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Practical Guide on Inhaler Devices

Guest Editor: Dr. Agam Vora

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According to the latest Global Burden of Disease Report, India has an estimated 93 million people suffering from asthma and COPD. Although India contributes to only 11% of the global asthma burden, 42% of all global asthma deaths occur in India. COPD is the 2nd leading cause of death in India. Despite this huge and growing burden, both asthma and COPD remain very poorly managed in India.

The best way to deliver medications in obstructive airway diseases is by the route of inhalation. Inhalation therapy is now recognized as the safest, fastest and most effective way of delivering drugs to treat asthma and COPD. The drug can be delivered with the use of inhaler devices that are broadly categorised into pressurised metered dose inhalers (pMDI), dry powder inhalers (DPI), breath actuated inhalers (BAI) and nebulisers. The modern-day inhaler devices have been in India since the 1970’s and have grown exponentially over the years. Today, several leading pharmaceuticals produce inhaler devices, giving us the opportunity to make appropriate patient-based choices.

Despite the wide spread availability of these devices in India, many physicians lack the knowledge and confidence to use inhalation therapy in clinical practice. As a result, only between 2 to 3 out of 10 asthmatics and COPD patients in India receive inhalation therapy. Even among those who are prescribed inhalation therapy, many are not educated properly about how to use them. This is contributing in a major way to the growing suffering and death associated with asthma and COPD.

The key to successful treatment of obstructive airway diseases is selecting the right drug, selecting the right device and most importantly is the correct use of the inhalation device. Since each of the devices have their own working principles, benefits and drawbacks, as Physicians, it is imperative for us to be well-informed on the knowledge and the differences amongst them to enable us to make appropriate choices for our patients.

This special issue was developed by a national task force comprising of pulmonologists, paediatricians, internists and respiratory therapists from across the country who were experts in this field. This is the most comprehensive document on Inhalation Therapy that will be of immense benefit to physicians as well as other healthcare professionals from across India to give them the knowledge base and skill set to start using correct inhalation therapy. It will also help physicians and healthcare professionals address myths, misconceptions and apprehensions of our patients for a better adherence to the therapy. This has the potential to significantly reduce the suffering and deaths associated with asthma and COPD in India.
Though Asthma did not have any name that time, Chinese literature, dated around 2600 BC mentions what could have been asthma. Roughly around the same time the ancient Egyptians mention symptoms of breathlessness and respiratory distress in their books on health and disease. 2,000 years later in Greece, Hippocrates coined the term “Asthma”. This Greek term means respiratory distress and panting. Hippocrates correlated the occurrence of asthma with environmental triggers.

The Canadian scientist, Sir William Osler, who is known as the “Father of Modern Medicine”, reported in his epoch-making book “The Principles and Practice of Medicine”, that asthma was a swelling of the bronchial membranes accompanied by spasm of the bronchial tubes, closely related to hay fever, often paediatric, and familial in nature. He recognized nervous stimulation as a cause of asthma attack. His research led to the idea that asthma was a psychosomatic disease. His choice of treatment approaches reflected his understanding of the nervous system as a trigger of asthma.

Since then our understanding of asthma has undergone a sea change. Over the last three decades it has been established that asthma is a chronic inflammatory disorder over and above the acute episodes of bronchospasm and inflammation. From treatment with only bronchodilators initially we now realize the importance of the need of regular treatment with anti-inflammatory drugs like corticosteroids. Like any other chronic disease, asthma also needs long term treatment. Very recently we also learnt that even mild intermittently symptomatic asthmatics would need combination therapy with beta agonists & corticosteroids for a better quality life. This has reemphasized the importance of the inhaled corticosteroid for asthma management.

Over the years the understanding of eosinophils been very interesting, from a detrimental role to a useful one to no role at all and now there is a school of thought that says there could be inflammatory as well as residential eosinophils, having a dual role. From guideline based standard care we are moving to more personalised phenotype based therapies. But, aerosol therapy is to stay. We may use oral therapies or biologics but the cornerstone of asthma therapy remains via the inhaled route and hence it is of paramount importance to understand the facts about this route of delivering drugs for asthma and COPD.

Unlike most other conditions, success of treatment of asthma is dependent on the choice of the route of delivering the drugs. Over the last four decades the focus has moved from oral therapies to inhaled therapy for all the right reasons. Inhaler devices deliver drugs directly into the airways, thereby allowing rapid action and allowing high local drug concentrations at the same time limiting systemic toxicity. While numerous clinical trials, literature reviews, and expert panel guidelines have been developed to assist physicians in their choice of inhalational drugs, deciding which aerosol device (i.e. metered-dose inhaler, dry powder inhaler, nebulizer, etc) best suits a given patient. To understand their importance, it is necessary to know the make-up of an aerosol, physical and chemical factors as well as anatomical factors that influence its deposition and clearance in the tracheo-bronchial tree. Equally important is the correct use or technique to be followed while using an inhaler device in order to achieve optimum outcomes.

COVID-19 has had a major impact on healthcare. For the last one year we only thought and spoke about the coronavirus. But last few weeks we have to some extent conquered this disease and it is the time we relearn our understanding of asthma.

I am very happy to present the detailed supplement on ‘A Practical Guide on the Use of Inhaler Devices for Asthma and COPD’, by Sundeep Salvi & his group of esteemed experts from across India which talks in detail about principles of aerosol therapy, the various devices available, the correct technique of using them, maintaining the device & choosing the right device for the right patient. I am sure this special issue is going to be very useful to you in making informed decisions while managing asthma and COPD patients with inhaled aerosol therapies.
A Practical Guide on the Use of Inhaler Devices for Asthma and COPD


Abstract

Inhalation therapy is the most important route of administering drugs for the treatment of asthma and chronic obstructive pulmonary disease (COPD) because of its quick onset of action, greatly enhanced safety profile and better efficacy than the oral route. Yet, most patients of asthma and COPD continue to be put on oral medications that have poor therapeutic efficacy and greater side effects. The majority of asthma and COPD patients still continue to be prescribed oral medications. This has contributed to increased suffering and deaths associated with asthma and COPD in India.

Although many physicians believe that they themselves know how to use inhaler devices correctly, the majority of them do not know the correct usage steps. In this special supplement, we describe the various types of inhaler devices available for the treatment of asthma and COPD, their advantages and disadvantages, and the steps for using them correctly. We hope that this supplement on inhaler devices will help physicians understand the importance of inhalation therapy, the various types of inhaler devices available, and guide them in prescribing the right inhaler device for their patients. Every patient of asthma and COPD must receive inhaled medications for their treatment and care must be taken to ensure good adherence and compliance.

Introduction

Inhalation therapy is the delivery of aerosolised medications directly into the lungs. It is the most favoured route of administration of drugs in the management of obstructive airway diseases (OADs) such as asthma and chronic obstructive pulmonary disease (COPD) as it offers faster speed of action, combined with greater safety and efficacy. Inhaled drugs are localised to the target organ, which generally allows for a lower dose than is necessary with systemic delivery and, thus, fewer and less severe adverse effects. This is a distinct advantage, especially when administering corticosteroids to reduce airway inflammation in asthma. Because the drug is directly delivered to the site of action, its effect starts within seconds to minutes. Patients of all age groups, including children and the elderly, suffering from OADs should be offered inhalation therapy. Different types of inhaler devices are available and recommended for specific groups of patients to aid drug delivery.

The Global Initiative for Asthma (GINA) and the Global Initiative for Chronic Obstructive Pulmonary Disease (GOLD) guidelines strongly recommend inhalation therapy for the management of asthma and COPD, respectively.

Inhalation Therapy – A Historical Perspective

As early as 2000 BC, people in southern India burnt the dried leaves of the Datura plant and inhaled the smoke for relief from symptoms of cough and breathlessness. When the British colonised India, they found this to be an effective remedy for asthma and related symptoms. They improvised on this method and made cigarettes of dried Datura leaves that were popularly marketed and used as ‘asthma cigarettes’.

Dry powder inhalers (DPIs) were developed only around the 1940s and were first used to deliver inhaled penicillin powder. In 1926, a Norwegian engineer designed a pressure valve to spray insecticides. Three decades later, the valve was improvised to create the Meshburg valve used in perfumes and hairsprays to deliver specific unit amounts of the ingredient. A 13-year-old American girl with asthma was instrumental in the development of the idea of a pressurised inhaler. Her father, who was a partner with 3M Laboratories, USA, built the first pressurised metered-dose inhaler (pMDI) device with the help of an old Coke bottle, freon from an old refrigerator and the Meshburg valve on the top (1956).

The Indian guidelines also discourage the use of oral therapy and strongly recommend the use of inhalation therapy for the management of OADs.

Pharmacokinetics of Inhaled Drugs

Around 20% of the inhaled medication is deposited in the lungs upon inhalation, thereby exerting the desired pharmacological effect. Part of the dose that reaches the airways is subsequently absorbed through the pulmonary vasculature from where it eventually ends in the systemic circulation. The remaining 80% of the drug that gets deposited in the oropharyngeal airways is swallowed.
and absorbed from the gastrointestinal tract and undergoes first-pass metabolism in the liver before entering the systemic circulation. The amount of drug in the systemic circulation is the sum of the fraction absorbed from the lungs and the gastrointestinal tract and, for all practical purposes, is much smaller than ingested oral drugs. At recommended doses, therefore, there are very little systemic effects of inhaled medications (Figure 1).7

Factors Affecting Drug Deposition

Several factors determine what proportion of the inhaled medication reaches the target site. Factors that affect drug deposition can be classified as device-, formulation- or patient-related.2 Device-related factors include the type of device and its usability, formulation-related factors include the nature and size of the drug particle, and patient-related factors include geometry of the airways, presence of disease, and the technique for using inhaler devices.7–12

Effect of Particle Size on Drug Deposition

The size of the inhaled drug particles has a major impact on drug deposition. Particles that are greater than 20 µm in diameter are very efficiently filtered by the nose. Particles in the size range of 10–20 µm are filtered and deposited in the upper respiratory tract. As shown in Figure 2, only particles in the size range of 0.5–5 µm have the ability to deposit in the airways. The smaller the particle, the farther it is deposited and those less than 0.5 µm diffuse into the systemic circulation (Figure 2).8

Methods of Drug Deposition in the Airways

Through inhalation, drugs reach the airways as a result of three physical properties: inertial impaction, sedimentation, and diffusion. These are influenced by particle size.

