



Mini-Symposium - Inhaled Corticosteroids Safety Panel

Inhalation devices, delivery systems, and patient technique



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ABSTRACT

Background: In real-life clinical settings, physicians often consider the properties of various inhaled corticosteroids (ICSs), but typically little consideration is given to the properties of different inhalers and formulations.

Objective: To discuss the effects of inhalation devices and user technique on efficacy, safety, and adherence with the aim of improving asthma management.

Methods: Relevant publications were selected to augment discussion.

Results: There are many types of devices available, each with advantages, disadvantages, ease of use, and rate of misuse. Aerosol particle size influences the deposition pattern of a drug in the lungs, and the optimal particle size range is 1 to 5 μm . Retrospective reviews suggest that smaller particles (1–2 μm) could provide improved asthma control, but randomized, prospective studies are needed. Multiple studies have demonstrated high misuse rates in patients for pressurized metered-dose inhalers and dry powder inhalers. Because of this, repeated education should include physical demonstrations of using the device, checking the patient's technique, correcting the technique, and rechecking the technique. This also means that dedicated, trained staff and placebo devices should be available for instructing patients. Furthermore, the device should be selected to be cost effective and to fit the patient's preference and ability to use it correctly to enhance compliance. Asthma management guidelines and algorithms are available to guide the clinician.

Conclusion: The choice of inhaler device should depend on cost effectiveness and the patient's preference and ability to use it correctly. Patient inhaler technique should be checked and, if necessary, corrected and rechecked, with retraining if needed, at every opportunity.

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Introduction

There is insufficient awareness of the effect of inhalation devices and user technique on the efficacy, safety, and treatment adherence with inhaled corticosteroids (ICSs) for asthma. Differences in efficacy and safety are affected by the potency of the molecule; pharmacokinetic properties of the ICS, such as bioavailability and elimination; particle size and distribution; constancy of dosing, which is influenced by the intrinsic airflow resistance of the inhaler; and patient characteristics, including differences in breathing patterns, airway caliber, and patient technique.^{1,2} Typically, little consideration is given to the properties of different inhalers and formulations,³ and clinical guidelines for asthma do not offer much guidance on how these properties ought to affect treatment choices.⁴ The purpose of this article is to help

improve the selection of ICS for asthma, including consideration of the effects of inhalation devices and user technique on efficacy, safety, and adherence.

Types of Inhalation Devices and Their Advantages and Disadvantages

Inhalation devices deliver the therapeutic drug topically to the airways. The drug can be in the form of a powder of micronized drug particles, a solution, or a suspension. Inhalers vary in drug delivery efficiency to the lower respiratory tract depending on the form of the device, the internal resistance of dry powder inhalers (DPIs), the formulation of the medication, particle size, velocity of the produced aerosol plume of pressurized metered-dose inhalers (pMDIs), and ease of use.⁵ Thus, each type of inhalation device has its advantages and disadvantages.

Pressurized Metered-Dose Inhalers

Pressurized MDIs use a metering device to accurately deliver a known volume of propellant that contains the drug in suspension or solution.⁵ pMDIs have been in use since the 1950s and are still widely used. Originally, chlorofluorocarbons (CFCs) were used as

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propellants, but CFCs have been phased out and replaced with hydrofluoroalkanes (HFAs) in accordance with the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer. The change in propellant caused a redesign in device components, and in the cases of beclomethasone dipropionate (BDP) and flunisolide, the switch from CFC to HFA also involved a switch from suspension to solution, allowing for extra-fine particle sizes and high lung deposition.^{5,6} Ciclesonide (CIC), a more recent ICS, was developed as a solution with HFA propellant. It, too, has extra-fine particle size and high lung deposition.⁷ Changes in formulation and device redesign have resulted in smaller particles, lower plume velocity, and a diminished temperature drop, which can decrease upper airway impaction and increase lower airway deposition, especially in smaller airways, compared with the earlier CFC-propelled formulations.⁵

Pressurized MDIs have many advantages, including being portable and compact.⁵ They are relatively inexpensive, are available for most inhaled medications, can deliver multiple doses, and provide for consistent dosing. However, pMDIs contain propellants, and many patients cannot use the devices correctly, even after repeated instruction, because the devices require good hand-to-breath coordination. Further, even when the device is used correctly, drug deposition in the oropharynx is high.

