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AARC Clinical Practice Guideline

Selection of an Aerosol Delivery Device for Neonatal and Pediatric Patients

NPAM 1.0 PROCEDURE:

This guideline addresses the appropriate selection of a device for the administration of aerosolized medications by small volume nebulizer (SVN), large volume nebulizer (LVN), metered dose inhaler (MDI), and dry powder inhaler (DPI) to neonatal and pediatric patients. Recommendations are made for patients both with and without an artificial airway, those spontaneously breathing, and those requiring assisted positive-pressure breathing. Evidence suggests that in pediatric patients a properly used MDI is as effective for delivering medications as is an SVN.(1-5)

NPAM 2.0 DESCRIPTION:

Effective administration of medication as aerosol depends on the delivery system and its position in relation to the patient.(6,7) Aerosol particle deposition is influenced by particle size, ventilatory pattern, and airway architecture.(8) Effective medication response is also influenced by the dose of the medication used.(9-12) In the neonatal and pediatric population, the process for determining the doses of specific aerosolized medications is not completely understood.(13) Drug pharmacokinetics and pharmacodynamics are markedly altered in neonates and may require dose adjustments.(13-16) This guideline addresses characteristics of an aerosol delivery system.

This guideline provides recommendations to assist the clinician in selecting an aerosol delivery device based on the patient's ability. Identifying the ability of the patient (ie, coordination and generated flows, rather than specific age requirements) is essential to selecting the appropriate aerosol delivery device in any population.

The three principal elements of an aerosol delivery system are the generator, the power source, and the interface.(6,7) Generators include small volume nebulizers (SVN), large volume nebulizers (LVN),

metered dose inhalers (MDI), and dry powder inhalers (DPI).(7,17) The power source is the mechanism by which the generator operates or is actuated and includes compressed gas for SVN and LVN and self-contained propellants for MDI.(7,17) The interface is the conduit between the generator and the patient and includes spacer devices/accessory devices with mouthpieces or face masks.(7,17) Depending on the patient's age (ability) and coordination, various interfaces are used in conjunction with SVN and MDI in order to optimize drug delivery.(7,17)

A SVN is a jet nebulizer that is powered by a compressed gas source. The medication is displaced up a capillary tube from the nebulizer's reservoir and is dispersed continuously as aerosolized particles.(7) The aerosolized particles are spontaneously inhaled by the patient or delivered in conjunction with positive-pressure breaths.(6,7) For patients > 3 years who are spontaneously breathing without an artificial airway and are able to cooperate, a mouthpiece with an extension reservoir should be used.(6,7) For patients unable to negotiate a mouthpiece (usually < 3 years), a face mask should be used.(18,19)

A MDI is a pressurized canister that contains a medication and propellant. Actuation of the MDI results in the ejection of one dose of medication as aerosolized particles, which can be spontaneously inhaled by the patient or delivered in conjunction with positive-pressure breaths.(7) A spacer device/ accessory device should be used with an MDI. A spacer device enhances delivery by decreasing the velocity of the particles and reducing the number of large particles.(20,21) A spacer device with a one-way valve, ie, holding chamber, eliminates the need for the patient to coordinate actuation and inhalation and optimizes drug delivery.(20,21) A spacer device without valves requires coordination between inhalation and actuation. The MDI with spacer device and face mask is appropriate for patients (usually < 3 years) unable to use a mouthpiece.(18,22-27)

A DPI is a breath-actuated device that uses a gelatin capsule containing a single dose of medication and a carrier substance to aid in the dispersion of the drug.(7) The capsule is inserted into the device and punctured.(28) The patient's inspiratory flow disperses the dry particles and draws them into the lower airways.(28) In spontaneously breathing patients, this device is appropriate in patients who are able to achieve an inspiratory flow > or = 50 L/min. This usually corresponds to children > 6 years of age.(13,29)

A LVN can be used to deliver a dose of medication continuously over a period of time.(30,31) A LVN is powered by a compressed gas source, and a face mask is typically used as the interface.(30) There has been only limited investigation of its use in the neonatal and pediatric population.