- **Inertial Impaction:** Particles that are emitted from inhaler devices generally travel at a speed of around 30 m/s or 110 km/hr.13 Due to the momentum generated, large particles of around 20 µm in size do not follow the anatomical path of the airway and get deposited in the oropharyngeal region. Particles of around 10 µm in size get deposited in the larger airways of the lungs.13
- **Sedimentation:** Particles between 0.5 µm and 5 µm in size are deposited in the lower airways due to gravitational force and if they remain in the airways for enough time to allow sedimentation. Particles in the 2 µm to 5 µm size range are ideal to achieve the appropriate therapeutic effect.3,13
- **Diffusion:** Particles of <0.5 µm in size are in erratic motion due to the Brownian diffusion effect at the alveolar surface. These particles either diffuse across the alveolar membrane into the bloodstream or are expelled out at the end of expiration.13

Effect of the Geometry of the Airways and Disease on Drug Deposition

The pattern of drug deposition in the lungs also varies according to the geometry of the airways. Due to the curvature of the airways and the bifurcation of the bronchi, larger particles tend to remain in the upper airways while smaller particles drift with the airflow and deposit in the lower airways. In diseases such as asthma and COPD, there is inflammation and obstruction of the airways. This alters the flow of air and the amount of drug deposited in the airways is reduced. In severe disease, narrower airways and mucus plugging increases turbulence in the airways and reduces drug deposition.14

Terminologies Associated with Particle Size in Inhalation Therapy

It is not easy to make all the drug particles in an inhaler of the same size; therefore, drug particles are hetero-dispersed, and lie within the size range of 0.5–5 µm. **Mass median aerodynamic diameter (MMAD)** is one of the most widely adopted metrics for particle-size distribution. Particle sizes that fit the definition of MMAD are those where half the quantity of aerosol particles is greater in size, and the other half is smaller than the median aerodynamic diameter (MAD). **Fine-particle dose (FPD)** is the dose of the aerosol particles that are <5 µm in diameter. **Fine-particle fraction (FPF)** is the ratio of the FPD to the emitted dose. Small-sized (fine) particles (0.5–1.5 µm) have recently attracted much attention because of their ability to reach the smaller airways. Emerging evidence suggests that asthma and COPD patients with predominant small airways obstruction may benefit from fine and ultrafine drug particles. Studies comparing fine and ultrafine particles with currently available inhaled products are yet to confirm the superiority of one over the other.

Types of Inhaler Devices

There are different types of inhaler devices, but the most common ones are the pMDIs, breath-actuated inhalers (BAIs), unit- or multidose DPIs, and nebulisers. Each device has its own working principle and a distinct set of advantages, disadvantages and technique of use (Figure 3).

Role of Devices in Drug Delivery and Deposition

- pMDIs (Pressurized Metered-Dose Inhalers): These devices are designed to emit a fixed amount of drug with each actuation. The drug is either in a solution or suspension form along with a propellant hydrofluoroalkane (HFA) and other excipients and is stored in the MDI canister under high pressure (about 300–500 kPa,
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BAIs (Breath-Actuated Inhalers):
BAIs are pMDIs that have been developed to overcome the coordination problems faced with a pMDI, where the inspiratory pressure generated by inhalation triggers the release of a unit dose of the drug.

During inhalation, the BAIs currently available automatically actuate at a flow of 23–35 L/minute (https://www.ciplamed.com/content/synchrobreathe-technical-dossier, Accessed 18 Jan 2021). Generally, the maximum drug deposition with a pMDI or DPI or BAI is only around 15–20%. However, this is enough to demonstrate that incorrect inhaler technique can lead to increase in symptoms, hospitalisations, deaths and economic loss. Hence, it is important to perform every step of inhalation correctly.

pMDIs

In pMDIs, the drug is stored in an aluminium canister under pressure. On actuation, the canister emits a unit dose with the help of a valve mechanism.

The unit dose is aerosolised when the pressure in the canister is released and is made available for inhalation. pMDIs were first developed in 1956 by Riker Laboratories, USA, and have revolutionised inhalation therapy across the world. The first pMDIs contained the bronchodilator epinephrine to give relief from acute episodes of bronchoconstriction. Development of inhalation devices has kept pace with advances in drug development and, now, the most commonly used drugs for the treatment of airway diseases are available via pMDIs.

The drugs are maintained in solution or suspension formulations under pressure, in an aluminium canister, with a capacity of 10–20 ml. Most of the drug formulations are in the suspension format. Apart from the drug, the canister contains a propellant, which in most cases is a hydrofluoroalkane (HFA 227 or HFA 134a) in a liquid form, stored in the canister under high pressure of about 300–500 kPa (or 3–5 atmosphere or 2,250–3,750 mmHg). The earlier pMDIs contained a chlorofluorocarbon (CFC) as a propellant, but because they were more ozone-depleting, they were slowly phased out. With each actuation, the Meshberg valve in the canister releases aerosol particles at a high velocity of >30 m/s. Particle size of the emitted drug is usually between 2 and 4 µm.

Key Components of a pMDI

**Metering Valve:** It is the most important component of the pMDI. The metering valve is designed such that each actuation releases the specified unit dose of the formulation.

**Container:** The canister is made of inert material such as aluminium,
which is able to withstand the high pressure generated by the propellant and also prevents adhesion of drug particles and chemical degradation of the drug. Canisters come in different sizes.

Propellants: Propellants are gases that are liquefied when compressed under high pressure, but regain their gaseous form under atmospheric pressure. Thus, when released from the canister, they rapidly evaporate, generating an aerosol of the drug that is dissolved or suspended in them. All pMDIs now use HFA 227 or HFA 134a as propellants. These have replaced the CFCs used earlier, which were banned due to their ozone-depleting effect. The HFA propellants also have the advantage of lower velocity (10–15 m/s) and are warmer as compared with CFCs.

Drug Formulations: Drug formulations in the pMDI are available either as a suspension or a solution. In suspensions, micronised drug particles are suspended in the liquefied or compressed gas; in the solution form, the drug is dissolved in the medium. The drug formulations also contain surfactants such as oleic acid or soya lecithin to prevent aggregation of the particles and clogging of the valve. Since surfactants are insoluble in HFA, a little ethanol is added to increase their solubility in many formulations.

Actuator: The pMDI canister is fitted into a plastic actuator. The actuator is a very important component of the pMDI. The diameter of the nozzle in the actuator from where the drug is released plays a key role in the particle size of the aerosol generated. The nozzle diameter ranges between 0.14 and 0.60 mm.

pMDI Dose Definitions

- Ex-Actuator Dose: The amount of the drug leaving the actuator and delivered to the patient is the ex-actuator dose. This is the dose available to the patient for inhalation.
- Ex-Valve Dose: This is the amount of drug leaving the valve, not all of which is available to the patient for inhalation.

In India, the pMDI doses are based on the ex-valve dose; in some countries like the USA, the ex-actuator dose is used as the therapeutic dose. For example, budesonide 200 mcg in India is equivalent to budesonide ex-actuator dose of 160 mcg in the USA.

Steps for the Correct Use of a pMDI

Table 1 lists the steps for the correct use of a pMDI and provides the rationale for each step.

<table>
<thead>
<tr>
<th>Priming of the Inhaler</th>
</tr>
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<tbody>
<tr>
<td>Priming means making a new pMDI ready for use by spraying it into the air several times to release a few doses (about two to four doses or as specified by the manufacturer).</td>
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</table>

Procedure for Priming

- Open the cap of the inhaler.
- Shake the inhaler up and down a few times.
- Test-fire the inhaler by pressing/actuating it a few times (about two to four times) by spraying into the air away from the face.

pMDI Priming Instructions for the Patient

- When a new inhaler is being initiated
  - When initiating therapy with a new pMDI, the metering chamber should be filled with the uniform dose as labelled on the device. To ensure filling of the metering chamber with this uniform dose, priming needs to be done.
- When an inhaler is being used after a gap of a few days
  - The pMDI may have been stored in a position where the metering apparatus is above and the solution/suspension below, which can cause the metering valve to clog due to the effect of gravity. Prolonged storage even in the correct position may lead to clogging of the valve due to the liquefied propellant. Hence, to fill the metering chamber with the uniform dosage and to clear the clog, priming needs to be done.

The Need for an Interval between Two Actuations

It is important for the pressure in the pMDI to equilibrate between actuations and this requires some time.

- Studies have shown that multiple actuations in quick succession reduce the total quantity of drug emitted from the chamber.
- A gap of at least 15–20 seconds between two actuations is recommended in the literature.

Recommendation: We recommend a gap of 30 seconds between two actuations.

The European Respiratory Society (ERS) and the International Society for Aerosols in Medicine (ISAM) Task Force and the Indian guideline on management of Asthma recommend rinsing the mouth or gargling with water and spitting out after the use of an inhaler, especially with inhaled corticosteroids.

Recommendation: We recommend rinsing of the mouth as well as gargling with water and spitting out, especially after the use of inhaled corticosteroids even when using a spacer.

