

A Patient's Guide to Aerosol Drug Delivery 2nd Edition

**What Are These
Things?**

**What Do I Need
To Know To Use
Them?**

**Why Is It
Important For
Me To Use Them?**



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Foreword (Second Edition)

Gaining as much information about your aerosol delivery devices is essential. You have taken a positive first step by obtaining this second edition of “A Patient’s Guide to Aerosol Drug Delivery.” The American Association for Respiratory Care (AARC) commissioned respiratory therapists who were noted aerosol delivery experts to author this guide. This guide was written with you in mind. As you know, the number of medications and the devices that deliver them change seemingly on a daily basis. That is why it is important for you to understand the critical differences between these devices and, more importantly, how to use your device(s) correctly so that you can maximize the intended results that the medication delivers. We encourage you to become proficient in the use of your aerosol delivery devices and never hesitate to ask questions of your physician or respiratory therapist.

This Patient Guide will provide you with step-by-step education on all available devices on the U.S. market today. Currently there are three basic types of delivery systems, which include nebulizers, metered-dose inhalers, and dry-powder inhalers. All three have their own specific characteristics and delivery

capabilities that required your physician to determine which was the most appropriate for you.

We hope that you find this useful. The American Association for Respiratory Care invites you to learn more about better self-management of lung disease through other online resources that again have been created to help you and to allow you to practice a higher level of self-management. Simply go to www.aarc.org or www.yourlunghealth.org. There you will find “Allergy and Asthma Health,” (an online magazine), smoking-cessation information, and so much more. We encourage you to learn the most you can about your lung health.

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Quotes

“I like the ‘Patient’s Guide to Aerosol Drug Delivery’ and think that it is going to be very helpful not only to patients but to medical professionals as well. Very good job.”

Vlady Rozenbaum, PhD
Founder-Administrator
COPD-ALERT

“My first reaction was ‘who is going to read 50-plus pages?’ After reading it my reaction is: ‘Where was this when I was first given an inhaler with no instructions.’”

Kenneth Benson
Patient

Acknowledgements

The American Association for Respiratory Care would like to formally thank and acknowledge the following individuals for their review of “A Patient’s Guide to Aerosol Drug Delivery.” Their unique knowledge of the cardiopulmonary patient, their disease process, and aerosol delivery devices were invaluable in the writing and publication of this guide.

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Introduction

Perhaps the shortness of breath, coughing, excessive phlegm, chest tightness and/or difficulty in catching your breath that you've been experiencing has recently been diagnosed as an obstructive airways disease. The good news is that your physician, respiratory therapist, or nurse professional provided you with a brief description of your condition — explained what it is, the causes, and the treatment options. He/she also probably recommended that you start taking medication in the form of a breathing treatment.

You may have already received a few treatments and find that they make your breathing easier. You may also have learned by now that taking control of your obstructive airways disease is the only way to improve your health to the point where you can do all the things you need and want to do. You may also know that controlling your condition will involve understanding as much as possible about these breathing treatments.

But you no doubt still have a lot of unanswered questions: What is an aerosol? What are these breathing devices? What's in them? How do they work? And, why do I have to use them? These are just a few of the questions that this Patient Guide has been developed to help address. It is written in language easy to understand and in a conversational style format that's easy to follow.

This Patient Guide was prepared for you by the American Association for Respiratory Care (AARC), a professional organization of over 52,000 respiratory therapists who are competent, caring, and compassionate individuals dedicated to the detection, management, and treatment of lung diseases.

Respiratory therapists (RTs) are the frontline caregivers for patients with asthma, pulmonary fibrosis, cystic fibrosis, chronic bronchitis, emphysema, chronic obstructive pulmonary disease (COPD) and many other respiratory diseases. They are committed to helping you control and manage your condition. We hope you will find our Patient Guide a valuable resource to assist you in understanding basic aerosol drug delivery for better symptom control and management.

It is important to note that this Patient Guide is **not** a substitute for medical information or treatment options provided by your physician. The Guide is primarily intended to focus on the various medical devices that are used to administer breathing treatment — explaining what they are, how they work, and how to use them correctly for maximum effect.

1

Aerosol Drug Delivery: The Basics

What is an aerosol?

