The Science Guiding Selection of an Aerosol Delivery Device

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Aerosol therapy continues to be considered as one of the cornerstones of the profession of respiratory care, even after 60 years. Aerosol therapy serves as a critical intervention for both exacerbations and chronic maintenance for a variety of respiratory care conditions. Aerosol therapy uniquely blends both the art and science of medicine together to produce the practical and necessary clinical outcomes for patients with respiratory diseases. This review was presented as part of the New Horizons Symposium on how to guide the scientific selection of an appropriate aerosol device. *Key words: aerosol therapy; respiratory care; inhaler; nebulizer.* [Respir Care 2013;58(11): 1963–1973. © 2013 Daedalus Enterprises]

Introduction

Medications are part of the management regimen and care in hundreds of medical conditions. The use of inhaled aerosols allows selective treatment of the lungs by achieving a high drug concentration in the airway while reducing systemic adverse effects.[1] Safe and effective medication

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Table 1. Five "Rights" of Medications

The right patient
The right medication
The right time
The right route
The right dose

Table 2. Advantages and Disadvantages of Inhaled Medications

Advantages
Generally smaller than systemic doses
Faster onset of action than oral dosing
Direct delivery
Less frequent and severe systemic effects
Less painful and relatively easy, compared to injections
Disadvantages
Lung deposition is low
Many variables affect efficacy and dose reproducibility
Hand-eye coordination required with pressurized metered-dose inhaler (pMDI)
Lack of knowledge among patients and clinicians
Number and variability of device types
Lack of standardization

(From Reference 2.)

delivery is a major focal area in hospitals and medicine in general today. This increased focus and scrutiny from a medical regulatory standpoint have led to numerous quality initiatives surrounding the 5 "rights" (Table 1) of medication delivery. While these 5 "rights" also apply to aerosolized medications, the delivery of inhaled medications or aerosol therapy is also intricately tied to the delivery devices themselves, which is not always the case with oral or injected medications. Table 2 lists the advantages and disadvantages of inhaled medications.

Aerosols are part of everyday life and play a critical role in the management and treatment of patients with chronic respiratory conditions. Understanding the science of the therapy and its associated technology are vital to successful intervention, treatment, and education for the care and management of chronic respiratory disease.

Methods for generating aerosols, formulating drugs, and administering medications effectively to the desired site of action constitute the science of aerosol drug delivery,[2] an intricate science in that it is also an art. The art of the therapy involves matching the right aerosol delivery device with the patient's physical and cognitive abilities to promote optimized care.

Effective inhalation of aerosolized medications from a scientific perspective relies on both the mechanism of aerosol deposition and its relationship to aerosol particle size. The size of aerosol particles plays an important function in lung deposition, in addition to the velocity of the particle, and settling time during the inspiratory cycle of breathing.

The primary mechanism of aerosol deposition within the respiratory system involves 3 distinct factors of deposition: inertial impaction, gravitational sedimentation (settling), and diffusion. When aerosolized particles tend to be larger (> 5 μm) and faster-moving, inertial impaction occurs most commonly in the upper airways or is filtered out in the naso-oropharynx by the narrow passages and high airways resistance. Particles that fall within the 1–5 μm size typically deposit based on a function of particle mass and inspiratory time, with the rate of settling proportional to particle size and mass, which is referred to as gravitational settling. The smallest aerosol particles (< 1 μm) tend to be deposited based on diffusion. Particle size is especially important when dealing with the pediatric population.

Delivery technology for aerosolized medications, regardless of device, produces a mixture of aerosol particle sizes (polydisperse particles). The scientific unit of measure (in μm) that quantifies a polydisperse aerosol is referred to as the mass median diameter. When the science talks about deposition, it is typically reported as the mass median aerodynamic diameter, or MMAD. The MMAD is the numerical value where particle size evenly divides the mass, or amount of the drug above and below which 50% of the mass of the particles is contained.

Optimal particle size for most inhaled respiratory medications to achieve deposition in the periphery of the lung falls into the particle size range of 1–5 μm. As particle size increases above 5 μm, aerosol deposition shifts from the periphery of the lung to the conducting airways. Oropharyngeal deposition increases as particle size increases above 10 μm. Exhaled loss is high with very small particles of 1 μm or less.