Local Side Effects of pMDIs

The common local side effects caused by the use of pMDIs are attributed to inhaled corticosteroids use and includes dysphonia and oropharyngeal candidiasis. The speed of the drug emitted from the pMDIs is between 100 and 140 km/hr, because of which 80% of the inhaled drug hits the throat and gets deposited there due to the force of impaction. These side effects are attributed to the drug rather than the device.

Dysphonia

The postulated mechanisms for dysphonia are probable bilateral adductor myopathy, supraglottic hyperfunction or inflammatory infiltrates in the mucosa.

Oropharyngeal Candidiasis

Candidiasis is a side effect of inhaled corticosteroids that occurs in about 3% of patients due to their immunosuppressant properties. The occurrence of candidiasis can also lead to noncompliance to therapy. Rinsing and gargling with water to wash out the mouth and throat and the use of spacers lower the risk of Candida infections.

Recommendation: To minimise the occurrence of side effects, the following is recommended:

- The lowest dosages of inhaled corticosteroids should be used to control the disease.
- A spacer should be used during inhalation of the drug.
- The patient should be instructed to use the correct technique of inhalation.
- Rinsing of the mouth and gargling should be done after each inhalation.
- The patient should be instructed to keep the spacer clean.
Cold-Freon Effect

When the propellant, which is under pressure in the canister, is released out through the nozzle, the temperature of the aerosol drops to around -30°C and by the time it hits the throat, the temperature is around 0°C. When the propellant, which is moving at around 100–140 km/hr, hits the throat at 0°C, it causes pharyngeal spasm and stimulates cough in some subjects. This is described as the cold-freon effect and occurs only in a few people and can easily be overcome with the use of a spacer.22

Indicators that the Inhaler may be Empty

A pMDI device may actuate and release an aerosol even when the canister is devoid of the active drug. The aerosol may contain only the propellant and other excipients. When a patient continues to inhale from a canister devoid of the active drug, there may be loss of disease control, leading to an exacerbation. If the patient is having an exacerbation but the rescue inhaler is empty of medication, it can lead to significant morbidity. Hence, it is important that the patients are educated on the ways to identify an empty pMDI.

Dipping the inhaler in water to see if it floats or weighing the canister are inaccurate and harmful methods to assess the amount of drug present in the canister. However, irrespective of whether the inhaler has a dose counter or not, patients should be advised to mark the inhaler carton with the date when the first dose was taken (Figure 4). This is the simplest way to track the number of doses remaining in the canister with the expected number of doses the patient should have taken. If the patient is on reliever therapy, the patient should keep a record of the dosages taken. Most inhalers now come with a dose counter and we recommend the use of these inhalers.

| Recommendation: Irrespective of whether a pMDI has a dose counter or not, the patient should mark the date of initiating the inhaler for use on the inhaler carton. |

Cleaning the Actuator Mouthpiece

Removing the canister and washing the entire inhaler device in mild detergent and water (as per older recommendations) is likely to damage the device, especially the newer devices with dose counters. Hence, it would be best to follow the manufacturer’s advice for cleaning the actuator mouthpiece.

| Recommendation: The actuator mouthpiece should be cleaned with a soft cloth or a tissue paper after each actuation. It is best to follow the manufacturer’s recommendations. |

Common Errors When Using a pMDI

The commonest errors when using a pMDI include patients not exhaling out completely before inhaling, not holding their breath, and inhaling too rapidly and/or shallowly.27

Spacers

Spacers are holding chambers that allow the patient to take some extra time (2–20 seconds) to inhale the drug after it has been released from the pMDI.20,21

Advantages of Using a Spacer

Spacers act as holding chambers for the drug once it is actuated, thus eliminating the need for actuation-inhalation coordination by the patient. They are also useful for patients of any age who have difficulties with hand-breath coordination. The oropharyngeal impaction of the drug is also significantly reduced when using a spacer, which also decreases the risk of oropharyngeal candidiasis with ICS use, and eliminates the cold-freon effect. There is a possibility of reduced dysphonia when spacers are used with inhaled corticosteroids.25 The use of repeated doses of inhaled short-acting beta₂-agonist bronchodilators via a pMDI + spacer has been found to be as effective as a nebuliser in controlling an acute exacerbation of asthma.

Many spacers are made up of non-static material that reduces the deposition of the drug along the inner walls of the spacers. The drug particles have an electrical charge that works opposite to that of the spacer material; hence, they get attracted and stick to the walls of the spacer. Some spacers have a valve, also called valved-holding chambers, which are particularly useful as they allow patients to re-breathe without introducing moisture into the spacer.21,22 Re-breathing is necessary in small children and among those who are unable to hold their breath, such as during an exacerbation.

Although spacers and holding chambers are different, the terms are used interchangeably.24 A spacer increases the distance between the actuator of the pMDI and the patient, thereby adding volume to capture the aerosol from the pMDI. A holding chamber, on the other hand, is usually a valved chamber that holds the drug for a while after actuation until the patient’s inspiration opens the valve and the drug is inhaled. It allows for some delay between actuation and inhalation.

The ideal spacer size for all age groups, including infants, is 100–700 ml.30 Most spacers available in India have a volume range between 130 and 300 ml.

Techniques for Using a Spacer14

Table 2 provides the correct steps for using a spacer with a pMDI.

Features that Affect the Efficiency of the Spacers

Several factors affect the efficiency of the spacers. These include spacer shape, valves, the material with which the spacer is made, and spacer size and volume.

Spacer Shape

Spacers are of various shapes, including cylindrical or tubular spacers, collapsible spacers, collapsible bag-type spacers and pear-shaped spacers. The aerosol plume released by the pMDIs has a distinct morphology that favours the theory of better drug deposition when using a pear-shaped spacer. In vitro studies have found that drug deposition improves with increasing diameter but the effect of increasing the length of the spacer tube beyond 20 cm may not have any incremental effect on drug deposition.13 Increasing the diameter also correlated with better improvement in lung function with pear-shaped spacers as compared
with straight-tube spacers. A recent in vitro study, however, found that drug delivery may not be impacted by the shape of the spacer.

**Recommendation:** Though the shape of the spacer is not a key determinant of its efficacy, a pear-shaped spacer should be preferred. In the absence of a pear-shaped spacer, one may use a tubular spacer.

### Valves in Spacers

Spacers with valves were designed to overcome the limitations of pMDIs requiring actuation-inhalation coordination. Unidirectional, low-resistance valves, which open when the patient inhales and shut when the patient exhales, offer an advantage because they act as holding chambers and a few seconds of delay in inhalation is permissible. This obviates the need for actuation-inhalation coordination. Shunting of the valves during exhalation ensures that the aerosol is protected from the humidity in the exhaled air, which would otherwise make the hygroscopic aerosol particles absorb it, become heavier and settle down on the spacer floor or in the oropharynx.

**Anti-Static Spacers Improve Lung Deposition**

Presence of a static charge in the spacers was first detected quite serendipitously. In the late 1980s, O’Callaghan et al. found that spacer output increased when it was dipped in diluted household detergent solution prior to use. Further experiments showed that reducing the static charge on the spacers with anti-static sprays substantially increased the drug delivered by the spacer. The first anti-static spacer was patented in 1991 and involved spraying of the spacer with anti-static coating. Several methods have since been tried successfully to reduce the static charge. Use of steel spacers or spraying the drug into the spacer to coat the inner surface of the spacer reduces the static charge. The spacer can also be dipped in a mild household detergent solution in the dilution recommended by the manufacturer, thereby providing an anti-static coating. The spacer should not be washed or wiped after dipping in such detergent solution; it should be allowed to just air-dry.

The first transparent spacer made of anti-static polymer was patented and marketed by Cipla Ltd—these have been shown to have a better lung deposition profile and bioavailability.

**Recommendation:** Patients should, preferably, use spacers that are made of anti-static material.

### Spacer Size/Volume

Spacers are classified as small volume (up to 100 ml), medium volume (100–350 ml) and large volume (>700 ml). Most spacers currently available in India are in the volume range of 130–300 ml; earlier, spacers of 600–700 ml were available.

Studies have shown that large-volume spacers are either equal or better in efficacy compared with small-volume spacers, as assessed by plasma concentrations of salbutamol. This is because the plume released by the pMDI, when it comes in contact with the walls of the small-volume spacer, gets more turbulent and a large quantity of the drug gets impacted onto the wall and is thus lost to inhalation. On the other hand, the large-volume spacers offer more space for the drug to remain suspended in the form of a static, uniformly distributed aerosol within the spacer and offers evenly distributed drug delivery. However, for children and patients with a low tidal volume, a small-volume spacer, which would have a higher concentration of drug, would be better than a large-volume spacer with diluted drug that will remain available for inhalation for a few seconds only. Also, large-volume spacers are likely to be less favoured for use due to their bulkiness.

This review also considered the fact that in a country like India where inhaler use is still not very popular, most patients are unlikely to accept a spacer, let alone a large-volume one. Hence, the recommendations below have been made pragmatically.

**Recommendation:** Medium-volume spacers (100–300 ml) should be used for all age groups.

### Best Breathing Pattern for Spacer Use

There have been several studies conducted in the past to evaluate the effects of different inhalation manoeuvres and it has been found that whether taken as a single slow and deep inhalation or repeated multiple breaths through the spacer, the inhalation manoeuvres have little impact on the clinical outcomes.

**Recommendation:** A single, slow and deep inhalation followed by breath holding for about 10 seconds or multiple breaths that are comfortably possible (e.g. in an exacerbation) is recommended for adults and children over 6 years of age. Depending upon the patient’s ability to take a deep breath and actuation-inhalation coordination, the physician may advise the patient to take a second breath to inhale any drug that might have remained in the spacer. Children who are unable to perform controlled breathing or adults who are unable to hold their breath may perform repeated sufficiently deep tidal breathings to open the valve.