Remove the top from a perfume bottle, aftershave, hairspray, bug spray, room deodorizer, or household disinfectant and depress the button. What you see is an aerosol — a small cloud made up of thousands of tiny particles floating in the air. But, did you know that aerosols and particles also exist virtually everywhere there is air to breathe? For example, there are naturally occurring aerosols in the atmosphere such as pollen, fog, steam, and ocean spray when waves crash into the shoreline. Other types of man-made atmospheric aerosols are harmful, such as cigarette smoke, automobile emissions, and pollution from factories, power plants, and coal mines.

Some aerosols are seemingly beneficial and can make us smell fresh and appealing, can eliminate odors, can clean and disinfect, and can even prevent disease.

However, all inhaled aerosol particles have the potential to cause our obstructive airways disease to flare up. The aerosols we will address in this Guide are *medical aerosols* that are designed to treat your condition, while managing and controlling the symptoms of your obstructive airways disease.



Medical aerosols

A *medical aerosol* is a mixture of drug particles and gas. When you take your breathing treatment, which we'll call an *aerosol treatment*, you are inhaling an

aerosol that will help you breathe easier. Aerosol treatments can be delivered with a portable, hand-held device that you can carry in your purse or pocket, which is called a pressurized metered-dose inhaler (pMDI) or a dry-powder inhaler (DPI).

Aerosol treatments can also be delivered with a portable aerosol-producing device called a small-volume nebulizer (SVN). An SVN has a small plastic tube and cup (nebulizer) that connects to an air compressor. The liquid medication is put into the nebulizer cup and the compressor makes the liquid into an aerosol for breathing.



All of these devices are designed to assist you in administering the medication you need to help you breathe easier. We will discuss all of

these devices in more detail throughout this Guide. But first, let's explain some of the terms you need to know about aerosol drug delivery. The most important terms for you to know and understand are listed below.

Common terms

Aerosol: A mix of liquid and solid particles produced by an aerosol generator such as the small-volume nebulizer (SVN), a pressurized metered-dose inhaler (pMDI), or a dry-powder inhaler (DPI). It's that mist we talked about above.

Aerosol Deposition: It's what happens when the drug particles land on the inside of your airways. This is how the medication is absorbed into the body after breathing it in through the device.

Aerosol Generator: A device used for producing the aerosol particles.

Aerosol Output: All the particles that make up the cloud or mist that you see coming from your aerosol device. It's really a collection of millions of tiny little droplets of liquid or particles of medication.

Aerosol Therapy: Delivery of solid or liquid aerosol particles to your lungs for the purpose of treating your breathing problem.

Drug Formulation: Composition and preparation of a drug or medicine, which could be considered the ingredients or a drug recipe.

Dry-Powder Inhaler (DPI): An aerosol delivery device that dispenses the drug in a very fine powdered form. Since DPIs have no propellant, the medication is drawn into your lungs as you take in a fast breath. This means you need to inhale quickly and deeply to get the medication from the device deep into your lungs.

Hydrofluoroalkane (HFA): A newer, liquefied gas propellant used to deliver drug from a pMDI. It's the replacement propellant for the older chlorofluorocarbon (CFC) propellant, but is much more environmentally friendly. CFCs were potentially harming the earth's ozone layer.

Inhaler: A generic term for any type of self-contained drug-delivery device (e.g., dry-powder inhaler or metered-dose inhaler). Either type of inhaler delivers a single dose of medication for inhalation. You're possibly carrying one type of inhaler in your purse or pocket right now. With an inhaler, you can take a dose of inhaled medication anytime, anyplace.

Pressurized Metered-Dose Inhaler (pMDI): A drug delivery device that contains multiple doses of your medication and dispenses a single dose by means of a pressurized propellant with a metering valve. The pressurized propellant ejects medication out of the device, and the metering valve provides just the correct amount of medication. The outlet of the device is put into your mouth; and when you squirt it, a dose of medication is delivered. But remember, you still need to breathe in at the same time with a slow, deep breath.

Small-Volume Nebulizer (SVN): A device that converts a liquid medication into an aerosol form. An SVN includes (1) an air compressor (either electrically or battery powered) and (2) a small plastic nebulizer cup that is connected to the compressor with a plastic tube. When the liquid medication is instilled into the nebulizer cup and the compressor is turned on, this compressed gas creates the aerosol and its particles.