NPAM 3.0 SETTING:

Aerosolized medications can be administered in a number of settings including hospitals, clinics, extended care facilities, the home, and during transportation.

NPAM 4.0 INDICATIONS:

An aerosol delivery system is indicated when a medication approved for inhalation is prescribed.

NPAM 5.0 CONTRAINDICATIONS:

5.1 Contraindications associated with specific medications may exist. Pharmaceutical information should be consulted for relative contraindications.
5.2 An MDI or DPI should not be used
5.2.1 for patients with known allergies to medication preservatives;
5.2.2 for patients unable to perform the respiratory maneuver required to disperse/deliver the drug.

NPAM 6.0 HAZARDS/COMPLICATIONS:

6.1 Aerosol delivery
6.1.1 Malfunction of device and/or improper technique may result in underdosing. Overuse may result in overdosing.(32,33)
6.1.2 Specific pharmacologic agents can produce adverse side effects.(34)
6.1.3 The prescription of aerosol delivery devices for use in the home can lead to misuse if the user has not been properly trained.(33-35)
6.2 SVN
6.2.1 Continuous nebulizer flow increases tidal volume and associated pressure during volume-targeted ventilation.(36-38)
6.2.2 Continuous flow creates a bias flow in the ventilator circuit and may interfere with patient-triggered modes of ventilation.(36-39)
6.2.3 Continuous flow of aerosol may damage the expiratory flow transducers found in some ventilators.(37)
6.2.4 The continuous flow of gas from a flowmeter or compressor to an inline nebulizer used with a continuous-flow ventilator may result in

an excess of flow and may cause an increase in airway pressure and/or expiratory retard or PEEP.
6.2.5 The continuous flow of gas from a flowmeter or compressor to an in-line nebulizer used with a ventilator may result in variable FIO2s.
6.2.6 Aerosol particles may deposit and crystallize on expiratory mechanisms and may create inadvertent expiratory resistance or PEEP.(36,37)
6.2.7 Medication reservoirs may become contaminated and can be a source of infection.(40)
6.2.8 Diluents that are not isotonic may increase airway reactivity.(34)
6.3 MDI

6.3.1 The volume of gas discharged with actuation of the canister/inhaler may add a clinically important volume to tidal volume particularly in neonates.(37)
6.3.2 Additional dead-space volume can occur when a spacer device is placed at the end of an artificial airway.
6.3.3 Volume of gas discharged from MDI may affect FIO2.
6.3.4 Inappropriate patient use may result in underdosing or overdosing.
6.3.5 Reaction to propellants and other additives including coughing and wheezing may occur.(34,41,42)
6.3.6 Chlorofluorocarbons may contribute to ozone depletion.(43-45)
6.3.7 Oropharyngeal impaction from corticosteroid supplied in MDI form may result in local side effects.(7,46)
6.4 DPI
6.4.1 Airway irritation from dry powder may occur.(7,28)
6.4.2 Reaction to lactose or glucose carriers may occur.(7,28)
6.5 LVN
6.5.1 Side effects may occur at any time during continuous nebulization, and frequent assessment is required.(30,31)
6.5.2 Medication reservoirs may become contaminated and can be a source of infection.(40)

NPAM 7.0 LIMITATIONS OF PROCEDURE OR DEVICE:

7.1 SVN
7.1.1 Deposition of medication into the lungs is reduced to as little as 2-10% of the dose,(6,8,14,47-52) and may vary from brand to brand and unit to unit of the same brand.
7.1.1.1 Patients with smaller tidal volumes, particularly neonates(14,53-55) or dyspneic patients with shallow breathing may inhale less of the aerosolized agent and receive less of the dose when nebulization is continuous.(14,47,52)