### Timing of Inhalation after Actuation

When using spacers that are not made of anti-static material, inhalation immediately after actuation is preferred as the respirable fraction falls to about 67% after a time lag of 20 seconds from actuation. It has been shown that using an anti-static spacer increases the respirable fraction by 260% even at the end of a 20-second delay compared with a spacer without an anti-static coating.

**Recommendation:** A time lag of 2 seconds between actuation and inhalation is acceptable, irrespective of the static charge in the spacer.

### Number of Actuations Required for Inhalation with a Spacer

Both in vitro and in vivo studies have shown that multiple actuations into a spacer actually reduces the drug availability. If multiple doses need to be taken, the patient must repeat all the steps for using the pMDI with the spacer after a gap of about 30 seconds, as recommended in the section *The Need for an Interval between Two Actuations.*

### Contamination of Spacers and Ways to Keep Them Clean

The American Thoracic Society and the European Respiratory Society Task Force on inhaler devices recommend weekly washing of spacers with mild dishwashing liquid and allowing them to air-dry. Spacers have been found to be contaminated with both non-pathogenic and pathogenic bacteria. Washing the spacers after every use protects from contamination. However, the clinical implications of these infections are yet unclear.

**Recommendation:** Spacers should be disassembled and washed at least once a week if being used by a single patient in a home setting. In a hospital setting, one spacer should be used for a single patient and washed weekly. It should also be washed before using it for another patient. Anti-static spacers should be washed with plain room temperature water. Static spacers should be washed with a mild detergent.
Table 1: Steps for the correct use of a pMDI and rationale for the same

<table>
<thead>
<tr>
<th>Steps</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hold the inhaler vertically and shake it up and down four or five</td>
<td>This ensures uniform dispersion of the drug within the canister. This is important for pMDIs with a suspension formulation and may not be required for pMDIs containing a solution. Most manufacturers do not specify whether the pMDI contains the drug in a suspension form or a solution. It is, therefore, recommended that all pMDIs be shaken well before use.</td>
</tr>
<tr>
<td>times.</td>
<td></td>
</tr>
<tr>
<td>2. Remove the cap.</td>
<td>The cap of the pMDI which protects the actuator needs to be removed, prior to inhaling the dose.</td>
</tr>
<tr>
<td>3. Prime the inhaler if using a new inhaler canister.</td>
<td>When using a new pMDI, after shaking the inhaler, actuate the device twice into the air, away from the face. Priming ensures that the required dose is available in the chamber. If the pMDI has not been used for more than a week (e.g. salbutamol), it will be necessary to prime the device even if the pMDI has been used earlier.</td>
</tr>
<tr>
<td>4. Exhale slowly and empty the lungs to functional residual capacity.</td>
<td>It is important that the patient exhales completely, as much as possible, before actuating the pMDI. This is because, a complete exhalation will allow the patient to inhale more and ensure greater and deeper drug deposition.</td>
</tr>
<tr>
<td>5. Hold the inhaler in an upright position.</td>
<td>The metering chamber of the inhaler fills due to gravity; hence, it is important to hold the inhaler upright so that the chamber fills up for the next dose.</td>
</tr>
<tr>
<td>6. Place the inhaler mouthpiece in the mouth between the teeth, with</td>
<td>The inhaler mouthpiece should be placed between the upper and the lower front teeth, lightly biting down on it. Neck should be kept straight, not flexed, to keep the airways open.</td>
</tr>
<tr>
<td>the tongue flat under the teeth.</td>
<td></td>
</tr>
<tr>
<td>7. Ensure that the lips have formed a tight seal around the mouthpiece.</td>
<td>This is to avoid leakage of the drug.</td>
</tr>
<tr>
<td>8. Start inhaling slowly through the mouth and, at the same time, press</td>
<td>It is important for actuation to be done at the exact point when inhalation begins because maximal drug deposition occurs during the beginning of the inhalation. Drug wastage is high if there is a lack of coordination between inhalation and actuation.14</td>
</tr>
<tr>
<td>the inhaler canister to actuate a dose.</td>
<td>Slow inhalation over 4–5 seconds reduces the flow rate and can achieve better drug deposition compared with rapid inhalation. Supporting inspiration over 4–5 seconds reduces the flow rate and can achieve better drug deposition compared with rapid inhalation.</td>
</tr>
<tr>
<td>9. Maintain a slow and deep inhalation through the mouth until the drug is</td>
<td></td>
</tr>
<tr>
<td>completely inhaled. This should take an adult around 4–5 seconds.</td>
<td></td>
</tr>
<tr>
<td>10. At the end of the deep inhalation, take the inhaler out of the mouth and close the lips. Continue to hold the breath for 10 seconds or as long as comfortably possible before breathing out.</td>
<td></td>
</tr>
</tbody>
</table>

Contd. 2
Table 1: Steps for the correct use of a pMDI and rationale for the same14 (Contd.)

<table>
<thead>
<tr>
<th>Steps</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. Breathe out normally.</td>
<td></td>
</tr>
<tr>
<td>12. After waiting for 1 minute, if another dose is required, repeat steps 4–12</td>
<td>It is important for the pressure in the pMDI to equilibrate between actuations and this requires some time. Studies have shown that multiple actuations in quick succession reduces the total drug emitted from the chamber. A gap of at least 15–20 seconds between two actuations is recommended in the literature.</td>
</tr>
<tr>
<td>13. If inhaled corticosteroids are used, rinse out the mouth and gargle after taking a dose.</td>
<td>This helps reduce the amount of steroid deposited in the mouth/throat and reduces the risk of oropharyngeal candidiasis/dysphonia.</td>
</tr>
</tbody>
</table>

Note: Steps 4–8 should be performed in quick succession, without a significant time gap. For children below 6 years of age, the pMDI should always be used with a spacer.

### Use of Face Masks with Spacers

Very young children (below 4 years of age) cannot perform controlled breathing using a spacer and pMDI and need to be given inhalation therapy using a face mask attached to the spacer. The mask needs to be tightly fitted onto the face; therefore, an appropriately sized mask should be selected.

Some children may be unable to generate enough peak inspiratory flow rates to open the valve of the valved holding chamber in the spacer. In such cases, it is better to use a non-valved spacer or the valved spacer may be tilted slightly to let the valve fall open due to gravity.

**Recommendation:** In children who are unable to generate sufficient peak inspiratory flow rates, use a non-valved spacer or tilt the valved spacer slightly and let the valve fall open due to gravity. The device will then function like a non-valved spacer.

### Inhalation Therapy in a Crying Child

Crying is a process of prolonged exhalation followed by shallow erratic inspiration. Inhalation therapy given to a crying child causes the drug to deposit more in the larger airways and the upper gastrointestinal tract; so, drug deposition in the lungs is significantly reduced.46 Hence, inhalation therapy is best given to a calm infant, whenever possible.47,48 However, if there is no other option in an emergency, it is better to give inhalation therapy even to a crying child rather than giving only oral/injectable drugs.

**Recommendation:** Inhalation should preferably be given to a child who is calm and not in distress. However, if there is no other option (which is a common scenario in an emergency), it is better to give inhalation therapy rather than not giving it just because the child is crying.

### Inhalation Therapy in a Sleeping Child

To overcome the challenges of administering inhalation therapy to a crying or uncooperative child, one might want to resort to giving it when the child is asleep. However, it has been shown that placing a face mask onto a sleeping child’s face awakens and distresses the child. Esposito et al. found that 69% of children woke up when the face mask was placed and 75% of them were distressed.48

**Recommendation:** In children who are unable to coordinate the pMDI well.

### Use of Impaired Spacers such as Plastic Bottles and Paper Rolls

Ideally, the technically tested and validated anti-static spacers manufactured specifically to fit a pMDI should be used. However, in exceptional cases or an emergency or absolute non-availability of spacers, improvised spacers may be used. According to the International Consensus on Asthma (ICON), if commercially produced spacers are not available or not affordable, a 500 ml plastic bottle may be adapted to serve as an effective spacer for patients using a pMDI. Other home objects such as a paper roll can also be improvised for use. Shehth et al. showed that there was no difference in the respirable mass using improvised spacers (bottle-holding chamber, paper towel roll, paper roll, plastic bottle, toilet paper roll) and conventional spacers, but there was significant reduction in oropharyngeal deposition when compared with a pMDI alone.49-51

**Recommendation:** Ideally, the technically tested and validated anti-static spacers manufactured specially to obtain maximal drug deposition in the lungs should be used. However, in case of an emergency or absolute non-availability of a spacer, improvised spacers may be used.

### BAI s

BAIs were devised to overcome the major challenges of coordination between dose actuation and inhalation in patients using a pMDI who do not or could not use a spacer.52 BAIs can lead to a three-fold improvement in drug deposition in the lungs compared with a poorly coordinated pMDI actuation (21% versus 7%),53 and similar deposition is seen in patients who can coordinate the pMDI well.

BAIs have a sensing mechanism that actuates the dose when the patient achieves a minimal inspiratory flow rate of around 23–35 L/min. These rates can be easily generated in children,
the elderly population, and even those having severe-to-very severe airway obstruction.

The BAI is a pMDI with an additional breath-actuator mechanism. It consists of a mouthpiece cap, a mouthpiece, a dose-release mechanism, a body that encases the canister, and a flow-sensing mechanical feature that gets triggered on attaining the minimum inspiratory flow (Figure 5). Table 3 lists the correct steps for using a BAI.