Pressurized Metered-Dose Inhalers With Spacers or Valved Holding Chambers

The spacer or valved holding chamber (VHC) attaches to a pMDI and is used as a holding chamber for the aerosol.⁵ The patient inhales drug from this holding chamber. Because this method requires less coordination between actuating the medication and breathing, it is recommended for people who do not have sufficient hand-to-breath coordination, such as young children.

Using a spacer or VHC makes the pMDI easier to coordinate and results in less drug deposition in the oropharynx and more deposition in the lung compared with pMDIs alone. For this reason, National Asthma Education and Prevention Program (NAEPP) guidelines recommend that spacers or VHCs be used with pMDIs.⁴ However, spacers and VHCs make the inhalation device bulkier and less portable and are an additional cost.⁵ Furthermore, plastic spacers and VHCs can acquire an electrostatic charge, which can cause inconsistent dosing.

Breath-Actuated Pressurized Metered-Dose Inhalers

Breath-actuated MDIs (BA-MDIs) are actuated by the user's inhalation, and thus no hand-to-breath coordination is needed.⁵ Examples include the Autohaler (3M Pharmaceuticals, Maplewood, Minnesota) and the Easi-Breathe (Teva Pharmaceutical Industries, Petah Tikva, Israel). Like pMDIs and pMDIs with spacers or VHCs, BA-MDIs are portable and compact and deliver multiple doses. However, as with pMDIs, the device contains propellants. BA-MDIs also require higher inspiratory flow than that needed for pMDIs to be triggered.

Dry Powder Inhalers

Dry powder inhalers deliver the therapeutic drug as a powder containing micronized particles in the respirable range.⁵ DPIs have been used since 1970, and multidose DPIs have been available since the late 1980s. Multidose devices measure the dose from a powder reservoir or dispense pre-metered individual doses from blisters. Examples of single-dose DPIs include the Aerolizer (Novartis Pharma, Basel, Switzerland) and the HandiHaler (Boehringer Ingelheim Pharmaceuticals, Ingelheim am Rhein, Germany). The Diskus (GlaxoSmithKline, London, United Kingdom) and Turbuhaler (now Flexhaler; AstraZeneca, London, United Kingdom) are examples of multidose DPIs.

There are 2 types of DPIs: those whose fine particle fraction (FPF; fraction of particles $<5\ \mu\text{m}$) output depends on inspiratory flow rate (IFR; eg, Turbuhaler) and those whose FPFs are independent of IFR (eg, Diskus).⁸ Although IFR-independent inhalers would appear to be the logical choice because the FPF remains constant regardless of IFR, the amount of drug that reaches the central and peripheral airways does not remain constant because of increased turbulence with increased IFR. As shown in Figure 1, the computed dose reaching the peripheral airways for an IFR-independent device decreases from 6.7% to 2.2% with a pressure drop of 2 to 8 kPa, reflecting an increase in IFR.⁸ In contrast, with IFR-dependent inhalers, the FPF increases as IFR increases, but the amount of drug deposited in the central and peripheral airways remains generally constant, compensating for the increased deposition owing to turbulence in the larger airways that occurs with increasing IFR.

Dry powder inhalers are portable and compact and, unlike pMDIs and BA-MDIs, do not contain propellants.⁵ DPIs are actuated by the breath, and thus good hand-to-breath coordination is not required to effectively deliver the drug to the airways. However, the user needs to have forceful and deep inhalation to de-aggregate the powder formulation into small respirable particles with the IFR-dependent DPIs. Generating sufficient inspiratory flow could be a problem for very young children or patients with severe airflow limitation. However, there are newer power-assisted DPIs that