In addition to particle size, the inspiratory flow rate of the patient also plays a synergistic role in the location of the medication deposition. Higher inspiratory flow in the upper airways promotes impaction of particles from the nares to the larynx, particularly for particles of MMAD of 3–5 μm.[3]

When dealing with an infant or a child, these principles also apply, but are also influenced by other variables as well. Studies of a variety of respiratory tract disorders have shown that the major patient related factors that determine and/or limit lower respiratory tract aerosol deposition are lower respiratory tract anatomy and physiopathology, rather than specific diseases.[4]

Types of Aerosol Delivery Devices

Aerosol delivery devices predominantly reside in one of 3 classifications: small-volume nebulizer (SVN), pressurized metered-dose inhaler (pMDI), and dry powder inhaler

Table 3. Types of Aerosol Delivery Devices

Small-volume nebulizer	Converts liquid drug solution or suspension into aerosol particles of varying particle sizes
Metered-dose inhaler	Small, portable device that dispenses multiple doses by metered value; self-contained system
Dry-powder inhaler	Small, portable device that delivers powdered drug with breath-actuated dosing system based on inspiratory flow

(From Reference 2.)

(DPI). Table 3 provides a brief description for each of the delivery devices. Each specific device has its own nuances, which leads to a large potential disadvantage for inhaled medications. Inappropriate technique can lead to suboptimal dosing of medications and less than acceptable disease control. In the last few decades (Fig. 1), a proliferation of inhalation devices has resulted in a confusing number of choices for the healthcare provider, and in confusion for both clinicians and patients trying to use these devices correctly.[5]

For several decades, clinicians and patients alike believed that SVNs were more effective than pMDIs, particularly for quick relief mediations during exacerbations of air-flow obstruction. A systematic review of the evidence documented equivalent clinical results, regardless of the device used, for quick relief medications, provided that the patient utilizes the device correctly, despite the SVN providing the higher nominal dose.[5]

As science has continued to refine the technology and devices for aerosol delivery, newer aerosol devices and drug formulations are increasing the efficiency of lung deposition, when compared to the traditional devices commonly used. New devices, such as the Respimat inhaler (Boehringer Ingelheim Pharmaceuticals, Ingelheim, Germany), have shown lung depositions of 40%.[6] While the dose of drug delivered to the lung has high variability between devices, aerosol delivery devices with relatively low lung deposition fraction have clinically demonstrated desired therapeutic outcomes in their target audience.

Small-Volume Nebulizers

SVNs are typically powered from a gas, electrical, or battery powered source and convert drug solutions or suspensions into aerosols that target the patient's lower respiratory tract with minimal patient cooperation. The mechanism of action and design of SVNs has a large variability, and each has its own specific design that requires background and knowledge to utilize the device to its fullest functionality. SVNs are typically designed and classified into one of 3 categories: pneumatic, ultrasonic, or mesh.

Pneumatically Powered Nebulizers

The main mechanism of action for the pneumatically powered nebulizer is to entrain the solution or suspension to be aerosolized through the generated gas stream, causing a shearing into a liquid film. As this liquid film is highly unstable, it disperses into droplets secondary to surface tension forces. A baffle in the SVN causes the aerosol stream to yield smaller particles. Aerosol particles can be further impacted by environmental factors such as the relative humidity of the carrier gas. Table 4 lists other factors that can impact SVN aerosol output. Nebulizer design changes over the past decade have created different nebulizer categories.[7,8] Figure 2 pictures the 4 different classes of pneumatically powered nebulizer: jet nebulizer with reservoir tube, jet nebulizer with collection bag or elastomeric reservoir ball, breath-enhanced jet nebulizer, and breath-actuated jet nebulizer.

Jet Nebulizer with a Reservoir Tube. These nebulizers are typically mass produced and are the least expensive and most widely used type of nebulizers in the market today (see Fig. 2A). Jet nebulizers continuously aerosolize, during both inhalation and exhalation, and require a breath-hold to promote optimal deposition. Jet nebulizers, due to their design, emit aerosol to the ambient air during the expiratory phase and any time when the patient is not breathing.[8,9]

Jet Nebulizer With Collection Bag or Elastomeric Reservoir Ball. This class of SVN creates aerosol particles by continuously filling a reservoir (see Fig. 2B). A built-in reservoir with a one-way inspiratory valve allows the patient to inhale medication from the reservoir, and exhales to the atmosphere through an exhalation port between the one-way inspiratory valve and the mouthpiece.[8,9]

Breath-Enhanced Jet Nebulizer. Breath-enhanced nebulizers utilize 2 one-way valves to prevent the loss of aerosol to the environment (see Fig. 2C), while using a reservoir with the inspiratory valve to front-end load medication at the beginning of inspiration. During the expiratory phase, gas passes through an expiratory valve in the mouthpiece to the atmosphere.