Currently, passive breath-actuated DPI devices are being developed, which actively bring about disaggregation of the dry powder and disperse the medication to be inhaled, like in the case of BAIs. This helps to overcome the dependence on the patient’s inspiratory flow and provides consistent drug delivery.

**Flow Rate Required to Actuate a Dose through a BAI**

The inspiratory flow rates required to actuate the dosing mechanism in the BAI is as low as 23–35 L/min\(^3\) a flow rate that can be easily achieved by children, geriatric patients and patients with severe-to-very severe airflow obstruction. While pMDIs work independent of inspiratory flow rate, DPIs require inspiratory flow rates of 50–90 L/min.

**Priming of the BAI**

The BAI needs to be primed once before using for the first time. It is also advisable to prime the BAI if it has not been used for over 2 weeks. All BAIs have a dose-release button, which needs to be activated to release a dose when priming. Kindly refer to the individual manufacturer’s instructions for specific and detailed instructions for priming.

**DPIs**

The first DPI (with potassium chloride) was patented in 1864 by an English physician, Alfred Newton, for the treatment of breathing disorders. He had observed that the medication powder that was to be used in this manner had to be very finely pulverised and kept dry at all times. Today, we know that these are important prerequisites for all DPIs. The first DPI to be marketed was the Aerohaler in the year 1949, which was also the first reliever inhaler. Frederick Roe patented another dry powder device called the Carbolic Smoke Ball,\(^5\) which could be refilled at repeated intervals.

The first Rotahaler DPI was introduced in the early 1970s by Allen & Hanburys.\(^6\) Subsequently, the Spinhaler was introduced by Fisons. These were all single-dose DPIs. In India, the Rotahaler was developed by Cipla Ltd in the 1980s and this was followed in 1997 by the transparent Rotahaler. This dramatically changed the way inhaled medications were used since the new-generation Rotahaler was transparent and, for the first time, patients could actually see the medication and confirm visually that the medication had been taken. Thereafter, several other unit-dose DPIs were introduced, including the Revolizer (Cipla Ltd) and a number of variants of the Aerolizer (made in Italy) such as the Lupihaler (Lupin Ltd) and the Insthaler (Glenmark Pharmaceuticals Ltd). In the meantime, globally, multidose DPIs were developed to overcome the limitation of inserting a capsule for every inhalation. Multidose DPIs store up to a month’s supply of the medication and reduce the number of steps required to use a DPI.

Multidose DPIs can be classified as discrete multidose DPIs and reservoir multidose DPIs. While the discrete multidose DPIs have individually packed, discrete doses of medication within the device, e.g. Accuhaler (GlaxoSmithKline Ltd) and Ciphaler (Cipla Ltd), the reservoir multidose DPIs have a reservoir of the entire drug in one confined space in the device, e.g. Turbuhaler (Astra Zeneca).

**Principles of the Working of a DPI**

The performance of a DPI is affected significantly by the particle size and flow properties of the formulation, inspiratory flow rate, drug carrier adhesion, and design of the DPI.\(^7\) During inhalation, the inspiratory flow creates turbulence in the DPI and de-agglomerates the drug particles from the carrier lactose molecules. The effort required to generate the inspiratory flow to de-agglomerate is different for different DPI devices but generally varies between 37 and 111 L/min.\(^5\)

Generation of the turbulent energy is necessary to aerosolise the drug in the DPI device. The turbulent energy is the product of the resistance by the device and the inspiratory flow rate required to be generated by the patient. It is, therefore, important to inhale rapidly and deeply when using a DPI.

Apart from the patient’s inspiratory flow rates and the DPI’s resistance, de-agglomeration also depends upon the inhaled volume and the length of the inhalation.\(^8\) The inhaled volume required to completely empty the dose out of the DPI should be at least 500 ml.\(^9\) Patients who have reduced inspiratory lung volumes and inspiratory flow rates may, therefore, not be able to achieve the required lung deposition. These patients need to take a second inhalation to ensure that the dose is completely inhaled. However, this is possible only with those DPIs that have a transparent chamber, e.g. the Revolizer and the Rotahaler.

**Steps for the Correct Usage of a DPI and Rationale for the Same**\(^1\)

Table 4 presents the correct usage steps for a DPI.

**Taking Multiple Medications from a Unit-Dose DPI**

One can take multiple medications from the same unit-dose DPI.

**Recommendation:** If two drugs have been prescribed, it is recommended to finish inhalation from one capsule before using the second. It is important to note that it is better to use a unit-dose DPI and capsules from the same manufacturer.

**Use of DPIs in Young Children**

In order to use a DPI efficiently, the patient is required to generate an inspiratory flow rate of at least 30 L/min. Most children below the age of 5 years are unable to generate average inspiratory flow rates of ≥60 L/min and, hence, it is advisable to not prescribe DPIs to children below the age of 5 years.\(^8\) Moreover, due to a 30–35% lower lung function in the Indian population,\(^5\) it can be speculated that the inspiratory flow generated by Indian patients will be lower than their counterparts in the West. Hence, the Indian Academy of Pediatrics has recommended that DPIs should not be used in children below the age of 6 years. The pMDI with a spacer and with or without a face mask remains the primary choice of inhaler device in children below 6 years of age. In children aged 6 years and above, a DPI can be used.

**Use of DPIs during Exacerbations**

During exacerbations, the inspiratory flow rate and inspiratory time reduce significantly. Furthermore, patients may also not be able to perform the breath hold of 4–10 seconds. However, during exacerbations, the
Table 2: Correct steps for using a pMDI with a spacer

1. Assemble the spacer if needed. Shake the pMDI four or five times.

2. Remove/open the cap.

3. Prime the inhaler if the pMDI is being used for the first time or after a gap of 1 week.

4. Insert the mouthpiece of the pMDI into the open end of the spacer and ensure a tight fit.

5. Empty the lungs by exhaling slowly through the mouth and hold the breath. (Do not begin inhalation)

6. * Place the mouthpiece of the spacer in the patient’s mouth – it should be placed between the front teeth and patient should be told to seal his/her lips tightly around it.

7. * Actuate one dose from the pMDI into the chamber of the spacer and ask the patient to start inhalation slowly through the mouthpiece. Some spacers will make a whistling noise if inspiration is too fast.

8. Maintain a slow and deep inhalation through the mouth, until the lungs are full of air. This should take a child 2–3 seconds and an adult about 5 seconds.

9. At the end of the inhalation, take the spacer mouthpiece out of the patient’s mouth and ask him/her to close his/her mouth.

10. Continue to hold the breath for up to 10 seconds or as long as comfortably possible before breathing out.

11. Breathe out normally.

12. If another dose is required, repeat steps 1–11.

13. If inhaled corticosteroids are used, ask the patient to rinse out his/her mouth and gargle after taking a dose.

*Steps 5, 6 and 7 should be done in quick succession without much time gap between steps. *Steps 6 and 7 can be interchanged. Ask the patient to actuate the inhaler into the spacer, then open the cap to hold the spacer in the mouth, and then begin inhalation. This is applicable for a valved spacer, which has a cap on the other side. If a child 6 years of age or above is unable to hold the breath and is following a tidal breathing pattern, then ask the child to breathe five to seven tidal breaths, taking slow and deep inhalations each time.

Managing Cough after Using a DPI

The carrier molecule in a DPI is lactose. In comparison with the active drug molecule, lactose has a larger particle size ranging between 10 and 40 microns. Particles with a mean diameter of over 5 microns get deposited in the oropharynx. Moreover, high inspiratory flow rates are needed when inhaling through a DPI, leading to greater oropharyngeal deposition of the particles. The deposition of the larger lactose molecules through rapid impaction stimulates the oropharyngeal epithelium, inducing cough in some patients.

Rinsing/Gargling after a DPI Dose

As mentioned earlier, following the impaction of larger lactose molecules, agglomerates of the lactose molecule may not be as effective as pMDIs with a spacer or a nebuliser. It is advisable to, therefore, use a pMDI with a spacer (with or without a face mask) or a nebuliser in cases of exacerbations. There are limited studies on the use of DPIs in exacerbations, more specifically in milder exacerbations. A study conducted in 153 children above 5 years of age with mild-to-moderate acute exacerbations of asthma showed that they could effectively use the Rotahaler DPI. The study concluded that the Rotahaler and a pMDI with a spacer have equal efficacy in delivering salbutamol in mild-to-moderate acute exacerbations of asthma in children. However, due to the lack of large studies, a pMDI with a spacer may, therefore, be considered as a preferred option in more severe cases.