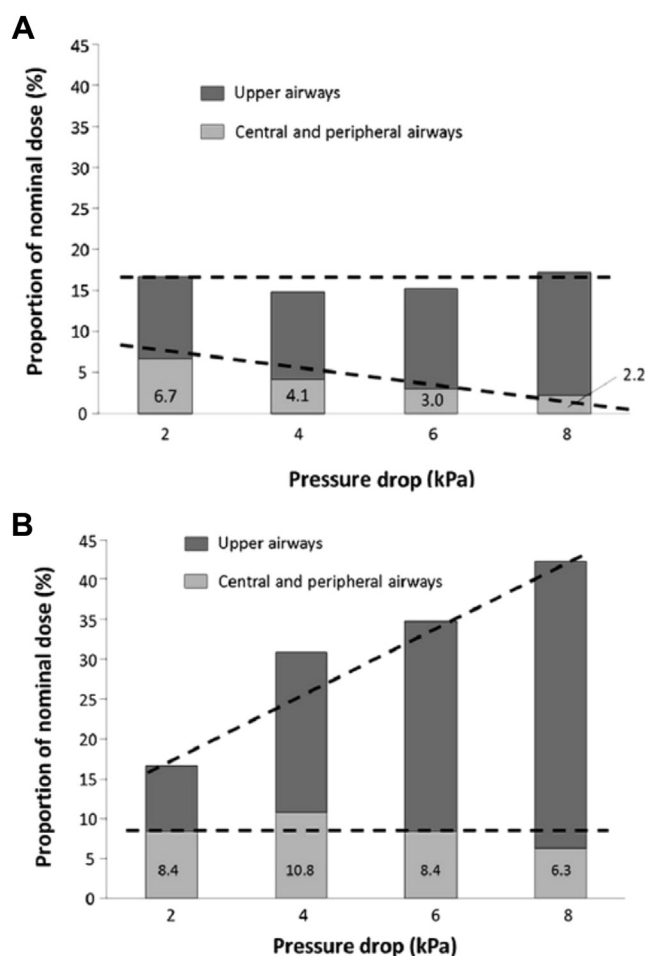


Figure 1. Distribution of the nominal dose to the upper airways and to the central and peripheral airways for a dry powder inhaler (A) independent of inspiratory flow rate and (B) dependent on inspiratory flow rate. Reprinted from *Respir Med*, Vol. 108, Demoly P, Hagedoorn P, de Boer AH, Frijlink HW, The clinical relevance of dry powder inhaler performance for drug delivery, Pages 1195-1203⁸, Copyright 2014, with permission from Elsevier.

could be easier to use for many of these patients. Other disadvantages of DPIs include sensitivity to moisture, expense, and user-unfriendliness of some models.

Soft Mist Inhalers

Soft mist inhalers (SMIs), a new type of delivery system, transform aqueous liquid solution to inhalable liquid aerosol droplets like a nebulizer but are handheld, multidose devices like MDIs and DPIs.⁵ One type of SMI, the Respimat (Boehringer Ingelheim Pharmaceuticals), is available in some European countries. SMIs are portable and compact, can deliver multiple doses, offer consistent dosing, and result in high lung deposition. Like DPIs and unlike pMDIs and BA-MDIs, SMIs do not contain propellants. However, SMIs are not actuated by the breath, and the inhalation technique is similar to that needed for pMDIs. SMIs are not currently available in most countries and are relatively expensive.

Nebulizers

Nebulizers generate aerosol particles with a jet of high-velocity gas such as air or oxygen (jet nebulizer) or a rapidly vibrating piezoelectric crystal (ultrasonic nebulizer).⁵ Nebulizers tend to be second-line devices because they are bulky and inconvenient to use. However, no special inhalation technique is necessary to use a nebulizer, and thus nebulizers can be used at any age. In addition, nebulizers can dispense drugs that are not available with MDIs or DPIs. Disadvantages of traditional nebulizers include needing an outside energy source to run the device and long treatment times. However, some newer models are powered by batteries and are triggered by inspiration. In addition, nebulizers can be expensive, and there is a risk of bacterial contamination.