Breath-Actuated Jet Nebulizer. Perhaps the most technical and expensive class of SVN nebulizers is the breath-actuated nebulizers. The construct of these devices is designed to increase aerosol drug delivery to patients by generating aerosol only during inspiration. Consequently, loss of medication during expiration is greatly reduced (see Fig. 2D).[9] Breath-actuation triggering mechanisms are categorized as manual, mechanical, and electronic.

Fig. 1. Common inhalers available in the United States. (From Reference 2.).

Table 4. Factors That Impact Aerosol Drug Delivery With Small-Volume Nebulizers

Gas flow and pressure
Fill volume and dead volume
Gas density
Humidity and temperature
Breathing pattern
Device interface

(From Reference 2.)

Ultrasonic Nebulizer

Ultrasonic nebulizers convert electrical energy to high-frequency vibrations using a transducer. These high frequency vibrations are transmitted to the surface of the liquid solution, producing a standing wave that generates aerosol. Small-volume ultrasonic nebulizers are commercially available for delivery of inhalable bronchodilators, but should not be used with suspensions such as budesonide. Ultrasonic nebulizers tend to heat the medication. This raises concerns about disrupting proteins, but that does not affect commonly inhaled medications.[10]

Mesh Nebulizer

Mesh nebulizers use electricity to vibrate a piezo (at approximately ~128 kHz) plate or aperture that forces liquid formulations through a fine mesh to generate aerosol. The aerosol particle size can be manipulated to a variety of particle sizes, based on the diameter of the mesh or aperture. Mesh nebulizers are highly efficient and produce minimal residual or dead volume (0.1–0.5 mL) left over in the device at the end of a treatment. Mesh nebulizers operate on one of 2 basic mechanisms of action: active vibrating mesh, and passive mesh. Active vibrating mesh nebulizers have aperture plates with thousands of funnel-shaped holes vibrated by a piezo-ceramic element that surrounds the aperture plate, while passive mesh nebulizers employ an ultrasonic horn to drive fluid through a mesh screen.

Other Nuances and Characteristics of SVNs

The design of SVNs and the medications that they aerosolize also add one other unique characteristic: the ability of the pneumatically powered nebulizers to be utilized for continuous aerosol delivery or powered by alternative gas sources (helium-oxygen combinations).

Continuous aerosol drug administration of a bronchodilator is often a consideration in asthma exacerbations. Continuous nebulization therapy is a safe treatment modality, administered with a typical dose range for continuous albuterol of 5–15 mg/h.[11] Several configurations have been described for continuous nebulization, including frequent refilling of the nebulizer, use of a nebulizer and infusion pump (Fig. 3), and use of a large-volume nebulizer.

While often an area of clinical controversy, studies have demonstrated that continuous nebulization may be as effective as intermittent aerosol therapy, or may, in fact, be superior to intermittent nebulization in patients with severe pulmonary dysfunction.[12,13] A meta-analysis of results from 6 randomized trials indicated that intermittent administration and continuous administration have similar effects on both lung function and the overall rate of hospitalization,[14] whereas a Cochrane review of findings from 8 trials suggested that continuous administration resulted in greater improvement in peak expiratory flow and FEV_1, and a greater reduction in hospital admissions, particularly among patients with severe asthma.[12]

The second area of aerosol therapy that is unique to SVNs is the use of an alternative gas to power the nebulizer: in this case a combined mixture of helium and oxygen, or, as it is more commonly referred to, heliox. In obstructive airways disease the opportunity to decrease turbulent air flow through obstructive airways with a less dense gas offers the hypothetical advantage of delivering aerosol particles and medications distal to the obstructions.[15–18] Heliox is a gas mixture of helium (60–80%) and oxygen, which is used to improve air flow in patients with partial airway obstruction.[19]

Clinical studies utilizing heliox as the driving gas for delivery of aerosolized asthma medications in asthmatics have reported conflicting results,[20] which makes evidence-based decisions on its use undeterminable for several possible reasons. As an example, one of the possible reasons for variability in results can be traced to the liter flow used to power the nebulizer. Hess et al[21] determined that the flow of heliox with 80% helium and 20% oxygen must be increased by about 50% to generate optimally sized respirable particles.