7.1.1.2 Patients with airways of smaller diameter may receive a smaller fraction of the total particles produced.(14,53,55-57)
7.1.1.3 High inspiratory flows, as those associated with crying, may reduce deposition.
7.1.1.4 Approximately one half the initial solution volume is deposited on the internal walls and reservoir of the SVN.(6,8,47,58-60)
7.1.1.5 Concentration of the solution increases during nebulization resulting in retention of much of the dose in the SVN.(6,8,47,58,59) The effects of changing osmolality on bronchoreactivity are not clear.
7.1.1.6 Aerosol is lost during the expiratory phase of breathing.(6)
7.1.1.7 Treatment length may result in premature termination prior to complete nebulization of medication.(36)
7.1.1.8 Fill volume in the SVN affects the output.(58)
7.1.2 Use is labor intensive and costly.(61-64)
7.1.3 Duration of treatment is variable and may be prolonged.(6,7,61,62) (Increasing diluent volume lengthens treatment time but may improve drug delivery.(8,58))
7.1.4 The need for a power source makes the SVN less portable, particularly in the home setting.(6,7)
7.1.5 SVNs require preparation and cleaning.(7)
7.1.6 The brand of SVN used (ie, those that operate effectively only in the upright position).
7.2 SVN in conjunction with positive-pressure breathing.
7.2.1 Impaction of aerosol particles on artificial airways greatly reduces deposition.(37,65-71) The presence of artificial airways of smaller diameter results in a greater reduction in particle deposition and delivered dose.(6,7,67,71,72) The smaller the artificial airway, the greater the reduction in particle deposition.
7.2.2 Limited research on use of aerosols in neonatal and pediatric patients has been published.(37,54,73)
7.2.3 Aerosol delivery may be less effective in conjunction with manual ventilation than with mechanical ventilation.(13,72)
7.2.4 Mechanical ventilator modes, flows, and flow patterns may affect particle deposition.(25,65,66,74)
7.2.5 The presence of an in-line humidifier may reduce aerosol delivery by 50%.(37)
7.2.6 Use of SVN with continuous-flow ventilators may result in the loss of a large percentage of the aerosolized particles through the exhalation valve.(37)
7.2.7 Positioning of the SVN too close to the artificial airway results in less airway deposition.(37,65,66,69,75)
7.3 SVN with face mask
7.3.1 Cold, wet mist may be irritating to children and may limit the time that the treatment is tolerated.(13)

7.3.2 Nasal breathing results in a reduction in particle deposition.(57,76,77)
7.3.3 Particle deposition is reduced because of upper airway impaction.(57,76,77)
7.4 MDI
7.4.1 Use of an MDI without a spacer device with one-way valve (ie, holding chamber), requires the patient to coordinate the actuation of the canister with inhalation, which may be particularly difficult for small children (eg, < 7 years).(13,78)
7.4.2 Use of an MDI without a spacer device results in greater oropharyngeal impaction and a reduction in airway deposition.(6,7,78,79)
7.4.3 Use of an MDI without a spacer device may result in a cold sensation when the propellant reaches the back of the throat (ie, cold-Freon effect) that may interfere with proper delivery technique.(7,17,80)
7.4.4 Inadequate or inaccurate instruction and technique may result in misuse and reduced aerosol deposition.(13,81-83)
7.4.5 Propellants may cause bronchospasm in some patients with reactive airway diseases.(41)
7.4.6 Average deposition in the lungs is 10% to 25% of the total dose.(49,84-86)
7.4.7 Particle size varies with operating pressure which is directly related to canister temperature.
7.5 MDI with spacer device
7.5.1 Addition of the spacer/accessory device increases cost over cost of the MDI alone.(6,7)
7.5.2 The spacer/accessory device is relatively cumbersome and less convenient than the MDI alone.(6,7)
7.5.3 All spacer/accessory devices may not fit all MDIs.
7.5.4 All spacer devices/accessory devices do not eliminate coordination problems.
7.5.4.1 A spacing/accessory device with a one-way valve (ie, holding chamber) eliminates coordination problem.
7.5.4.2 Open tube spacer/accessory devices (non-valved) require coordination.
7.6 MDI with spacer device-face mask--The inspiratory flow and the number of inhalations required by neonates and small children (< 3 years) to effectively use these devices is not completely understood.(13,52,54,87)
7.7 MDI with spacer device designed for mechanical ventilation
7.7.1 Research is limited in this population.(13,21)
7.7.2 The smaller the diameter of the artificial airway, the greater the reduction in particle deposition and delivered dose.(13,37,88)