Use of DPIs in COPD Patients

DPIs can be successfully used in most patients with COPD. COPD patients can generate an inspiratory flow rate in the range of 26–95 L/min (lower inspiratory flow rates are associated with increasing severity of COPD). All DPIs may be used in patients with mild COPD. Almost 20–30% of patients with advanced COPD may be unable to generate a sufficient inspiratory flow/lung volume to be able to use a DPI effectively.
Table 3: Correct steps for using a BAI (Synchrobreathe, Cipla Ltd) and rationale for the same

<table>
<thead>
<tr>
<th>Steps</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hold the device in an upright position and shake it up and down four or five times.</td>
<td>Same as for pMDI. Pulling open the cap (as in the Synchrobreathe) loads the dose and readies the device for inhalation. It is therefore imperative to close the cap in the Synchrobreathe after inhalation is complete. This is important to load the next dose.</td>
</tr>
<tr>
<td>2. Remove/open the cap (as per the device).</td>
<td>When starting use of a new BAI, after shaking the inhaler, actuate the device twice into the air away from the face. Priming ensures that the required dose is available in the chamber. If the BAI has not been used for more than a week (e.g. salbutamol), it will be necessary to prime the device even if it has been used in the past.</td>
</tr>
<tr>
<td>3. Priming</td>
<td>Same as for pMDI. When starting use of a new BAI, after shaking the inhaler, actuate the device twice into the air away from the face. Priming ensures that the required dose is available in the chamber. If the BAI has not been used for more than a week (e.g. salbutamol), it will be necessary to prime the device even if it has been used in the past.</td>
</tr>
<tr>
<td>4. Exhale completely to empty the lungs to functional residual capacity. Place the inhaler mouthpiece between the teeth, with the tongue flat below the mouthpiece, and make a tight seal around it with the lips before inhalation.</td>
<td>Same as for pMDI. When starting use of a new BAI, after shaking the inhaler, actuate the device twice into the air away from the face. Priming ensures that the required dose is available in the chamber. If the BAI has not been used for more than a week (e.g. salbutamol), it will be necessary to prime the device even if it has been used in the past.</td>
</tr>
<tr>
<td>5. Now inhale slowly and deeply.</td>
<td>To be continued even after hearing a click as the click is the indication of an actuation. It should be emphasised to the patient that a continued breath after the click is mandatory.</td>
</tr>
<tr>
<td>6. Take the mouthpiece out of the mouth and close the lips. Hold the breath for 10 seconds or for as long as comfortably possible.</td>
<td>Same as for pMDI. When starting use of a new BAI, after shaking the inhaler, actuate the device twice into the air away from the face. Priming ensures that the required dose is available in the chamber. If the BAI has not been used for more than a week (e.g. salbutamol), it will be necessary to prime the device even if it has been used in the past.</td>
</tr>
<tr>
<td>7. Breathe out normally.</td>
<td>Same as for pMDI. When starting use of a new BAI, after shaking the inhaler, actuate the device twice into the air away from the face. Priming ensures that the required dose is available in the chamber. If the BAI has not been used for more than a week (e.g. salbutamol), it will be necessary to prime the device even if it has been used in the past.</td>
</tr>
<tr>
<td>8. Put back/close the cap (as per the device).</td>
<td>Ensures loading of the next dose.</td>
</tr>
</tbody>
</table>

Nebulisers

Nebulisers are devices that convert a liquid solution or suspension form of the medication into a fine mist that can be easily inhaled. They are usually used by patients during an acute exacerbation. The nebuliser device generates this aerosol, allowing the patient to inhale at his or her own pace. No actuation-inhalation coordination or breath hold or rapid/slow and deep inhalation is required. The patient can breathe at tidal volume, although deeper inhalation and breath hold for as long as possible should be encouraged.

Generally, conventional jet nebulisers are the most widely used nebulisers – these generate a continuous flow of aerosol irrespective of the breathing. This, however, leads to loss of a significant proportion of the drug into the environment during administration. The amount of drug to be administered through the nebuliser is, therefore, larger than for a pMDI and DPI (e.g. the dose of salbutamol.
Table 4: Correct steps for using a DPI and rationale for the same

<table>
<thead>
<tr>
<th>Steps</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. If there is a mouthpiece cover, remove it/open it.</td>
<td>Unless the cover or cap is removed/opened, the mouthpiece of the device will not be accessible for use. Every DPI has its unique step for preparing a dose prior to inhaling. Patients should follow the steps mentioned in the patient information leaflet supplied with the device. The two images given here are an example of dose preparation when using the Rotahaler (Cipla Ltd).</td>
</tr>
<tr>
<td>2. Load/prepare a dose for delivery.</td>
<td>Before taking a deep inhalation through the DPI, it is necessary for the patient to exhale up to his/her functional residual capacity. This will ensure good inhalation volume. As the drug in the DPI is vulnerable to humidity, which may affect the performance of the DPI, it is advisable to not exhale into the device. It is also important to remember that the DPI should be held only in the upright position, as the drug powder prepared in the holding chamber would otherwise be wasted.</td>
</tr>
<tr>
<td>3. Exhale completely, prior to inhalation.</td>
<td>Positioning the mouthpiece firmly between the teeth, with the tongue flat under the mouthpiece, and making a tight seal around it with the lips helps in generating the high inspiratory flow rate required when inhaling from a DPI and thereby ensures good drug delivery.</td>
</tr>
<tr>
<td>4. Place the mouthpiece between the teeth, with the tongue flat below the mouthpiece, and make a tight seal around it with the lips before inhalation.</td>
<td>The patient must be instructed to inhale as fast and as deep as possible. The inhalation effort of the patient generates an inspiratory flow. In order to aerosolise the powder in a DPI, turbulent energy is essential.</td>
</tr>
<tr>
<td>5. Inhale rapidly and deeply until the lungs are full.</td>
<td>The two images below are an example of inhalation through the DPI. The equipment required for jet nebulisation includes the following: • Jet nebuliser or gas source with flowmeter • Nebuliser interface, which includes face mask or mouthpiece, and nebuliser cup with baffle</td>
</tr>
<tr>
<td>6. At the end of the deep inhalation, take the mouthpiece out of the mouth and close the lips. Continue to hold the breath for 10 seconds or as long as comfortably possible before breathing out.</td>
<td>Larger drug particles deposit in the airways by inertial impaction but the particles between 4 and 5 microns deposit in the bronchial and conducting airways mainly by sedimentation due to gravity.</td>
</tr>
<tr>
<td>7. Breathe out normally.</td>
<td>As mentioned earlier, following the impaction of larger lactose molecules, agglomerates of the lactose molecule and the active drug remain impacted in the oropharynx. Rinsing out of the mouth and gargling is recommended after inhalation of a corticosteroid.</td>
</tr>
<tr>
<td>8. After each use, rinse out the mouth and gargle thoroughly.</td>
<td>In a jet nebuliser, compressed gas passes through the liquid medication at high pressure. This causes a region of negative pressure, in which the solution or suspension is entrained into the gas stream and is sheared into an unstable liquid film, which breaks into aerosol particles due to surface tension forces. These are further broken down into smaller particles with the help of the baffle within the medication cup. Larger particles are returned to the liquid drug reservoir while the patient inhales the smaller particles.</td>
</tr>
</tbody>
</table>

Types of Nebulisers

Nebulisers are available as jet nebulisers, ultrasonic nebulisers and mesh nebulisers.

Jet Nebulisers

Jet nebulisers are pneumatically powered aerosol delivery systems that have been in use now for several decades and, therefore, remain the most widely used nebulisers. They generate the desired aerosol particles with the help of pressurised gas flow created by the nebuliser compressor or the supply of gas flow through high-flow systems (Figure 6). Generally, a gas flow of 6–8 L/min is required to create the necessary aerosol particles. The biggest advantage is that they efficiently nebulise drugs in solution as well as in suspension formulations.

In a jet nebuliser, compressed gas passes through the liquid medication at high pressure. This causes a region of negative pressure, in which the solution or suspension is entrained into the gas stream and is sheared into an unstable liquid film, which breaks into aerosol particles due to surface tension forces. These are further broken down into smaller particles with the help of the baffle within the medication cup. Larger particles are returned to the liquid drug reservoir while the patient inhales the smaller particles.

Jet nebulisers can be driven by both air as well as oxygen. However, care must be taken to avoid the overuse of oxygen in patients with COPD. Jet nebulisers can be used along with mechanical ventilators in the acute-care setting.

The equipment required for jet nebulisation includes the following:

- Jet nebuliser or gas source with flowmeter
- Nebuliser interface, which includes face mask or mouthpiece, and nebuliser cup with baffle
Ultrasonic Nebulisers

Ultrasonic nebulisers utilise a piezoelectric crystal (a crystal that vibrates when supplied with an electrical charge) to generate the aerosol. This crystal vibrates at a frequency of 1–3 MHz when supplied with electrical energy and creates ripples in the medication cup, which contains the liquid drug reservoir (Figure 7). These vibratory ripples create a fountain and break down the medication into smaller particles, which is then delivered to the patient during inhalation. This type of nebuliser can be used along with a mechanical ventilator.

Mesh Nebulisers

This is a new type of nebuliser, which contains a mesh with many tiny holes through which the drug is passed to create the desired aerosol. Typically, these devices are categorised as either static mesh nebulisers or vibrating mesh nebulisers (Figure 8). Static mesh or passive nebulisers push the liquid drug through the mesh holes to create the aerosol; in the vibrating mesh or active nebuliser, a piezoelectric element creates vibrations, which pushes the drug through the mesh. Table 5 presents a comparison of various nebulisers.

Medications used in Nebulisers

Nebulisers are predominantly used to administer bronchodilators and inhaled corticosteroids. However, recent advances have led to the development of inhaled forms of mucolytics and antibiotics that can be delivered via the nebuliser (Table 6).

Understanding the Difference between a Ready-to-Use Solution for Inhalation and Concentrated Respirator Solution

A respule (as it is commonly known in India) is a ready-to-use form of solution for inhalation via nebulisation. It is a plastic container that contains a liquid drug, which is pre-diluted with 0.9% normal saline. Respules are easy to use and can be used directly for nebulisation. There is also less chance of contamination. Generally, these respules contain 2–4 ml of the solution, which is appropriate for all nebuliser devices (Figure 9).

A concentrated respirator solution is also used for nebulisation, where
the solution needs to be diluted with normal saline in the proportion of one part drug and three parts 0.9% normal saline. They are not easy to use and have high chances of contamination. Using distilled water or tap water as a diluent is not recommended as it has been shown to irritate the bronchi and cause bronchoconstriction (Figure 9).

**Volume of Drug to be Added to the Nebulisation Chamber**

At least 2 ml volume of drug is required for nebulisation. As the fill volume increases, the aerosol output increases – but the nebulisation time also increases. Hence, an optimal range would be 2–4 ml. Generally, it takes 15–20 minutes to nebulise one respule of medication (i.e. 2–3 ml) and once a splutter is heard, nebulisation can be stopped.