Aerosol Characteristics and Deposition

Variations in efficacy and safety can be a function of not only a corticosteroid's potency but also its particle size and delivery method.^{9–11} Aerosol particle size distribution is a main factor influencing the deposition pattern of a drug in the lungs.⁸ Aerodynamic particle size distribution, in combination with the inspiratory maneuver and airway geometry, determines the penetration of drug particles into the airways and deposition on the walls of the airways and thus determines the dose delivered to the target site. The optimal range in particle size is 1 to 5 μm . Particles larger than 5 μm tend to be deposited on the oropharynx and swallowed, thus decreasing efficacy and increasing the risk of systemic effects and the risk of adverse events such as oral candidiasis.^{8,12} Particles smaller than 1 μm are more likely to be exhaled because of their low settling velocity.⁸ Currently available ICSs have mean particle sizes in the range of 1.0 to 5.4 μm (Table 1).¹²

Table 1
Particle size and lung deposition for several inhaled corticosteroids^a

Drug	Formulation	Particle size (μm)	Lung deposition (%)
Fluticasone propionate DPI	dry powder	5.4	15
Triamcinolone acetonide CFC	suspension	4.5	22
Flunisolide CFC	suspension	3.8	20
Beclomethasone dipropionate CFC	suspension	3.5	4
Fluticasone propionate CFC	suspension	2.4	26
Fluticasone propionate HFA	suspension	2.4	unknown
Beclomethasone dipropionate HFA	solution	1.1	>56
Ciclesonide HFA	solution	1–2	52
Flunisolide HFA	solution	1.2	68

Abbreviations: CFC, chlorofluorocarbon; DPI, dry powder inhaler; HFA, hydrofluoroalkane.

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Studies have shown variation in lung deposition, reflecting the dependence on drug and device. Lung deposition was 4 times higher in children after inhalation of budesonide (BUD) from the Turbuhaler than after inhalation of fluticasone propionate (FP) from the Diskus (30.8% for BUD vs 8.0% for FP).¹³ The 4-fold difference in lung deposition mirrors the previously observed difference in fine particle delivery between the 2 devices, supporting the idea that fine particle dose could be a good predictor of lung deposition. In a study of BUD, lung deposition of BUD was approximately 2.2 times greater with the Turbuhaler than with pMDIs. Pulmonary availability was 32% for the Turbuhaler and 15% or 18% for the pMDI in adults.¹⁴ Although BUD administered with the Turbuhaler had approximately twice the lung deposition compared with administration with the pMDI, systemic availability was only approximately 50% greater, suggesting that patients can achieve the same degree of asthma control with a lower dose when given BUD through the Turbuhaler vs the pMDI. This in turn lowers the risk of undesired systemic effects. This relation between the Turbuhaler and the pMDI also is in agreement with a previous study in children.¹⁵

Advantages of Small Particle Size

Small particle size allows delivery of more drug to the lung,^{4,16} potentially allowing better asthma control by improved delivery to the small airways. Small-airway disease is an important component of the pathophysiology of asthma.^{12,17} The distal airway contributes dramatically to total lung resistance in patients with moderate-to-severe asthma compared with healthy individuals or individuals with mild asthma,¹⁸ and early closure of small airways is associated with recurrent, severe exacerbations.¹⁹ Furthermore, small-airway remodeling is common in fatal asthma.²⁰ Thus, distal airways 0.5 to 2 mm in diameter are important targets for asthma disease management.^{12,17}

Because inflammation in airways smaller than 2 mm in diameter results in increased air trapping and bronchial hyper-responsiveness and is associated with increased nocturnal asthma and severe uncontrolled asthma,^{21–24} targeting these smaller airways is believed to be an effective strategy for managing asthma. Several studies have compared the effect of conventional and small-particle aerosols of the same ICS on indirect measurements of small-airway function. Compared with CFC-propelled BDP (CFC-BDP), small-particle HFA-propelled BDP (HFA-BDP) was associated with decreased evidence of air trapping after methacholine challenge, as assessed by high-resolution computer tomography, and with significantly greater improvement in small-airway function, as assessed by impulse oscillometry.²⁵