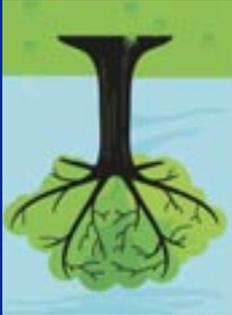
Spacer: A plastic tube that is placed between the pMDI outlet and the patient's mouth. The spacer helps coordination and timing so that more of the aerosol gets into your airways when using a pMDI.

Valved Holding Chamber: A spacer (that plastic tube we just talked about) with a 1-way valve used to hold aerosol particles within the tube when you squirt a pMDI until you actually breathe. A valved holding chamber is considered an enhancement to the simple spacer.

How does the aerosol get into my lungs?

Basic lung structure

If you imagine the structure of the lung as an upside-down tree, you can begin to get a picture of the relative size and design of the lung and its corresponding airways (breathing tubes). The base of the tree (the trunk) represents the trachea or windpipe, which is about an inch in diameter in adults, but smaller in kids. Just as the tree continues to branch out into smaller and smaller limbs, so do the breathing tubes, or airways of the lung. The major airways (the large limbs) are called bronchi and the smaller limbs (the twigs) are called bronchioles. This branching will eventually end with tiny air sacs (the leaves). It is within these branches (airways of the lungs) that the problem of airway obstruction occurs, and it is within this area that we need to deliver medication.



Air passages

Obstructive airway diseases such as asthma or COPD cause the inside size (or opening) of the airways to narrow from the size of a dime to that of a pencil. In some severe disease states, the size could be that of a drinking straw or a coffee stirrer.



Airway obstruction, which occurs when your asthma or COPD flares up, will generally happen at about the fourth or fifth airway branching level. Picture the tree and its branching (from trunk to limbs to twigs)! This is important because we want most of the aerosol particles to deposit further out in the lung (branches), so the size and speed of the aerosol particles and other factors become important.

Aerosol particle size

It's often hard to imagine how small individual particles of an aerosol really are. Instead, you might find it helpful to think of the millions of individual aerosol particles in another way. Think of an aerosol as a collection of water droplets — like what you see when walking in a heavy fog along the coast or the steam in a wet sauna.

All of the droplets that make up the fog or steam will be about the same size and in the same round shape. If we wanted to describe the size of each droplet, we would measure the diameter of the droplet — the distance between the 2 sides of the droplet. These same features hold true when we talk about aerosol particles; and when we measure the size of these particles, we use the term micron (μM). Now, 50 microns would be about the size of a human hair. That's awfully



small. And while we will talk more about the actual size of these particles a little later, I think you can begin to see how their size and number can have an impact on where and how these aerosol particles will settle in your airway.

Breathing pattern

In addition to particle size, the way we take a breath also is important to get particles deep into the airways. For example, you may be instructed by your health care practitioner to inhale slowly and deeply when taking an aerosol treatment. You may also be told to hold your breath for a few seconds after breathing the medicine into your lungs. This deep, slow breathing with a breath-hold helps the medication particles get deeper into the airway. This is where the medicine does the most good.

Once the medication particles reach the desired location, they settle themselves on the inside surface of the airways to be absorbed. The type of medication will determine what happens to the airways (we will discuss the actions of various medications a little later).

Medication particle deposition

So basically, the size of the aerosol particles (which we just discussed), the way you breathe, and the condition of your airways will determine where the aerosol particles deposit in your lungs. Unfortunately, it is a rather complex process since so many things have to work right.

Aside from not having aerosol particles in the right size, there is also the common problem of obstructed airways. For example, this might happen with a sudden asthma episode, where there is a lot of wheezing. Another cause could be an increase in the amount of mucus in the air passages, especially in those people who are unable to cough it up. In these examples, the movement of medication particles into the lungs is physically blocked.

And sometimes patients don't breathe properly. This can be the result of a flare-up, where the person typically breathes faster as they get increasingly short of breath. Or it could be that the person was never taught the correct way to breathe when taking an aerosol treatment. You can probably begin to see what we mean about this being a complicated process.

What are the different types of aerosol devices?

There are 3 different types of devices used for aerosol treatments.

- Small-volume nebulizer (SVN)
- Pressurized metered-dose inhaler (pMDI)
- Dry-powder inhaler (DPI)

A description of each device can be found in the Common Terms list on page 5. Note that pMDIs and DPIs are called *inhalers*, whereas the SVN is called a *nebulizer*.