Nevertheless, new evidence suggests certain benefits in patients with more severe obstruction. In a review, Frazier and Cheifetz summarized the possible uses of heliox in asthma exacerbation (Table 5).[22] However, since that information is based on between-group comparisons and small studies, the conclusions are not definitive.[23]

Often a question of effective nebulization time becomes a clinical question, and when to discontinue treatment. Two frequently seen practices are for clinicians and patients to tap the SVN to reduce dead volume and increase output,[24] while the second practice continues nebulization beyond device sputtering, to decrease dead volume.[1] In fact, research has suggested that after the onset of sputter very little additional drug is inhaled.[1,25] As patient adherence to therapy is a critical component to out-patient main-

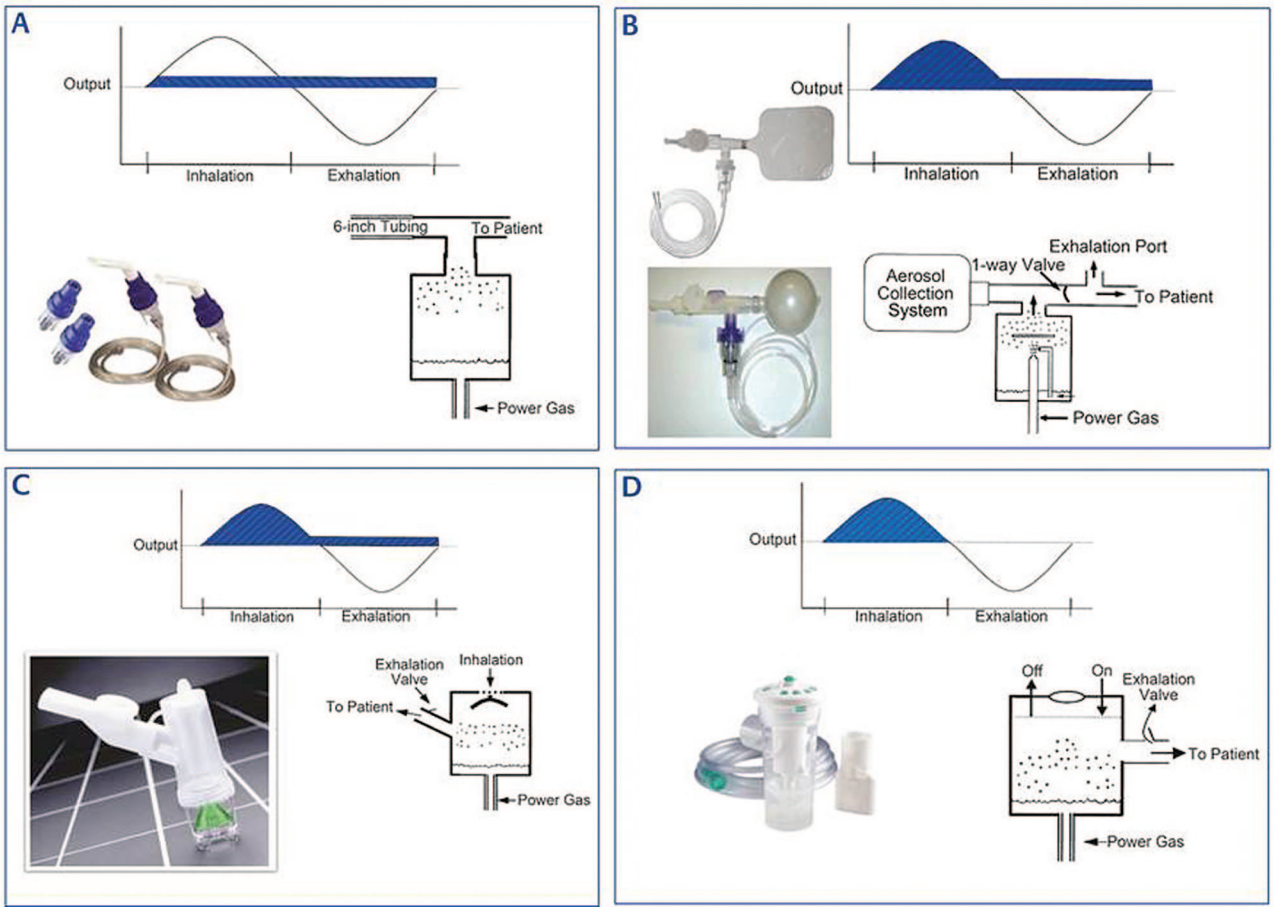

Fig. 2. Types of pneumatic jet nebulizer. The aerosol output is indicated by the shaded areas. A: Pneumatic jet nebulizer with reservoir tube. B: Jet nebulizer with collection bag. C: Breath-enhanced jet nebulizer. D: Breath-actuated jet nebulizer. (From Reference 2.)