Inhaled corticosteroids with smaller particles are available as HFA-propelled formulations of BDP, CIC, and flunisolide. All 3 HFA formulations are solutions, with particle sizes ranging from 1 to 2 μm (Table 1). Real-world effectiveness of fine-particle ICS has been investigated in several retrospective studies of HFA-BDP. A direct comparison of HFA-BDP and CFC-BDP in a large retrospectively matched cohort study in the United Kingdom found significantly better asthma control with HFA-BDP compared with CFC-BDP, but there was no statistically significant difference between groups in exacerbation rates.²⁶ Similarly, in a comparison of real-life effectiveness of HFA-BDP, CFC-BDP, and FP by a pMDI in 4,133 patients in the United Kingdom, HFA-BDP led to more successful asthma control and a lower risk of exacerbations.²⁷ In addition, 2 large retrospective studies found that compared with FP, HFA-BDP increased the likelihood of asthma control, decreased the likelihood of an emergency department visit or hospitalization, and lowered health care costs.^{28,29} Although there is some evidence suggesting that extra-fine-particle ICSs treat the small airways more effectively than standard-size ICSs, large, well-designed, controlled clinical studies of patients with verified small-airway

disease are needed to determine whether extra-fine particle size improves asthma control.

Patient Performance With Inhalers

Incorrect use of inhalers is common and can result in unwanted local side effects or the delivery of insufficient doses. A recent multicenter cross-sectional observational study in Italy of 1,664 patients at least 14 years old with asthma or chronic obstructive pulmonary disease who had been prescribed various MDIs or DPIs found that mistakes in use were widely distributed across inhaler types.³⁰ The frequency of critical errors was 12% for pMDIs and 35% to 44% for the Diskus, HandiHaler, and Turbuhaler DPIs. For pMDIs, the most common errors were insufficient duration of holding the breath after inhalation (53%), too forceful inhalation (52%), not exhaling before actuation (50%), and not shaking suspension inhalers (37%). For DPIs, the most common errors were not holding the breath a sufficient period after inhalation (25%–32%) and not inhaling deeply and quickly (22%–29%). Errors were most strongly correlated with older age, lower schooling, and lack of instruction by a health care provider. Misuse was associated with increased risk of hospitalization, emergency department visits, courses of oral steroids and antibiotics, and poor disease control.

Another study associated poor inhaler technique with poor asthma control.³¹ This study conducted in the United Kingdom evaluated pMDI usage and asthma control in nearly 4,000 primary care patients of any age with asthma. Patients who displayed significant errors when using pMDIs had higher risks of poor asthma control and more bursts of systemic corticosteroids. Patients using pMDIs with spacers or BA inhalers had better asthma control than those using pMDIs alone. Synchronization—initiating inhalation shortly before actuation of the device—was the main step of inhalation technique that most patients failed (58% of patients). However, a large proportion of patients failed the other 2 major steps: 40% failed to breathe in at a rate of 10 to 50 L/min before actuating the device and 34% failed to hold their breath for at least 5 seconds at the end of inspiration.

A review of 21 studies estimated that the frequency of pMDI misuse ranged from 14% to 90%, with an average of approximately 50%.³² In turn, misuse decreased lung deposition from 20% to 7%.³³

Importance of Instruction in the Use of Inhalers

Patient Education Improves Inhaler Technique

Studies reporting misuse of inhalers also have reported that risk of inhalation technique errors decreased when patients were instructed in correct use. In the cross-sectional observational study of patients in Italy with chronic obstructive pulmonary disease and asthma described earlier, instruction in inhalation technique by a health care provider, such as a respiratory specialist, general practitioner, nurse, or pharmacist, and checking patient technique at least once decreased the risk of critical errors.³⁰ In a Dutch study, inhaler technique instruction significantly improved rates of correct use in children for pMDIs with spacers, but not for pMDIs alone.³⁴ A study of 342 patients 15 to 84 years old in Turkey showed that rates of correct use increased from 58.9% before a standardized, 3-minute, applied, face-to-face training to 92.6% after training for DPIs and from 31.1% to 45.2% for pMDIs.³⁵ Incorrect use before training was associated with using a pMDI (vs a DPI), being female, having a low education level, living in an urban area, shorter time since diagnosis, and being diagnosed and trained by someone other than a chest disease specialist.

Even with training, there remains a proportion of patients who cannot use their inhaler correctly, whether they are pMDIs or DPIs.^{36,37} In the Turkish study that investigated rates of correct use before and after training for DPIs and pMDIs, factors that affected

continued misuse after training were old age and type of pMDI.³⁵ The investigators recommended that device selection be done on a trial basis, particularly for older patients, and that alternative treatment options be reviewed for those patients who continue to use their devices incorrectly despite training.