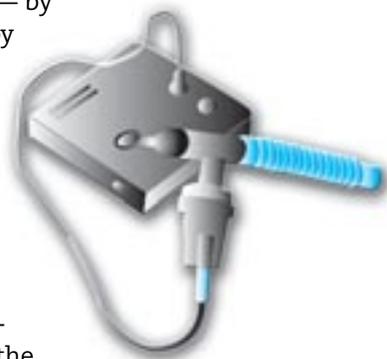
When used correctly, all 3 types of aerosol devices can provide good aerosol treatments. However, there are differences in how each device creates the aerosol. What follows is a brief description of how the various devices differ from each other. A more detailed explanation of how each type of device works appears later in this Guide.

Small-volume nebulizer

While there are many different models of SVNs, they all do the same thing — convert a dose of liquid medication into a breathable aerosol. SVNs do this in 1 of 2 ways — by using compressed gas (the traditional way), or by using electric current (the newest way).

The traditional SVN is actually 2 separate parts — a tabletop electric air compressor and a small plastic jet nebulizer. The 2 parts are connected together with a 2-3 foot length of plastic tubing. The compressor provides the pressurized gas that the nebulizer needs to turn the liquid into an aerosol mist.

The newer electronic SVNs use high-frequency sound waves or high-tech vibrations to turn the liquid medication into an aerosol mist. However, electronic SVNs cost 2 to 3 times more than traditional SVNs.

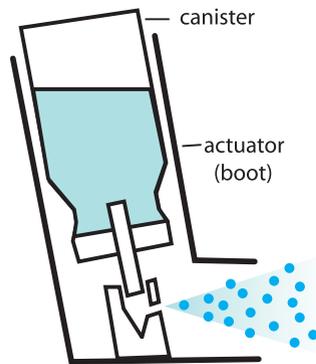


Pressurized metered-dose inhaler

A pMDI is a small, aluminum canister that contains a mixture of both medication and its pressurized propellant. Since the pMDI contains both medication and propellant, you don't have to put the liquid medication into the device like you do with an SVN. The pressure from the expanding propellant forces the medication from inside the

canister through the nozzle each time the canister is pushed down into the boot or actuator, a process often called *actuation*.

A new alternative device called a *Respimat* can also be used to deliver your medication. It does not have a propellant but rather a spring-mechanism to release your medication. We will discuss this in more detail a little later in the Guide.



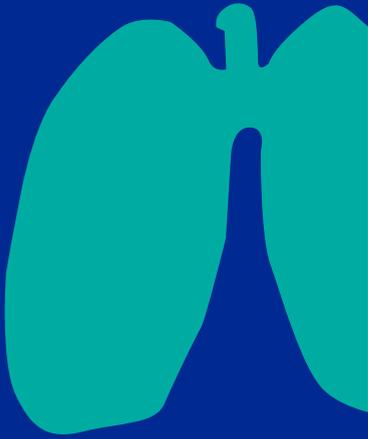
Dry-powder inhaler

A DPI is a different type of inhaler. However, unlike an SVN or pMDI (which both deliver medication as a liquid mist), DPIs deliver medication as a fine, or very small dry powder. DPIs do not rely on a compressor or a pressurized propellant to deliver the aerosol medication. Instead, the patient provides the energy when they take a deep and fast breath through the DPI mouthpiece.

This deep breath also helps to carry the powdered medication into the lungs.

All of these devices will be described in more detail in later sections of the Guide. But hopefully you are getting a general idea of what these various aerosol delivery devices look like and how they work to deliver medication to the airways.





What are the advantages and disadvantages of inhaled aerosol drugs?

There are a number of advantages and disadvantages that go along with the inhalation of drugs to treat your obstructive airways disease compared to oral medications or needle injections. The most important advantages are:

- ✓ Smaller doses (you don't need as much)
- ✓ Quicker action (they simply work faster)
- ✓ Direct delivery to the lung (hey, it's going directly to the problem area)
- ✓ Fewer unwanted side effects (because we use smaller doses)
- ✓ Medicine doesn't travel to other places where it can cause trouble
- ✓ No pain (no needles).