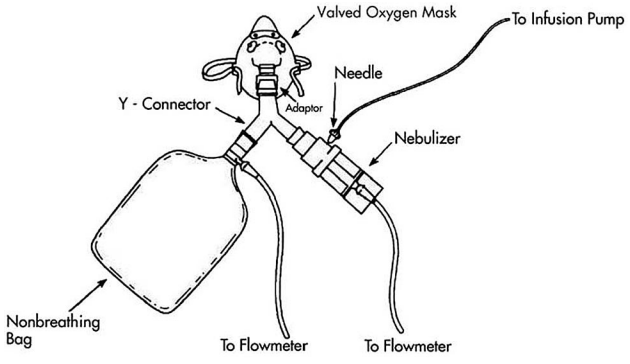

Fig. 3. Setup for continuous aerosol therapy. (From Reference 2.)

tenance therapy, many clinicians recommend discontinuing treatment either at or 1 min after sputter onset.

The final area of clinical concern revolves around the patient-device interface, which occurs mainly in the pediatric and in-patient settings. Mouthpieces and face masks are the 2 interfaces with SVNs, and studies suggest that a mouthpiece interface promotes greater lung deposition than a face mask[26,27] and is effective in the clinical treatment of children.[26,28,29] However, using a preferred device can promote adherence, inhaled dose, and desired clinical response. The importance of a closely fitting face mask is a critical

Table 5. Summary of the Clinical Application of Heliox in Asthma Exacerbation

Heliox may benefit initial treatment of pediatric asthma, serving as a bridge until corticosteroids have clinical effect.
Heliox benefits initial treatment of moderate-to-severe asthma exacerbation in the emergency department.
Heliox is most beneficial in the initial treatment period; clinical improvement with heliox, as compared to oxygen-enriched air, becomes less evident over time.
Heliox appears to improve gas exchange in patients with asthma to require intubation, potentially decreasing the ventilator support required.
Heliox allows lower ventilator settings and lower F_{IO_2}, decreasing the risk of ventilator-induced lung injury.
With the increasing use of noninvasive ventilation, heliox might be an adjunct.

(From Reference 2.)

Table 6. Advantages and Disadvantages of Small-Volume Nebulizers

Advantages
Many drug solutions
Can deliver combinations
Minimal patient cooperation required
Can deliver to all patient ages
Concentration and dose can be modified
Normal breathing pattern
Disadvantages
Treatment time variation (5–25 min)
Poor portability
Need for power source
Risk of drug exposure to eyes
Performance variability
Assembly and cleaning issues

(From Reference 2.)

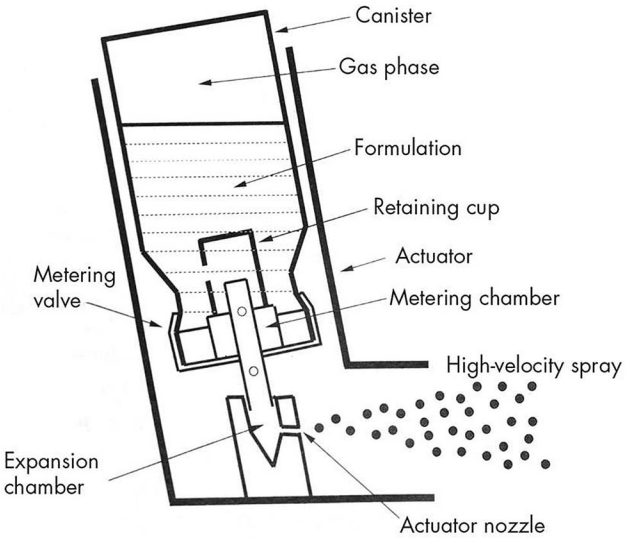

Fig. 4. Standard components of a pressurized metered-dose inhaler. (From Reference 2.)