7.7.3 Particle deposition may be as low a 2-10% of the total drug delivered.(13,3769,89-91)
7.7.4 Use of an elbow-type spacer results in less airway deposition than a chamber-type spacer.(36,87,89,92)
7.7.5 The chamber type spacer if left in-line with a ventilator circuit potentially increases the compressible volume of the ventilator circuit.
7.7.6 The gas discharged from the MDI may affect FIO2.
7.8 DPI
7.8.1 Reduced inspiratory flow (< 50 L/ min) can lead to reduced deposition.(14,29,92,93) This may be more likely in children < 6 years(13,29) and in an acute exacerbation when peak flows are significantly reduced.
7.8.2 Some drug preparations are water soluble and, thus, humidity may affect DPI performance.(6,7)
7.8.3 Oropharyngeal impaction of much of the dose occurs and results in a reduction in lower airway deposition.(14,28)
7.8.4 The patient must be able to load each dose, for most medications.(47)
7.8.5 Average deposition in the lungs is 10-25% of the total dose.(7,13,92,94)
7.9 LVN with mask
7.9.1 The use of LVN for continuous nebulization in the pediatric population has not been widely investigated.(30,95)
7.9.2 Cold, wet mist may be irritating to children and may limit the time that the treatment is tolerated.(13)
7.9.3 Nasal breathing results in a reduction in lower airway deposition.(57,76,77)
7.9.4 Bronchial deposition is reduced because of upper airway impaction.(57,76,77)
7.9.5 Limited to use in a critical care setting. Not appropriate for home use.
7.10 Drug pharmacokinetics and pharmacodynamics are markedly altered in neonates and may require dose adjustments.(13-16)

NPAM 8.0 ASSESSMENT OF NEED:

8.1 SVN: General Indications
8.1.1 The need to deliver aerosolized medications that are approved in solution form to the lower airway of spontaneously breathing patients with or without an instrumented airway.(6,7,13)
8.1.2 The need to provide supplemental gas flow in conjunction with aerosol treatment.(7)
8.1.3 The need to modify drug concentration.(7)
8.1.4 The need to deliver a particular aerosolized medication that is only available in solution form.

8.1.5 The need to deliver aerosolized medications to patients in acute distress or with reduced inspiratory flow.
8.1.6 The need to deliver aerosolized medications to patients who are unable to coordinate or perform the necessary inspiratory maneuvers required with an MDI or DPI.
8.2 SVN with mouthpiece and extension reservoir--The need to deliver aerosolized medications approved in solution form to the lower airways of spontaneously breathing patients without an instrumented airway who are able to utilize a mouthpiece (patients > 3 years).(6,7)
8.3 SVN with face mask
8.3.1 The need to deliver aerosolized medications that are approved in solution form to the lower airways of spontaneously breathing patients without an instrumented airway who are unable to negotiate a mouthpiece (usually < 3 years).(18,19)
8.3.2 The need to deliver aerosolized medications to the upper airway.
8.4 SVN with T-connector (15-mm and 22-mm openings)
8.4.1 The need to deliver aerosolized medications approved in solution form in-line with a mechanical ventilator circuit or manual resuscitation bag.(74,96)
8.4.2 The need to deliver aerosolized medications approved in solution form to patients with instrumented airways who are spontaneously breathing.
8.5 MDI: General indications
8.5.1 The need to deliver aerosolized medications that are approved in MDI form.(18)
8.5.2 The need to deliver a particular medication that is only available in MDI form.
8.5.3 The need to reduce the length of time for the aerosol treatment.
8.5.4 The need for maximum portability.(55)
8.6 MDI with spacer device with one-way valve--
8.6.1 The spacer device with one-way valve and face mask is appropriate for small children (usually < 3 years) and others unable to use a mouthpiece.(18,22-27,97)
8.6.2 The need to eliminate actuation and inspiratory maneuver coordination.(20,21)
8.6.3 The need to reduce oropharyngeal impaction,(20,21) particularly with the delivery of corticosteroids by inhalation.(98,99)
8.6.4 The valved-spacer device with mouthpiece is the method of choice if patient is able to use a mouthpiece.
8.6.5 A specially designed spacer device is used for MDI delivery during mechanical ventilation or with manual resuscitators.(73,100)
8.7 MDI with a non-valved spacer device
8.7.1 The need to use a MDI when a patient can coordinate inspiration and actuation.