**Continuous and Intermittent Nebulisation Therapy**

In a stable situation, no significant difference has been found between intermittent and continuous nebulisations and both are considered equally effective as they reduce the hospital stay and improve pulmonary function. Continuous therapy has been shown to significantly improve peak flow values and reduce the frequency of hospitalisations in severe asthma exacerbations. Generally, continuous bronchodilator therapy is given to patients who do not respond to the standard dose of bronchodilator therapy. These patients are nebulised with higher doses of bronchodilators, typically 5–15 mcg/hr until the patient is relieved of the bronchospasm. Patients on continuous nebulisation should be monitored for beta-agonist side effects such as tachyarrhythmias, tremors, hyperglycaemia and hypokalaemia.

Intermittent therapy is when a patient is administered nebulisation every 20 minutes for the first hour.

Table 7 lists the steps for using jet, ultrasonic and mesh nebulisers.

**Common Errors when Using a Nebuliser**

Common errors include the following:

- Incorrectly assembling and operating the nebuliser.
- Under-filling or over-dilution of the medicine in the medication cup.
- Errors with compatibility between the device and drug formulation.
- Improper use of the nebuliser and its interface, usage technique and the pattern of breathing. Lack of regular cleaning and disinfection of the device can also lead to the spread of infection.

**Importance of Cleaning and Disinfection of the Nebuliser and its Parts**

It is recommended to follow the manufacturer’s guidelines for cleaning and disinfecting the nebuliser and its parts. The nebuliser unit should be wiped with a clean cloth and a surface disinfectant daily (e.g. sodium hypochlorite solution). The drug chamber /medication cup should ideally be washed and discarded as per the manufacturer’s recommendations. However, they may be reused with proper disinfection and storage for up to 3 months or as per manufacturer’s recommendations. Multiple methods can be used to clean and disinfect the parts of the nebuliser (face mask, mouthpiece, medicine cup). Any one of the following methods can be adopted:

---

**Table 6: Drugs available for nebulisation in India**

<table>
<thead>
<tr>
<th>Drug type</th>
<th>Class</th>
<th>Name of molecule</th>
<th>Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bronchodilators</strong></td>
<td>Short-Acting Beta₂ Agonists (SABAs)</td>
<td>Salbutamol</td>
<td>2.5 mg/2 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Levosalbutamol</td>
<td>0.31 mg/2 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.63 mg/2 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.25 mg/2 ml</td>
</tr>
<tr>
<td></td>
<td>Long-Acting Beta₂ Agonists (LABAs)</td>
<td>Formoterol</td>
<td>12 mcg/2 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20 mcg/2 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aformoterol</td>
<td>15 mcg/2 ml</td>
</tr>
<tr>
<td></td>
<td>Short-Acting Muscarinic Antagonists (SAMAs)</td>
<td>Ipratropium Bromide</td>
<td>500 mcg/2 ml</td>
</tr>
<tr>
<td></td>
<td>Long-Acting Muscarinic Antagonists (LAMAs)</td>
<td>Glycopyrronium</td>
<td>25 mcg/1 ml</td>
</tr>
<tr>
<td><strong>Inhaled Corticosteroids (ICS)</strong></td>
<td></td>
<td>Budesonide</td>
<td>0.5 mg/2 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 mg/2 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fluticasone Propionate</td>
<td>0.5 mg/2 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 mg/2 ml</td>
</tr>
<tr>
<td><strong>Combination</strong></td>
<td>SABA + SAMA</td>
<td>Salbutamol + Ipratropium</td>
<td>2.5 mg + 500 mcg/2.5 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Levosalbutamol + Ipratropium</td>
<td>1.25 mg + 500 mcg/2.5 ml</td>
</tr>
<tr>
<td></td>
<td>ICS + SABA</td>
<td>Budesonide + Levosalbutamol</td>
<td>0.5 mg + 1.25 mg/2 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 mg + 1.25 mg/2 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Budesonide + Formoterol</td>
<td>0.5 mg + 20 mcg</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 mg + 20 mcg</td>
</tr>
<tr>
<td><strong>Mucolytics</strong></td>
<td></td>
<td>Ambroxol</td>
<td>15 mg/2 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N-Acetylcysteine</td>
<td>Each ml contains 200 mcg</td>
</tr>
<tr>
<td><strong>Antibiotics</strong></td>
<td></td>
<td>Tobramycin</td>
<td>300 mg/5 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Colistimethate Sodium</td>
<td>1 MIU in a 10 ml vial</td>
</tr>
</tbody>
</table>

**MIU=million international units**

---

**Fig. 8: Schematic diagram of a vibrating mesh nebuliser**

**Fig. 9: Nebulisation – ready-to-use solution for inhalation (respule) and concentrated respirator solution**
• They can be boiled in water for 5 minutes.
• They can be soaked in a solution of one part household bleach and 50 parts water for 3 minutes.
• They can be soaked in 70% isopropyl alcohol for 5 minutes.
• They can be immersed in 3% hydrogen peroxide solution for 30 minutes to disinfect.

It is important to remember that when using a mesh nebuliser, one should not touch the mesh during cleaning as it can get damaged. Mesh and ultrasonic nebulisers can only nebulise solutions and not suspensions due to the risk of clogging and breaking up of the drug particles with the use of a suspension. Corticosteroid products are usually in a suspension form and it is, therefore, preferable to administer them through a jet nebuliser.

Selection of the Right Device, Ensuring Compliance, and Patient Counselling

Once a correct diagnosis of asthma or COPD is made, choosing an appropriate inhaler device for a patient is critical for successful treatment outcomes. For disease management, an ideal inhaler would be one that is compact in size, provides the maximum doses, is preferably breath-activated, has inspiratory flow-independent lung deposition, is suitable for all age groups, uses inhaler techniques that are easy to learn, teach and remember, has a dose counter, a reminder system and is cost-effective.39 So far, a perfect inhaler device like this does not exist and, therefore, there is a constant drive to develop newer and newer inhaler devices.

Selection of the Right Device

The guidelines recommend individualising inhaled therapy for each patient, taking into consideration patient preferences in conjunction with training and regular monitoring of inhaler technique.19 Choosing the correct inhaler device for the patient is crucial to ensure compliance and adherence to treatment and thereby achieve control of symptoms. Very little research has been carried out on how physicians should select the right inhaler device for the patient. The choice depends on several factors, including availability of the drugs in a particular device, the ability of the patient to use it (age, disease severity, education, and understanding), cost, and the likes and preferences of the treating physician.

Each type of inhaler requires a different inhalation technique and breathing pattern to achieve optimal delivery of the medication to the lungs. A pMDI requires slow and deep inhalation and actuation-inhalation coordination, whereas a DPI requires rapid and deep inhalation. It is seen that errors are made not only in inhalation technique but also in the handling of
cannot coordinate

Table 8: Common myths about inhalers

<table>
<thead>
<tr>
<th>Myths</th>
<th>Facts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inhalers are addictive</td>
<td>Inhalers are not addictive. Medications delivered through inhalers help to control the symptoms of the disease and the quality of life without causing significant side effects. They must be taken regularly to help lead a near-normal life.</td>
</tr>
<tr>
<td>Inhalers cause a lot of side effects</td>
<td>When used at the recommended doses, inhalers rarely cause side effects. Inhalers are the safest, fastest and most effective way of delivering medications directly to the lungs. The amount of drug used in inhalers is in micrograms, a fraction of that used in oral drugs.</td>
</tr>
<tr>
<td>Why should a patient use inhalers when tablets and syrups are available?</td>
<td>Inhalers are the safest, fastest and most effective way of taking medication than oral medications. This is because inhalers provide better disease control at doses up to 20 times lower as compared with oral formulations.</td>
</tr>
<tr>
<td>Inhalers are the last resort for the treatment of asthma or COPD</td>
<td>No. In fact, inhalers are the first and foremost form of medications to be given in all patients with asthma and COPD, as recommended in the GOLD and GINA guidelines.</td>
</tr>
<tr>
<td>Inhalers are very costly</td>
<td>In developing countries like India, inhalers are available at a very low cost and per dose cost of inhaled therapy is as affordable as tablets and syrups.</td>
</tr>
</tbody>
</table>

The child’s age and capability. The preferred device is a pMDI and spacer with a face mask for children below 4 years of age and a DPI with a spacer for children over 4 years of age. DPIs, on the other hand, are usually easier for patients to handle, but the key issue in dry powder inhalation is generating an adequate inspiratory flow rate. Severely ill patients who are confused and uncooperative, or those with advanced respiratory disease and very young patients may not be good candidates for a DPI due to their inability to generate an adequate inspiratory flow or volume.

