator therapy.²

BDMV 9.0 ASSESSMENT OF OUTCOME

9.1 Evaluation of need and response

9.1.1 Assessment prior to therapy:

9.1.1.1 Establish baseline condition

9.1.1.2 Ascertain clinical indicators or need for therapy

9.1.1.3 Identify possible contraindications

9.1.2 During therapy, identify:

9.1.2.1 adverse responses;

9.1.2.2 any clinical change from baseline;

9.1.2.3 lack of response.

9.1.3 Following therapy, identify

9.1.3.1 adverse responses and

9.1.3.2 presence or absence of therapeutic responses

9.1.4 For trend analysis, identify:

9.1.4.1 change in patient baseline;

9.1.4.2 need to modify dose;

9.1.4.3 need to modify therapy;

9.1.4.4 need to discontinue;

9.1.4.5 apparent changes in bronchial responsiveness.

9.2 Action based on result of assessment and evaluation:

9.2.1 increase or decrease dose;

9.2.2 change or add medications;

9.2.3 continue or discontinue therapy. (Discontinuance of bronchodilator therapy should be considered in patients in whom no objective or subjective response is seen after repeated administration.^{40,71})

9.3 Documentation

9.3.1 Patient response to medication

9.3.1.1 Medication: type, dose, and time received

9.3.1.2 Responses measured including vital signs, lung function as reflected by changes in peak inspiratory pressure (PIP), plateau pressure (P_{plat}), auto-PEEP ($PEEP_i$), and bedside observations.

9.3.1.3 Note observations relative to time of administration .

BDMV 10.0 RESOURCES

10.1 Equipment

10.1.1 Ventilator with manometer and capability to measure end-inspiratory and end-expiratory pause.

10.1.1.1 Equipment required for measuring auto-PEEP

10.1.1.2 Pneumotachograph for moni-

toring pressure, flow, and volume changes at the airway.

10.1.2 Pulse oximeter

10.1.3 Stethoscope

10.1.4 Cardiac monitor, when available

10.2 Personnel:^{72,73}

10.2.1 Level II personnel—licensed or credentialed respiratory care practitioner (eg, RRT, RPFT, CRT) or persons with documented equivalent training and ability should possess knowledge and skills to:

10.2.1.1 perform initial assessments and care for the unstable patient;

10.2.1.2 assess patient condition and response to therapy;

10.2.1.3 identify the indications for and effects of specific medication and equipment;

10.2.1.4 instruct patients in proper breathing patterns and coughing techniques;

10.2.1.5 modify technique in response to adverse reactions;

10.2.1.6 modify dosages and/or frequency according to patient response;

10.2.1.7 use proper technique for administration of aerosols.

10.2.1.8 perform and document results of auscultation, inspection, and assessment of vital signs;

10.2.1.9 perform, interpret, and document $P_{\text{insp}} - P_{\text{plat}}$ or ventilatory mechanics

10.2.1.10 understand and comply with Standard Precautions, as set forth by the Centers for Disease Control and Prevention (CDC).

10.2.1.11 Level II personnel who care for long-term ventilator-dependent patients should be able to teach family members or other designated care giver to assess need for and response to bronchodilators and develop, teach, and assess self-care plans for the patient or the family care giver.

10.2.2 Level-I personnel—licensed or credentialed respiratory care practitioner (eg, CRT, CPFT) or person with documented equivalent training and ability to:

10.2.2.1 observe, measure, monitor,

and document measures of response established by the patient's care plan (eg, use of diary and peak flow meter);

10.2.2.2 use proper technique in administering medication;

10.2.2.3 maintain and clean equipment;

10.2.2.4 instruct patients in proper breathing patterns and coughing techniques;

10.2.2.5 modify therapy in response to changes in monitored variables, severity of symptoms, or adverse reactions, and communicate any modifications with Level II provider or physician.

10.2.2.6 Understand and comply with Standard Precautions.

10.2.3 When mechanically ventilated patients are cared for in the home, the patient, family member, or designated caregiver providing routine maintenance therapy must know and demonstrate ability to:

10.2.3.1 monitor or measure response to bronchodilator in accordance with the patient's care plan (eg, P_{insp} , P_{plat});^{9,11}

10.2.3.2 use proper technique for administration of medication and use of devices correctly (eg, MDI with spacer, SVN, USN);¹¹

10.2.3.3 properly use and clean equipment;

10.2.3.4 modify dosages and/or frequency as prescribed and instructed and assure appropriate communication with physician regarding severity of symptoms.