8.7.2 The need to reduce oropharyngeal impaction,(20,21) particularly with the delivery of corticosteroids by inhalation.(98,99)
8.9 DPI
8.9.1 The need to deliver aerosolized medications approved in DPI form.(38,101,102)
8.9.2 The need to deliver a particular medication that is only available in DPI form.(38,101,102)
8.9.3 The need to eliminate chlorofluorocarbon propellants.
8.10 LVN--The need to deliver continuously aerosolized medication, approved in solution form, to the lower airway of spontaneously breathing patients without an instrumented airway.(31)

NPAM 9.0 ASSESSMENT OF OUTCOME:

9.1 Desired medication effect is observed as indicated by an improvement in subjective (physical examination) and objective (pulmonary function measurements) assessments.(19,31,103-108)
9.2 Health care providers demonstrate competency with proper technique and patient instruction of aerosol delivery systems.(33)
9.3 Patients and patients' family members demonstrate proper technique and compliance with the application of aerosol delivery systems.(33)

NPAM 10.0 RESOURCES

10.1 Equipment
10.1.1 SVN capable of producing a high drug output, short nebulization time, aerosol particles with a mass median aerodynamic diameter (MMAD) < or = 5 microns, and with a low residual volume.(8,55,58,60) Characteristics of nebulizers may vary among brands and among units of the same brand.
10.1.1.1 Power source such as hospital compressed oxygen or air, portable oxygen or air cylinder, or domiciliary air compressor capable of producing a flow of at least 6-8 L/min.(6-8,58,108)
10.1.1.2 A blender for use with a ventilator to maintain desired FIO2.
10.1.2 Interface
10.1.2.1 Face mask for small children unable to utilize a mouthpiece which may include an additional 6-inch section of aerosol tubing.(18,19)
10.1.2.2 Mouthpiece with extension reservoir.(6)
10.1.2.3 T-connector with 15- and 22-mm openings or tracheostomy collar adaptation for patients with artificial airway and/or receiving aerosolized medications in conjunction with a manual resuscitation bag.
10.1.2.4 T-connector with inspiratory circuit reservoir for patients receiving aerosolized medications in conjunction with mechanical ventilation.(65)

10.1.3 Medication and isotonic diluent.
10.1.3.1 MDI, which includes the medication canister and actuator, with appropriate accessories for patient's ability and circumstances.
10.1.3.1.1 Chamber-style spacer with mouthpiece or mask, depending on the patient's ability.(109)
10.1.3.1.2 Chamber-style spacer with inspiratory circuit configuration for patients receiving aerosolized medications in conjunction with mechanical ventilation.(91)
10.1.3.1.3 Chamber-style spacer configured for patients with artificial airways and/or receiving aerosolized medications in conjunction with a manual resuscitation bag, placed between airway and bag.
10.3.1 DPI with accompanying medication capsule and dispenser.
10.4.1 LVN capable of producing aerosol particles with a mass median aerodynamic diameter (MMAD) < or = 5 microns with face mask.
10.5 Personnel
10.5.1 Health care providers responsible for delivery of aerosolized medications should have demonstrated and documented knowledge and skills related to
10.5.1.1 aerosol delivery devices and their limitations;(110)
10.5.1.2 assembly, care and use of aerosol delivery devices;(110)
10.5.1.3 provision of comprehensive patient and lay caregiver instruction;(18,111,112)
10.5.1.4 medications being delivered including contraindications, potential side effects and desired response;(110)
10.5.1.5 recognition and response to adverse reactions during medication delivery and modification of treatment accordingly;(110)
10.5.1.6 performance of the necessary subjective and objective assessments in order to determine medication efficacy and the patient's ability to properly utilize aerosol delivery devices.
10.5.2 Patient and/or family member or lay caregiver should
10.5.2.1 demonstrate proper use and understanding of aerosol delivery device and delivery technique;(32,108)
10.5.2.2 demonstrate proper assembly, cleaning, care of aerosol delivery device, and medication preparation;(32,108)
10.5.2.3 demonstrate an understanding of medication purpose, dosage, indications, and side effects, be able to alter medication as needed,108 and know when to report to physician or surrogate.