Teaching Inhaler Technique to Patients

The NAEPP Guidelines for the Diagnosis and Management of Asthma and the Global Initiative for Asthma (GINA) Pocket Guide for Physicians and Nurses recommend that skills such as inhaler technique and the use of a spacer or VHC be taught and reinforced at every opportunity.^{4,38} Because inhaler technique deteriorates with time after training, repeated checking and retraining are necessary.³⁹ Patients should demonstrate how they use their inhaler with a placebo inhaler, and their technique should be checked against a device-specific checklist, such as those available at the GINA and Aerosol Drug Management Improvement Team websites (<http://www.gina.org>, <http://www.admit-inhalers.org>). Errors should be corrected using a physical demonstration using a placebo inhaler and the technique should be rechecked, 2 to 3 times if necessary. For poor asthma control, GINA guidelines recommend checking inhaler technique and adherence before considering a step-up in dose.^{38,39} GINA guidelines also recommend a process of choose, check, correct, and confirm to ensure effective selection and use of inhaler devices.^{38,39}

However, many providers do not follow the guidelines of checking and demonstrating inhaler technique at every opportunity. In a cross-sectional survey of pediatric providers in an inner-city academic medical center, 82% of providers stated they demonstrate pMDI-and-spacer technique, but only 5% demonstrate the technique at every visit.⁴⁰ Providers identified limited access to pMDI and spacer devices, lack of time, and inadequate knowledge as barriers to demonstrating and assessing the pMDI-and-spacer technique.

Health care professionals' lack of knowledge of proper use of devices is a key barrier to instructing patients in inhaler technique. As clinical practices become increasingly busy and new devices are marketed as user-friendly, there is less priority given to provide real-life instruction on proper inhaler technique. Many health care professionals cannot instruct patients properly. An estimated 39% to 67% of nurses, physicians, and respiratory therapists were reported to be unable to adequately describe or perform critical steps of using inhalers.⁴¹ Among respiratory therapists, registered nurses, and medical house staff physicians, respiratory therapists had significantly more knowledge of inhalers—including pMDIs, pMDIs with spacers, and DPIs—and how to use them.⁴²

The key challenge to providing regular instruction to patients in inhaler technique is allocating time and personnel. It is commonly assumed that instructing patients is time consuming, but an Australian study showed that training sessions by pharmacists took only 2.5 minutes, and asthma outcomes improved.⁴³ In addition, training for health care professionals (ie, training the trainer) does not have to be elaborate or time consuming. Single-education sessions were shown to be effective among medical residents and pharmacists.^{44,45} A small-group lecture format with a web-based tutorial was effective among pharmacy students.^{46,47}

The best person to provide inhaler training to patients will vary by practice situation. However, the value of non-physician specialist health care professionals and certified respiratory educators is increasingly recognized.^{42,48} As discussed earlier, respiratory therapists were found to have better knowledge of inhaler technique than nurses or house staff physicians.⁴² In an Australian study, 3-visit and 4-visit asthma service provided by community pharmacists led to significant and sustainable improvements in