The Device Checklist

A good strategy for treating physicians will be to get familiar with all the available inhaler devices that their patients may need and adapt a methodical systematic approach towards selection of the inhaler device. A device checklist can be useful to facilitate device selection, individualised for each patient for the short-term or long-term management of the disease. Questions on the patient’s device preference, availability of the drug in the preferred device format in the geographical location of the patient, the patient’s ability to coordinate device actuation and inhalation and also generate sufficient inspiratory flow,
Table 9: Advantages and disadvantages of inhaler devices\textsuperscript{16,23,75–78}

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>pMDIs</strong></td>
<td></td>
</tr>
<tr>
<td>• Portable and convenient to carry.</td>
<td>• pMDIs require proper coordination between actuation and inhalation, which may be a challenge, especially in children and the elderly.</td>
</tr>
<tr>
<td>• Reproducible dosing with each actuation throughout the life of the inhaler canister.</td>
<td>• Requires use of propellants such as HFA (hydrofluoroalkanes)</td>
</tr>
<tr>
<td>• Aerosol dose released is independent of the patient’s inspiratory effort.</td>
<td>• Excipients in the inhaler may occasionally cause paradoxical cough and bronchoconstriction.</td>
</tr>
<tr>
<td>• Usable in almost all clinical situations, both acute and chronic, and across age groups with suitable add-on devices such as spacers and face masks.</td>
<td>• The drug, when released under pressure, is at a low temperature and can cause pharyngeal irritation.</td>
</tr>
<tr>
<td>• Since it contains many doses and can last for a long period, it is economical when considering per dose cost.</td>
<td>• Nearly 75% of the drug from the pMDIs is deposited in the oropharyngeal region and this may lead to local/systemic side effects in a small proportion of patients when high doses are used.</td>
</tr>
<tr>
<td>• Irrespective of the manufacturing company, the technique for using a pMDI remains the same.</td>
<td>• High oropharyngeal deposition leads to side effects such as oral candidiasis, change in voice quality, and increased hoarseness of voice.</td>
</tr>
<tr>
<td>• The contents of the inhaler canister are protected from contamination or oxidation.</td>
<td></td>
</tr>
<tr>
<td><strong>BAIs</strong></td>
<td></td>
</tr>
<tr>
<td>• No coordination required between actuation and inhalation.</td>
<td>• Patients may stop inhaling as soon as they hear a click (as seen with some BAIs) or feel the medication in their mouth.</td>
</tr>
<tr>
<td>• No need to use a spacer.</td>
<td>• Though these devices are auto-actuated, BAIs involve a step of manually loading the dose.</td>
</tr>
<tr>
<td>• Low inspiratory effort required.</td>
<td>• Are more expensive than pMDIs or unit-dose DPIs.</td>
</tr>
<tr>
<td>• Delivered dose is independent of inspiratory flow.</td>
<td></td>
</tr>
<tr>
<td>• Increased lung deposition (21%) as compared with an incorrectly used pMDI (7%).</td>
<td></td>
</tr>
<tr>
<td>• Simple to learn and use.</td>
<td></td>
</tr>
<tr>
<td>• Can be used across all age groups, including children and the elderly.</td>
<td></td>
</tr>
<tr>
<td><strong>DPIs</strong></td>
<td></td>
</tr>
<tr>
<td>• No need for patient coordination.</td>
<td></td>
</tr>
<tr>
<td>• Easy to teach: The general perception is that the DPI is simpler to use compared with a pMDI.</td>
<td></td>
</tr>
<tr>
<td>• Fewer device-handling steps, thereby reducing the chances of errors. Fewer errors may improve patient adherence and treatment efficacy.</td>
<td></td>
</tr>
<tr>
<td>• Use of discrete multidose inhalers reduces the chances of error by patients.</td>
<td></td>
</tr>
<tr>
<td><strong>Nebulisers</strong></td>
<td></td>
</tr>
<tr>
<td>• Nebulisers can be used during acute exacerbations of asthma and COPD, when the patient is critical or unconscious, and when the required medication is not available in an inhaler format.</td>
<td>• High oropharyngeal deposition, leading to side effects such as oral candidiasis, change in voice quality, and increased hoarseness of voice, etc.</td>
</tr>
<tr>
<td>• Nebulisers can also be used when high doses of bronchodilators are required to be given along with supplementary oxygen in patients with asthma.</td>
<td>• Vulnerable to ambient humidity as well as exhaled air. This may reduce the efficiency of the DPI.</td>
</tr>
<tr>
<td>• Nebulisers are very widely prescribed inhalers in India.</td>
<td>• If the DPI is held incorrectly after dose preparation, the dose may fall from the inhaler, leading to drug wastage.</td>
</tr>
<tr>
<td>• Nebulisers typically require longer time for drug delivery (15–20 minutes).</td>
<td>• Dependent on the patient’s inspiratory flow rate. Insufficient flow rates lead to reduced lung deposition of medication.</td>
</tr>
<tr>
<td>• Nebulisers can be used when high doses of bronchodilators are required to be given along with supplementary oxygen in patients with asthma.</td>
<td>• Possible toxicity caused due to high dosages compared with inhalers.</td>
</tr>
<tr>
<td>• Nebulisers are very widely prescribed inhalers in India.</td>
<td></td>
</tr>
</tbody>
</table>

and affordability of the device should be considered (Figure 10).\textsuperscript{73}

Is the desired device affordable to the patient?

In developing countries like India, the cost of medical care and affordability of the prescribed treatment is a huge concern amongst the majority of the patients, especially in chronic disease conditions requiring long-term treatment. Affordability has a direct impact on patient compliance with treatment, which, in turn, impacts the disease control or symptom improvement and, hence, plays a major role in disease management.

Would the patient be able to generate good inspiratory flow?

The inspiratory technique or the ability to actuate is one of the key factors in choosing an inhaler device for the patient. Figure 10 details a practical guide by the authors to choose a device for the patient based on his/her inspiratory technique or ability.\textsuperscript{73}

In what device is the desired drug available in the patient’s city/geographical location?

If the prescribed device or drug combination is not available easily to the patient, the risk of non-adherence and non-compliance to therapy or the patient taking a wrong replacement device or drug given by a dispensing pharmacy as an alternative treatment is very high.

Will the patient be able to coordinate the actuation and inhalation?

This is a crucial requirement when only a pMDI is used. When in doubt, adding a spacer to the pMDI or using a BAI would be a more beneficial approach for the patient.

Does the patient have a preference for any particular device?

Offering a choice of inhalers to patients can be a problem for those who do not have a clear understanding on the different types of inhalers and their advantages or disadvantages. A patient might go by the look and feel of the product rather than considering practical points such as ease of use and affordability. A choice of inhalers could be offered only to those patients who are well informed about the disease and the available treatment options.

Can the patient generate sufficient inspiratory flow?

Due to the ease of use and availability of a better range of combinations, DPIs are very widely prescribed inhalers in India. In order to be able to prescribe a DPI to a patient, it is important for the physician to understand whether the patient is able to generate a sufficient inspiratory flow required for successful drug delivery by a DPI. A fast and prolonged inspiration from the start is essential for DPI use. A visual inspection during the first follow-up visit wherein the patient is requested to take his/her regular dose via a DPI...
in front of the physician can provide a fair idea as to whether the patient is a good candidate for a DPI prescription. **Does the patient understand the importance of the inhaler technique?**

Incorrect inhaler technique is an independent risk factor for exacerbation in asthma and COPD patients. A physician’s responsibility does not end with a one-time teaching of the inhaler technique to the patient. Emphasis has to be laid on the practice and use of the correct inhalation technique by the patient by checking the same repeatedly, at intervals. Therefore, scheduling the first follow-up visit within 7–10 days of prescribing and teaching an inhaler technique to the patient gives the treating physician an opportunity to recheck and correct any incorrect inhaler technique of the patient and also provides an opportunity for patient counselling to address all the concerns of the patient and family members/caregivers and thus improve the treatment outcomes. Now, there are inhaler education videos and virtual educators available through the manufacturers and many associations and, hence, patients should be encouraged to visit the appropriate websites to access information on correct inhalation technique.

**Adherence to Inhalation Treatment**

Poor patient compliance with inhalated medication therapy is a known cause of morbidity and mortality in OADs. Various factors contributing to poor compliance or poor adherence in inhalational treatment for OADs include the following:

- Chronic nature of the disease requiring long-term treatment and follow-up.
- Myths associated with the use of inhalers that deter patients from long-term use.
- Lack of knowledge about the diseases.
- A false sense of wellbeing or achievement of cure after bronchodilators control the symptoms.
- Poor inhaler technique affecting drug deposition and efficacy.

Patient education and awareness on the disease, benefits of inhalation therapy and need for good treatment compliance are the keys to ensure good patient adherence to treatment and thereby help improve health outcomes in patients with asthma and COPD.**

Recommendation: Healthcare providers, especially treating physicians, need to understand and appreciate the role of patient counselling and patient education in the management of OADs. Educating the patient on the correct inhaler technique and dispelling the common myths or concerns that patients have about inhaler therapy are key to the successful management of OADs in patients (Tables 8 and 9).

**Conclusion and Summary**

Inhalation therapy is the safest, fastest and most effective way to deliver drugs directly to the airways in patients with asthma and COPD. All patients with asthma and COPD must, therefore, receive inhalation therapy, be it bronchodilator drugs such as beta-adrenergic agonists or muscarinic antagonists, or anti-inflammatory drugs such as corticosteroids. Inhalation therapy can be delivered by different devices and are largely divided into three groups, viz. pMDIs (including BAIs), DPIs (unit dose or multidose) and nebulisers. Each of these devices has its own advantages and drawbacks. Spacers and face masks are accessories that can be used with the pMDIs. When using the pMDI, the inhaled breath needs to be slow and deep; with the DPI, it should be rapid and deep. In infants and children, pMDIs are preferred with a face mask or spacer. Spacers should preferably be conical in shape and should be made of non-static material. They overcome the need for actuation-inhalation coordination, reduce oropharyngeal deposition and eliminate the cold-front effect. When using high doses of inhaled corticosteroids in asthma, pMDIs and spacers are the devices of choice as they reduce the side effects of oropharyngeal deposition significantly. There are several myths and misconceptions about inhalation therapy and these need to be cleared up by the treating physician through proper education and counselling. Physicians must choose the right device for their patient, taking into consideration the patient’s skill and ease in using the device correctly. It is important for the physician to check the inhaler technique during every visit to ensure that the patient is using it correctly. Maintaining adherence to inhalation therapy is a challenge and must be overcome through good communication and counselling. Inhalation therapy for asthma and COPD can save lives and reduce the suffering and economic loss associated with these very common OADs and must, therefore, be widely used in our country.

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