factor in achieving optimal drug deposition and avoiding nebulizing aerosol into the patient's eyes. Even small leaks of 0.5 cm around the face mask decrease drug inhaled by children and infants by more than 50%.[30-34]

Delivery of aerosolized medications in a blow-by fashion is commonly used for crying babies or uncooperative children, where the nebulization port of a nebulizer is directed toward the patient's face. Studies have documented blow-by medication administration is less efficient, compared with a face mask, as aerosol drug deposition decreases significantly with distance, and this use should be discouraged.[30,34-36]

In summary, while the domain of SVNs can be highly variable, based on the nuances and characteristics described previously, the entire category has some common advantages and disadvantages, which are listed in Table 6.

Pressurized Metered Dose Inhalers and Accessories

The pMDI has not changed much in the last 50 years. It is a marvel of engineering science, containing a valve that allows a metering of the drug, an actuator boot to trigger the medication and direct it toward the mouth, and medication formulation, which contains a propellant, excipients, and the medication (Fig. 4).[37]

The pMDI is a medical aerosol delivery system that combines a device with a specific formulation and dose of drug.[2] Actuation of the pMDI delivers a metered dose of medication that must be coordinated with a single inspiration of the patient. Each pMDI canister is required to create reproducible doses (± 20) from first to last dose, with a drug shelf life of 12–24 months.

Pressurized MDIs provide a mobile, manually actuated portable device that patients can utilize anywhere at any time, and can be used either alone or with an accessory device such as a spacer or valved holding chamber (VHC). There are 3 major types of pMDI: conventional, breath-actuated, and soft-mist. Table 7 lists the advantages and disadvantages of pMDIs in general terms.

Table 7. Advantages and Disadvantages of Pressurized Metered-Dose Inhalers

Advantages
Portable, light, and compact
Multiple-dose convenience
Short treatment time
Reproducible dosing
No drug preparation
Lower risk of contamination
Disadvantages
Hand-breath coordination required
Active patient required: activation, inhalation pattern, breath-hold
Fixed concentration/dose
Propellant reaction
Aerosol particle impaction in upper airways
Most lack dose counting

(From Reference 2.)

Conventional pMDI

The conventional pMDI has a press-and-breathe design. Actuation of the canister into the device boot aligns the hole in the metering valve with the metering chamber and releases the drug-propellant mixture, which then expands and vaporizes to convert the liquid medication into an aerosol. Release of the canister allows the metering valve

Table 8. Factors Affecting Pressurized Metered-Dose Inhaler Performance and Drug Delivery

Not shaking the pressurized metered-dose inhaler (pMDI) prior to use
Storage temperature
Nozzle size and cleanliness
Timing of actuation intervals
Not priming the pMDI per the manufacturer's recommendation
Patient characteristics (eg, age)
Breathing technique

(From Reference 2.)

to refill the chamber with another dose of the drug-propellant mixture. An important component of the pMDI, often overlooked, is the need to prime the metering chamber before use. Although improvements in valve design have reduced the need for priming, it remains prudent to prime the pMDI if it has not been used recently.[38,39]

Breath-Actuated and Breath-Controlled pMDI

The breath-activated nebulizer is a technology that senses the patient's inspiratory flow and delivers aerosol only when flow triggers the opening of a valve and decreases medication wastage.[40] Its mechanism is triggered by inhalation through a breath-actuated nozzle, which provides an automatic response to the patient's inspiratory effort. It is important to assess the patient to ensure that they are able to generate a high enough inspiratory flow to activate the triggering mechanism. Breath-actuated pMDIs are not recommended for the younger pediatric patient.

Breath-controlled nebulizers use computer technology to determine a patient's inspiratory flow and volume, and use those to deliver the medication at the beginning of inhalation, allowing the inspired air at the end of inhalation to drive the aerosol deep into the airway.[41] The theory behind these devices is that less medication is deposited in the oropharyngeal cavity and upper airways, increasing drug availability and deposition in the lung periphery. These devices require a slow inspiratory maneuver, contrasted to breath-actuated or DPIs that require higher inspiratory flow.