BDMV 11.0 MONITORING:(bronchodilator response)

11.1 Patient observation

11.1.1 General appearance, presence of tremor

11.1.2 Use of accessory muscles or patient-ventilator dysynchrony

11.2 Percussion and auscultation, including presence or absence of wheezing³³

11.3 Patient symptoms and vital signs¹²⁻¹⁴

11.4 Improvement in dyspnea^{26,27}

11.5 Changes in SaO_2 ²⁸ or SpO_2

- 11.8 Changes in exercise performance³²
- 11.9 Changes in ventilator variables³⁵
 - 11.9.1 $P_{\text{insp}}-P_{\text{plat}}$ difference
 - 11.9.2 Inspiratory and expiratory resistance. (Changes in minimal inspiratory resistance (R_{smin}) and/or maximal inspiratory resistance (R_{smax}) are being used as a research tool.¹⁰)
 - 11.9.3 Expiratory flow, flow-volume loop
 - 11.9.4 Auto-PEEP reduction
- 11.10 Subjective response
- 11.11 Changes in sputum clearance
- 11.12 Changes in arterial blood gas values
- 11.13 Adverse response to drug

BDMV 12.0 FREQUENCY:

- 12.1 Acute, unstable patient
 - 12.1.1 Full assessment with first treatment
 - 12.1.2 Assessment with documentation of all appropriate monitored variables before and after each treatment, with monitoring of breath sounds, vital signs, side effects during therapy, P_{insp} and P_{plat} ⁹
 - 12.1.3 Frequency of physical exam and $P_{\text{insp}} - P_{\text{plat}}$ should be based on patient status.
 - 12.1.4 SpO_2 should be monitored continuously, if available.
 - 12.1.5 Continue assessment at each level of dose to optimal response for patient.
- 12.2 Stable patient
 - 12.2.1 The $P_{\text{insp}}-P_{\text{plat}}$ difference should be measured before and after bronchodilator therapy.
 - 12.2.1.1 Periodic reevaluation for response to therapy.
 - 12.2.1.2 Standard frequency with albuterol and ipratropium should be every 4 hours and/or as required.
 - 12.2.1.3 Other drugs, frequency based on manufacturer recommendation (ie, salmeterol every 12 hours).

13.0 INFECTION CONTROL:

CDC Standard Precautions as CDC recommendations to control exposure to tuberculosis and droplet nuclei.^{74,75}

Nebulizers should not be used between patients without disinfection. Nebulizers should be changed or sterilized at conclusion of dose administration or at 24-hour intervals with continuous administration⁷⁶ and whenever visibly soiled. Nebulizers should not be rinsed with tap water between treatments

Medications should be handled aseptically.

Medications from multidose-dose sources in acute care facilities must be handled aseptically and discarded after 24 hours.

Synopsis

Recommendations for Bronchodilator Delivery during Mechanical Ventilation

1. Ventilator Settings

Caution: If gas other than that from the ventilator is used to power the nebulizer, that flow may affect the delivered tidal volume, the inspired oxygen concentration, and the patient's ability to trigger the ventilator. It may be necessary to decrease the set tidal volume. For a patient triggering the ventilator, the rate may need to be increased to maintain an appropriate minute ventilation

Recommendations: Consider the following, if not otherwise contraindicated—(1) Use of a tidal volume > 500 mL for adults; (2) addition of an inspiratory pause or lower flows, which may improve pulmonary deposition of aerosol; however clinical judgment and patient evaluation must assure that the patient's inspiratory flow demands are met (ie, the inspiratory-to-expiratory-time ratio is subjectively and physiologically appropriate and auto-PEEP is not increased); (3) because spontaneous breaths may improve aerosol delivery, spontaneous breathing should not be suppressed during aerosol therapy unless the patient's ability to trigger the ventilator is affected.

2. Humidifier Use

Caution: Use of an external gas source to power the nebulizer may cause heated circuit malfunction; (2) an artificial nose, or heat-and-moisture exchanger, must be removed before aerosol therapy is begun.

Recommendations: Although humidified gas has been shown to reduce aerosol delivery by as

much as 40%, the humidifier should remain inline because of the risks associated with the delivery of dry gas. An increase in aerosol dose may compensate for this effect.

3. Metered Dose Inhaler Use

Caution: The dose delivered from an MDI is reduced significantly by failure to actuate the inhaler with the onset of inspiration.

Recommendations: (1) Use an MDI fitted with a chamber device; (2) actuate the MDI manually and synchronize actuation with the beginning of inspiration; (3) 4 puffs are the usual recommended dose; however, greater doses may be required when clinical monitoring of the patient suggests incomplete or inadequate response.

4. Nebulizer Use

Cautions: (1) Do not leave the nebulizer inline between aerosol treatments; (2) change the nebulizer every 24 hours; (3) do not rinse the nebulizer with tap water.

Recommendations: (1) When possible place the nebulizer 30 cm from the proximal end of the endotracheal tube; (2) it may be necessary to add a filter in the expiratory limb of the circuit to maintain expiratory flow-sensor accuracy when large doses of aerosol are delivered by nebulizer.

5. Patient Monitoring

Monitor the response to therapy with each treatment.

- For volume ventilation: peak inspiratory pressure and the difference between peak inspiratory pressure and plateau pressure; for pressure ventilation: tidal volume.
- Auto-PEEP
- Peak expiratory flow and/or flow-volume loop
- Breath sounds

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