Just like anything else in life, there are some disadvantages as well. Some of the more critical disadvantages are:

- ✓ The lung does not absorb a drug very efficiently (you'll be shocked to know that only about 10–15% of what is delivered is absorbed by the lung!). That is why correct inhaler use and technique are so important.
- ✓ Your breathing pattern could create a problem (recall that with certain inhalers you may have to inhale slowly and deeply, something you're not likely to do when you are having an attack).
- ✓ Some folks have trouble pressing the device and breathing at the same time (difficulty with hand-breath coordination).
- ✓ Some folks simply cannot use them correctly.
- ✓ With so many different types of devices, we get confused with how each works.
- ✓ There is a lack of standard technical information (companies use their own confusing language to explain them).

So, when all is said and done, the advantages of aerosol drug delivery clearly outweigh the disadvantages. However, as the list above shows, the disadvantages must be overcome to get the best effect. This is why it is so important to listen, and fully understand, what your health care provider says when he/she explains how and why you should use your device.

2

Aerosol Drugs: The Major Categories

What are the currently available aerosol drugs?

You probably noticed that some of your aerosol drugs have different names and come in different forms. Some come in a liquid form that you squirt into your small-volume nebulizer (SVN). Some come in a pressurized metered-dose inhaler (pMDI), which you just squirt into your mouth and breathe in slowly and deeply. And some come in a dry-powder inhaler (DPI) from which you inhale a powder and do so fast and deeply.

We will talk later about how to use these devices correctly. But let's get back to the different names and different forms. The term drug formulation is used to describe all medications in greater detail. Table 1 provides you with currently available aerosol drug formulations — their generic name, brand names, and aerosol delivery device. We did not include the cost as they are subject to change (see note below Table 1 on page 13). You may also want to look back at the list of Common Terms on page 5 for a brief explanation of each.

Table 1. Currently available aerosol drug formulations with corresponding inhaler devices for use in the United States.

DRUG	BRAND	DEVICE
Short-Acting Bronchodilator		
Albuterol Sulfate	AccuNeb®	SVN
	Albuterol Sulfate	SVN
	ProAir HFA	pMDI
	Proventil HFA	pMDI
Levalbuterol	Ventolin HFA	pMDI
	Xopenex Inhalation Solution	SVN
Xopenex HFA	Xopenex HFA	pMDI
	Nephron	SVN
Metaproterenol	Nephron	SVN
Racemic Epinephrine	Alupent	pMDI
Ipratropium Bromide	Ipratropium Bromide	SVN
	Atrovent® HFA	pMDI
Ipratropium Bromide & Albuterol Sulfate	Ipratropium Bromide & Albuterol Sulfate	SVN
	Duoneb®	SVN
	Combivent® Respimat®	pMDI
Pirbuterol	Maxair	DPI

DRUG	BRAND	DEVICE
Long-Acting Bronchodilator		
Acclidinium	Tudorza™ Pressair®	DPI
Arformoterol	Brovana®	SVN
Formoterol	Perforomist™ Foradil Certihaler	SVN DPI
Indacaterol	Arcapta™	DPI
Salmeterol	Serevent	DPI
Tiotropium	Spiriva	DPI
Corticosteroids		
Beclomethasone	QVAR 40 QVAR 80	pMDI pMDI
Budesonide	Pulmicort Pulmicort	SVN DPI
Ciclesonide	Alvesco®	pMDI
Fluticasone	Flovent Diskus Aerospan HFA	DPI pMDI
Mometasone	Asmanex Twisthaler®	DPI
Combination Drugs		
Fluticasone & Salmeterol	Advair® HFA Advair Diskus®	pMDI DPI
Budesonide & Formoterol	Symbicort	pMDI
Mometasone & Formoterol	Dulera	pMDI
Other Drugs		
Cromolyn Sodium	Cromolyn Sodium Intal	SVN SVN
Zanamivir	Relenza®	DPI
Tobramycin	TOBI®	SVN
Aztreonam	Cayston®	SVN

HFA = hydrofluoroalkane; pMDI = pressurized metered-dose inhaler; SVN = small-volume nebulizer; DPI = dry-powder inhaler.

Cost information may be obtained from www.drugstore.com

NOTE:

Pharmaceutical firms continue to develop newer aerosol medications for the control of symptoms associated with obstructive airway diseases. This section describes the medications available at the time of this writing. Newer medications may not be included.

How do aerosol drugs work?