Soft-Mist pMDI

The Respimat (Boehringer Ingelheim Pharmaceuticals, Ingelheim, Germany) is a newly released, propellant-free, soft-mist inhaler that employs mechanical energy from a tensioned spring to generate the soft aerosol plume. When the dose release button is depressed, the energy from the spring forces solution to the mouthpiece, creating a soft aerosol plume that lasts approximately 1.5 seconds.[2] The soft mist pMDI, similar to a conventional pMDI, requires priming before use and at times when the device has had no use. Since the device is propellant-free, there is no need to shake it.

Most pMDIs are manufactured to deliver a targeted drug dose per actuation, of which approximately 10–20% of the nominal dose per actuation reaches the lung periphery as a fine particle fraction range in which the MMAD is < 5 μm. Several factors influence the pMDI performance and aerosol drug delivery, and are listed in Table 8.

Table 9. Advantages and Disadvantages of Pressurized Metered-Dose Inhaler Accessory Devices

Advantages
Reduce oropharyngeal deposition and dose loss
Increase deposition 2–4 times, compared to pressurized metered-dose inhaler (pMDI) alone
Allows pMDI use in patients with acute illness/dyspnea
No drug preparation
Simplifies drug delivery/coordination issues
Disadvantages
Accessory device decreases portability, compared to pMDI alone
Additional cost
Device assembly necessary
Possible dosing errors with use/compatibility
Potential source of contamination/infection

(From Reference 2.)

Table 10. Advantages and Disadvantages of Dry Powder Inhalers

Advantages
Small and portable
Built-in dose counting
Propellant-free
Breath-actuated
Short preparation and delivery time
Disadvantages
Inspiratory flow dependent
Patient dose awareness
High oropharyngeal deposition
Humidity problems
Limited range of drugs
Device instructions specific to brand

(From Reference 2.)

Accessory Devices

Spacer devices typically are reservoir-type devices that facilitate delivery of aerosol in patients who are unable to coordinate device actuation and inspiration, by allowing the patient to direct the aerosol into his or her mouth through the reservoir. The mechanism of a spacer device is to provide additional volume to decrease pMDI aerosol velocity, allowing a reduction in particle size. Aerosol

Fig. 5. Dry powder inhalers (DPIs) currently available in the United States, categorized by design features. (From Reference 2.)

retention and discharged dose depend on the size and shape of the spacer, and on the electrostatic charge on the inner walls of plastic spacers.[2] While actuation-breath coordination is less important with an accessory device, it is still important for the patient to coordinate their inhalation with actuating the inhaler. Table 9 lists the advantages and disadvantages of pMDI accessory devices.

A VHC is a spacer device that incorporates a one-way valve that holds medication within the device until the patient inhales and directs exhalation away from the aerosol in the chamber, reducing aerosol losses resulting from poor hand-breath coordination. For patients unable to use a VHC with a mouthpiece, a low-resistance face mask can be placed on the patient to allow the medication to flow from the chamber into the mask. As with face mask nebulizer therapy, it is important that the mask seals comfortably and completely on the face. Optimal aerosol dosing still depends on inhaling as close to or simultaneously with pMDI actuation into the chamber.

Volume may vary, although in the United States most holding chambers/spacers are $<$ 200 mL. Direction of spray may vary between forward (toward the mouth) and reverse (away from the mouth). Children with low tidal volumes (less than device dead space) may need to take several breaths from a VHC through a face mask for a single pMDI actuation.[2]

An area of clinical concern with pMDI accessory devices is electrostatic charge acquired by the aerosol when generated, or present on the accessory device surface, as it has been demonstrated to decrease aerosol delivery from VHCs.[42,43] A solution to electrostatic charge was to manufacturer VHCs made from conducting materials such as stainless steel or aluminum.[44,45] Electrostatic free VHCs tend to be more expensive than their counterparts, and there are some practical solutions. Priming a new spacer's walls with 20 doses will coat the inner surface and minimize static charge,[45] but is probably not cost-effective, as it utilizes up to 10% of a pMDI's doses. A more practical and real world solution is to wash a nonconducting VHC with dishwashing detergent to reduce surface electrostatic charge, and detergent-washing is now incorporated in most manufacturer instructions.[43] If this method is utilized, the VHC should not be towel-dried; the VHC should be allowed to air-dry.[42]

Dry Powder Inhaler

DPIs have become the trendy device over the past decade, and consist of powdered drug formulations that are either in a pure drug form or mixed with an inactive excipient such as lactose.[46] DPIs are inspiratory flow-driven, do not contain propellant, and are breath-actuated by the patient's inspiratory effort.