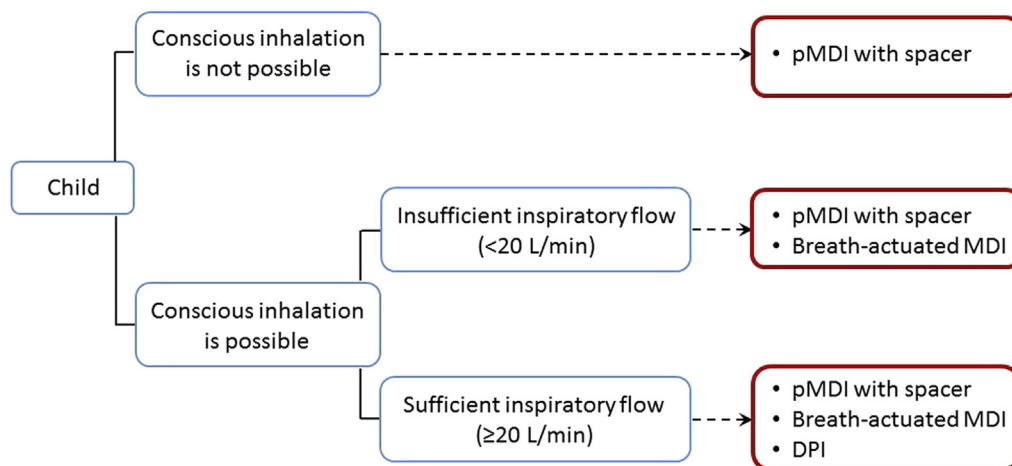


Figure 2. Inhaler selection algorithm for children as proposed by van Aalderen et al.⁵² DPI, dry powder inhaler; MDI, metered-dose inhaler; pMDI, pressurized metered-dose inhaler. Adapted from van Aalderen et al.⁵² and republished with permission.

inhaler technique, asthma action plan ownership, asthma control quality of life, adherence, and asthma knowledge.⁴⁹

Selecting the Appropriate Inhaler

There is increasing awareness of the importance of inhaler devices, and to address this, the 2015 update of GINA guidelines provided more information on selecting devices and skills training for correct inhaler technique.⁵⁰ There also is more device-related content in national asthma guidelines such as the British Thoracic Society/Scottish Intercollegiate Guidelines Network guideline, the National Institute for Health and Care Excellence Quality Standards for Asthma in the United Kingdom, and Australia's The Asthma Handbook.

Device Selection for Children

Children have unique issues with pulmonary drug delivery.⁵¹ Their lungs are developing, causing continuous change in the dimensions and number of airways. In addition, children have lower tidal volume and highly variable breathing patterns. Air leaks

from facemasks also are an issue. Recommended adaptations for infants and young children include facemasks with nebulizers and spacers because they cannot control their breathing patterns and have tidal breathing through the nose only. Spacers or VHCs also are recommended for infants and young children using pMDIs so that drug delivery is less dependent on hand-to-breath coordination. The spacer or VHC also allows the propellant droplets to evaporate and decelerate, which decreases particle size and deposition in the oropharynx.

The GINA guidelines address inhaler choice for young children and infants.³⁹ Because tidal breathing is the only possible inhalation technique in young children, a pMDI with a dedicated valved spacer is the preferred delivery system. Infants and children 0 to 3 years old should use a pMDI and dedicated valved spacer with a facemask or a nebulizer with a facemask. For children 4 to 5 years old, the recommended device is a pMDI and dedicated valved spacer with a mouthpiece. Alternatives include a pMDI plus a dedicated spacer with a facemask or a nebulizer with a facemask mouthpiece.

There is less guidance for children older than 5 years. Van Aalderen et al.⁵² provided an inhaler selection algorithm for