Table 1 lists most of the aerosolized medications in use at the time of publication for the treatment of airway obstruction due to bronchoconstriction (or bronchospasm), inflammation, and excessive secretions/mucus. However, it is common practice to group all of these medications into the following 5 major categories:

- ✓ Short-acting bronchodilators
- ✓ Long-acting bronchodilators
- ✓ Inhaled corticosteroids
- ✓ Combination drugs
- ✓ Others

We will use this list as a guide to explain, in easy-to-understand terms, how each medication works in treating your obstructive airways disease.

You should realize that the main goal of all the medications used for your obstructive airways disease is to open your airways, that is, to increase the internal size or diameter of your airways. If you recall the examples we discussed earlier, we mentioned a dime, a pencil, a drinking straw and a coffee stirrer. Well, what the medications do is help the size of the airways enlarge and go from the size of a pencil to that of a dime or the coffee stirrer become the size of the drinking straw. In essence, these medications make the inside of the air passages wider so that it is easier for you to breathe.

The problem with having an obstructive airways disease is that you can have 1, 2, or all of 3 bad effects (shown below in Figure 1) happening at the same time. For example, the muscles surrounding the outside of the airway squeeze the airway. This is called *bronchoconstriction*. Or the inside of the air passages could be irritated and swollen, similar to what happens when you accidentally burn your skin (like a sunburn) or get dust or smoke in your eyes. This is called *inflammation*, which incidentally is the primary problem with asthma. The third bad effect could be having the inside of airways fill with mucus or secretions. This is called *mucous obstruction* and often results in a rattling sound when breathing.

Having a basic idea of these 3 different bad effects (or *symptoms*) will better prepare you to understand the 5 medicine categories we are about to discuss. Take a closer look at Figure 1 for an illustration of these 3 bad effects.

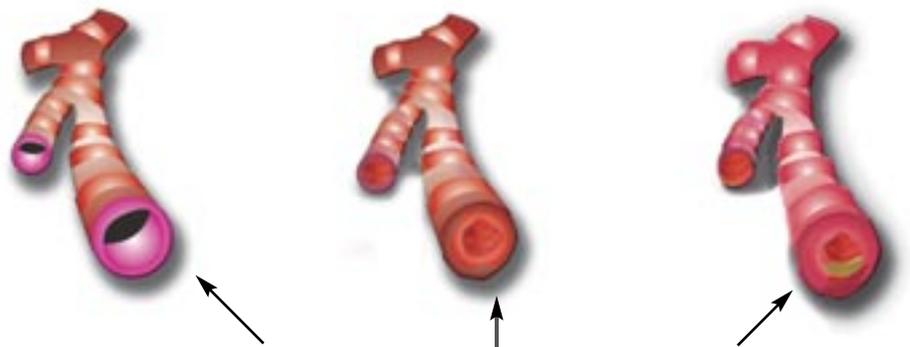


Figure 1. Illustration of bronchoconstriction, inflammation, and mucous obstruction

Short-acting bronchodilators

Short-acting bronchodilators, also known as SABAs, are commonly referred to as *quick-reliever medications*. These medications are designed to quickly relax constricted muscles surrounding the outside of your airways. The result is a *dilation* or widening of the inside diameter (or opening) of the airways. One way to think of this is to picture in your mind what happens when a snake wraps its long body around another animal. As the snake tightens its grip (constricts) around the body of the animal, the animal's ability to breathe is quickly impaired. A SABA loosens the grip of the muscle on the airway.



Fortunately, SABAs are pretty powerful drugs. That is why they are considered main medications for treatment of a sudden attack. This means that they are quick acting — the start of action is within a matter of minutes. However, the duration of effect is rather short — 2 to 4 hours. You should use a SABA when you have increased symptoms, such as shortness of breath, wheezing, coughing, or chest tightness and need immediate relief.

However, if you have asthma, you really should **not** be using SABAs on a daily basis. The newest asthma treatment guidelines now state that if SABAs are being used more than twice a week during the daytime, or more than twice a month during the nighttime, then your asthma is not as well-controlled as it should be. You should probably be under the watchful eye of your doctor and start using a more appropriate controller medication, such as an inhaled corticosteroid (addressed below). However, if you have COPD (emphysema or chronic bronchitis), you should ask your health care provider about using a long-acting bronchodilator.

Long-acting bronchodilators

Long-acting bronchodilators, also known as LABAs, are similar yet different from SABAs. Like SABAs, LABAs relax the muscle that surrounds the airway (much like the snake example) and thus have the effect of opening (dilating, thus the name dilator) the airways.