Based on the specific device (usually between 30 and 60 L/min, depending on the device), the patient's inspiratory flow creates energy to deaggregate small drug particles and disperses the particles as aerosol emitted from the device. DPIs do not require coordinated efforts of the patient with the act of inhalation.

There are some unique characteristics of DPIs that make them not applicable to all patient populations. All DPIs, due to the formulary of the drug as a powder, are humidity sensitive. The higher-resistance DPIs may be difficult for

young children to use, particularly when they are ill.[47] If patients exhale into the device, they risk blowing out the medication, and the humidification from exhaled breath can decrease the efficiency of the inhaler, as the particles stick to the orifice.[48] Table 10 lists the advantages and disadvantages of DPIs.

Currently, DPIs can be organized into 3 categories centered on the dispenser design: single-dose, multiple unit-dose, and multiple-dose (Fig. 5). Regardless of the type of DPI, they all have the same essential components incorporated with the inhaler: a drug holder, an air inlet, an agglomeration compartment, and a mouthpiece.[2]

Single-Dose DPI

Single-dose DPIs have individually wrapped capsules that contain a single-dose of medication and function by dispersing powder medication from a punctured capsule. When using a single-dose DPI, a new drug capsule must be loaded prior to each dose, and the old, used capsule discarded. A potential disadvantage of single-dose DPI is the time and manual dexterity needed to load a dose for each use. Moreover, the capsules should be used only in the intended device and should not be administered in any other device.[1]

Multiple Unit-Dose DPI

Multiple unit-dose DPIs disperse individual doses that are pre-metered into blisters of medication by the manufacturer. Each blister is mechanically punctured when the cover is lifted, allowing the medication to be inhaled through the mouth without damaging other blister capsules within the device. This design eliminates the potential disadvantages of the single-dose DPI with each capsule, but the patient still needs to periodically load a blister pack into the device.

Multiple-Dose DPI

Multiple-dose DPI either measures the dose from a powder reservoir or uses blister strips prepared by the manufacturer to deliver repeated doses.[2] All doses for the prescription (device-drug combination) are self-contained and require no medication loading or manipulation by the patient prior to or after use.

Selecting an Aerosol Delivery Device

At the end of the day, we are back to where we began: selecting the most appropriate delivery device is very important for optimizing the results of aerosol drug therapy. Evidence indicates that all 3 types of aerosol generators can be equally effective if they are used correctly by the patient.[5] The criteria to select an aerosol generator can be divided into 4 categories: patient-related, drug-related, device-related, and environmental and clinical factors.

Table 11. Questions to Consider in Matching Patient to Aerosol Delivery Device

In what devices is the desired drug available? Some formulations are available only for a single device, which dictates the device used with that formulation.
What device is the patient likely to be able to use properly, given the patient's age and the clinical setting? Devices that require manual dexterity will be more difficult for elderly patients. Devices that require considerable patient/device coordination may be difficult for the very young or elderly.
For which device and drug combination is reimbursement available? This is an important consideration if the cost is not covered by a third-party payer and the patient cannot afford the out-of-pocket expense.
Which device is least costly? This is an important consideration in the hospital.
Can all the types of inhaled drugs for asthma and COPD that are prescribed for the patient be delivered with the same type of device? Using the same type of device for all the patient's inhaled drugs may facilitate patient teaching and decrease the chance of confusion with multiple devices that require different inhalation techniques, although one study reported that concurrent use of pressurized metered-dose inhaler (pMDI) and dry powder inhaler (DPI) by children with persistent asthma did not adversely affect technique.
Which devices are the most convenient for the patient, family (outpatient use), or medical staff (acute care setting), given the time required for drug administration and device cleaning, and the portability of the device?
How durable is the device?
Does the patient or clinician have any specific device preferences?

(From Reference 2.)

In a Journal Conference review by Hess in RESPIRATORY CARE in 2008,[1] a systematic approach to a series of questions was presented in a step-wise, practical manner, questions that ultimately should be asked by every clinician who is responsible for prescribing or educating patients on respiratory medications and their associated delivery devices. Those patient/device related questions are highlighted in Table 11.

Conclusions

The science, characteristics, and nuances of each device has been described here, and it is critical that these considerations and factors, along with the specifications of the device, be considered and evaluated with each individual patient. Patient/caregiver evaluation and education are paramount to establish correct device/patient matching, proper administration techniques, and the ultimate efficacy of the drug provided to the patient.

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