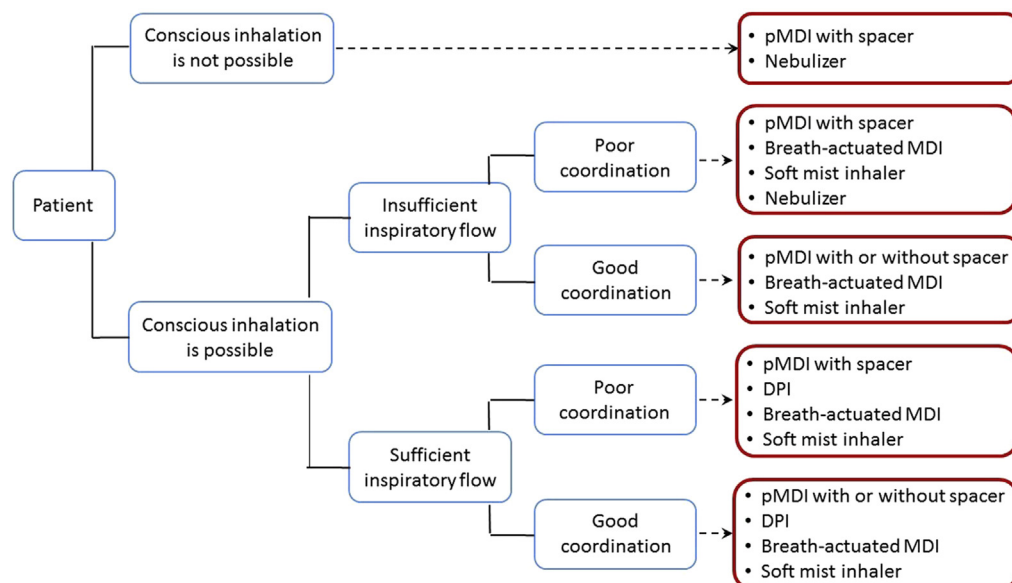


Figure 3. Inhaler selection algorithm for adults as proposed by Dekhuijzen et al.⁵³ DPI, dry powder inhaler; MDI, metered-dose inhaler; pMDI, pressurized metered-dose inhaler. Adapted from Dekhuijzen et al.⁵³ and republished with permission.

children that asks 2 questions: (1) is the child conscious of his or her inhaling and (2) is the child's inspiratory flow sufficient? As shown in Figure 2, if the child is unaware of his or her inhaling, then it is recommended that the child use a pMDI with a spacer. If the child is aware of his or her inhaling, then the recommended device depends on whether the child's inspiratory flow is at least 20 L/min. If the child's inspiratory flow is sufficient, then a pMDI with a spacer, a BA-MDI, or a DPI is recommended. If the child's inspiratory flow is insufficient, then a pMDI with a spacer or a BA-MDI is the recommended option.

Device Selection for Adults

The GINA guidelines offer very little guidance on device selection for adults other than devices should be portable, be simple to use, have minimal maintenance requirements, and not require an external power source.³⁹ Thus, clinicians have offered algorithms to guide inhaler selection. Dekhuijzen et al.⁵³ proposed an inhaler selection algorithm designed for the general practitioner's office or hospital outpatient clinic (Fig 3). This algorithm is similar to that for children proposed by van Aalderen et al.,⁵² but it includes a component on the patient's coordination. The first step of the algorithm is concerned with whether the patient can consciously inhale medication, because some patients (eg, elderly patients) might have cognitive limitations that prevent this. Patients who are not conscious of their inhaling should use a pMDI with a spacer or a nebulizer. For patients for whom conscious inhalation is possible, the next questions in the algorithm are whether the patient has sufficient inspiratory flow and whether the patient has good hand-to-breath coordination. Recommended devices for patients with insufficient inspiratory flow and poor coordination are a pMDI with a spacer, a BA-MDI, an SMI, or a nebulizer; for patients with insufficient inspiratory flow and good coordination, options include a pMDI with or without a spacer, a BA-MDI, or an SMI. Similarly, patients with sufficient inspiratory flow and poor coordination have options of a pMDI with a spacer, a DPI, a BA-MDI, or an SMI, whereas recommended devices for patients with sufficient inspiratory flow and good hand-breath coordination include a pMDI with or without a spacer, a DPI, a BA-MDI, or an SMI.

Conclusions

In the future, inhaled bronchodilators and corticosteroids will remain the cornerstone of asthma therapy, and the development of inhaler devices might become more important than the development of new drugs.⁵ Clinicians need a better understanding of the effects of inhalation devices, delivery systems, and user technique on the safety, efficacy, and treatment adherence to ICS use to maximize asthma control. The aerosol, the device, and the patient play a role.

Effective delivery of ICS to the airways requires drug formulations with drug particles of 1 to 5 μm . Different drug-and-device combinations have different rates of lung deposition, with the drug needing to get into the smaller airways. It has been suggested that extra-fine-particle ICS pMDIs might provide enhanced control because of their improved delivery to the peripheral small airways. However, superior efficacy of these extra-fine particles has not been proved.

There are many types of devices available, each with advantages and disadvantages, including ease of use and rate of misuse. For this reason, education in proper inhaler technique, for patients and for the health care providers who are tasked with instructing the patients, is important. To accomplish this, it is important that offices have placebo inhalers of each type they prescribe to demonstrate proper use to the patient. After training, there is no difference in the ability of patients to use DPIs or pMDIs; however, even with training, there are some patients who cannot use their

inhaler correctly, whether they are pMDIs or DPIs. The choice of inhaler device should depend on the patient's ability to use it correctly, cost effectiveness, preference, and compliance. Patient inhaler technique should be checked and, if necessary, corrected and rechecked, with retraining if needed, at every opportunity.

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