However, while LABAs have a similar action as SABAs, the effect lasts much longer, up to 12 hours for some and as long as 24 hours for others. Thus, LABAs are considered *controller* or *maintenance* medications and are **not** to be used when immediate relief is needed. Instead, LABAs are to be used on a daily basis for the long-term control of recurring bronchoconstriction (bronchospasm). Depending on the particular medication, they are taken either once or twice a day to *maintain* an open airway.

It is important to restate that LABAs are not quick-acting drugs. They should not be used when you are having an active asthma attack or increase in your symptoms. While the duration of action is much longer than with a SABA, the start of action is delayed, meaning it takes awhile for them to start to work. LABAs should not be used in asthma alone, that is, without an inhaled corticosteroid.

Inhaled corticosteroids

Inhaled corticosteroids (ICS), also called *anti-inflammatories*, are very important medications that doctors frequently prescribe for lots of medical conditions, including obstructive airways disease. For example, doctors sometimes inject steroids to temporarily treat joints (shoulder, knee, wrist, elbow) or muscles that are inflamed or swollen due to an injury. In asthma, doctors prescribe steroids in the inhaled form to help reduce airway inflammation. Before we talk about how they work, let's address the obvious concerns that most people, especially parents, have about the word *steroids*.

Medical and inhaled corticosteroids **are not** the same drugs as the steroids taken by athletes, weight lifters, or bodybuilders who are trying to bulk up their bodies and enhance their athletic performance. These types of steroids are called anabolic steroids and, as most of us know, they are bad for you. They have dangerous side effects and can seriously hurt you later in life. This makes you wonder why so many athletes use them.

All steroids, especially when taken for a long period of time, do have some potential side effects. However, the side effects are not to the degree that we see with the anabolic steroids. Medical steroids are usually administered by a single injection to the affected site (e.g., the shoulder) or over several hours through an IV (as might be necessary during a severe asthma attack). Medical steroids can also be taken by mouth in the pill form. The most common steroid pill is prednisone.

But let's get back to *inhaled* corticosteroids. These medications are used to treat the inflammatory part of your obstructive airways disease. This is where the insides of the airways become irritated and swollen — recall the examples of skin burn and dust in the eye that we mentioned in the beginning of this section or even, the swollenness of your thumb if you accidentally hit it with a hammer.

Inhaled corticosteroids help reduce the inflammation of the inside lining of the airways and allow the inside surface of the airway to return to its normal, non-swollen size.

It is very important to remember that for inhaled corticosteroids to be effective, they must be taken daily.

Also, it may take several days to a few weeks before the effects of inhaled corticosteroids can be observed.

Since inhaled corticosteroids do **not** work immediately, they are **not** effective for a sudden asthma attack or increase in symptoms.

The good news is that when taken in the inhaled form for the long-term control of asthma or COPD inflammation, the side

effects of properly dosed steroids are minimal. This is one of the great benefits of using inhaled medications — undesirable side effects are significantly reduced. In fact, there is more harm caused by **not** taking inhaled corticosteroids to effectively control airway inflammation, especially in children with persistent asthma.

Combination drugs

Combination drugs, as the name implies, consist of 2 of the categories mentioned above combined into one medication. Most often, this will be a LABA combined with an inhaled corticosteroid. The advantage of this form of therapy is that it is much easier to take when your doctor has prescribed both a LABA and inhaled corticosteroid to control your symptoms as one medication instead of two separate medications. It is important to remember that when your doctor prescribes a combination drug, then you should **not** continue to take any other LABA or inhaled corticosteroid by itself. This will result in overmedicating and could cause problems. These drugs are to be taken only once or twice a day and never for the treatment of sudden symptoms.

Mast cell stabilizers

These medications (such as cromolyn sodium) are used to prevent asthma symptoms, like wheezing and shortness of breath, from ever occurring in the first place. They work by blocking the release of certain natural chemicals in the body that eventually start the asthma attack.

The most common of these natural chemicals are called *histamines*, which are generally released during allergic reactions. Histamines are released by a certain type of cell in the lung (called *mast cells*) and this category of medications controls (or stabilizes) this reaction, thus the drug category, *mast cell stabilizers*. The release of histamines by mast cells in the airways is often triggered by inhaling airborne irritants, such as dust, mold, and pollen. In some individuals who are highly allergic, this could lead to a serious asthma attack.