NPAM 11.0 MONITORING

11.1 Observe delivery technique of spontaneously breathing patients who are able to self-administer aerosolized medications.
11.1.1 A slow deep inhalation with an inspiratory pause/hold is performed during SVN treatments.(55) A flow of 6-8 L/min and fill volume of 4 mL (dependent upon the brand of SVN used) provide a

maximum volume of delivered drug.(53) The sides of the SVN are periodically tapped in order to minimize the dead volume (ie, volume of solution not nebulized) and maximize the volume nebulized.(53)
11.1.2 MDI actuation occurs at end-exhalation followed by a slow inspiration and breath hold for 10 seconds.(55,111,112)
11.1.3 Patient is able to produce a rapid inhalation in order to fully activate and discharge DPI.(101)
11.2 Observe patient and/or patient's family member following instruction and demonstration.(108)
11.2.1 Proper understanding and return-demonstration of delivery device and accompanying equipment is observed.(47,108)
11.2.2 Proper understanding and preparation of medication is observed.(47,108)
11.3 Observe response to medication by performing subjective (eg, physical examination) and objective (eg, pulmonary function measurements) assessments and other diagnostic techniques that are appropriate for the specific medication being delivered.(19,31,103-107)
11.3.1 Ensure that medication volume is nebulized over desired amount of time when using LVN.
11.3.2 Continuous monitoring of ECG is recommended when delivering a bronchodilator by LVN.
11.4 Monitor ventilator function for inadvertent increases in tidal volume or airway pressures, changes in FIO2, difficulty with patient triggering and patient-ventilator synchrony, or other system problems.(36)
11.5 Documentation
11.5.1 Successful training of patients and/or patient's family member are documented in the patient's medical record.(33,108)
11.5.2 Treatments administered in a clinical setting are documented in the patient's medical record. Information on medication dose, frequency, response and adverse reactions are included.

NPAM 12.0 FREQUENCY

Aerosol delivery devices are used according to the frequency of the prescribed medication.

NPAM 13.0 INFECTION CONTROL

13.1 Universal Precautions and measures to limit the transmission of tuberculosis must be adhered to at all times.(113,114)
13.2 SVN are for single patient use.
13.2.1 Between treatments on the same patient, disinfect, rinse with sterile water, and air-dry.(40) In the home environment, cleaning,

rinsing with solution of vinegar and water, and air drying may be adequate, although clear evidence to support this procedure is lacking.
13.2.2 Between patients, replace SVN with those that have undergone high level disinfection or sterilization.(40)
13.3 MDI, DPI and accessories are for single patient use only. Clean or replace when they appear dirty.
13.4 LVN are for single patient use. LVN should be subjected to high-level disinfection or sterilization between patients.
13.5 Aerosol solutions.
13.5.1 Use only sterile fluids and dispense them aseptically.(40)
13.5.2 Medications obtained from multidose vials are handled, dispensed and stored according to manufacturers' instructions.
13.6 Patients with a natural airway should be instructed to rinse the mouth with water following each administration of inhaled steroids.

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