Mast cell stabilizers do not work quickly, nor do they work well for all kinds of asthma. For best effect, mast cell stabilizers must be taken regularly over a period of time. In fact, it may take up to 4 weeks before any improvement is observed with this type of medication. And as mentioned, some people will not experience any effect.



3

Aerosol Drug Delivery Devices: Small-Volume Nebulizers

What are SVN's?

As mentioned previously in Chapter 1 of this Guide, a small-volume nebulizer (SVN) is a device that turns a liquid medication into a mist (or aerosol) that can be inhaled. SVNs are frequently used by respiratory therapists in the hospital to administer aerosol treatments to patients. However, SVNs can also be used at home, although the SVNs for home use are a little different from those used in the hospital.

What are the different types of SVN's?

There are basically 2 different types of small-volume nebulizers: jet nebulizers and electronic or mesh nebulizers.

Jet nebulizers

Although there are many different types or models of small-volume medication nebulizers on the market, the jet nebulizer is the most common (see Figure 2). Jet nebulizers are inexpensive because they are mass produced (they make a lot of them), which is why they don't cost very much. They are also designed for single-patient use, so you don't want to share yours with someone else. Jet nebulizers are also disposable devices. You simply throw them away when you are advised by your respiratory therapist to replace it with a new one.

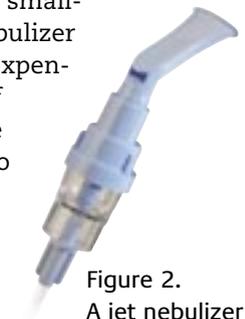
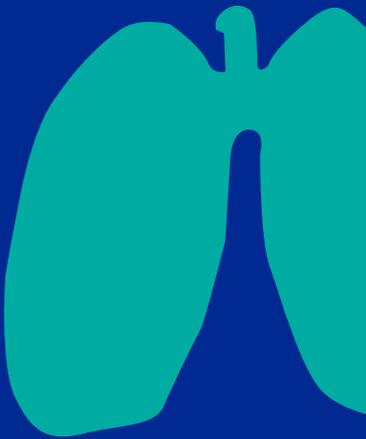


Figure 2.
A jet nebulizer

Electronic nebulizers

Besides the standard jet nebulizer, there are several other types of hand-held, portable SVNs on the market. These other models are called *electronic nebulizers* and can be classified as either “ultrasonic” or “vibrating mesh.”

The main difference is that these other types of electronic nebulizers do not use a compressor and jet nebulizer. Instead, they use electrical energy to turn the liquid medication into a mist. Electronic nebulizers are small, quiet, and are powered by a variety of different types of batteries.



How does a jet nebulizer work?

The jet nebulizer consists of 2 parts — an electric compressor and a plastic jet nebulizer. Figure 3 shows a cut-away view of a jet nebulizer. The word “jet” is used because the pressurized gas is forced through a small narrow opening (a jet). As the pressurized gas leaves the jet, it mixes with the liquid medication to create a mist.

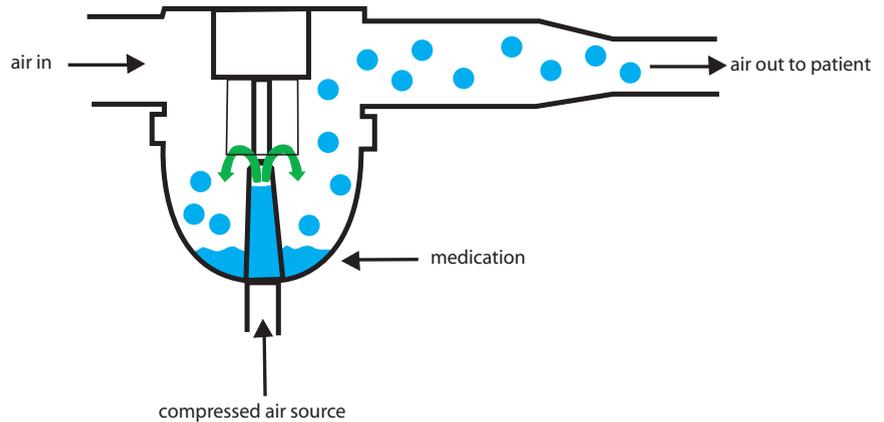


Figure 3. Illustration of the function of a jet nebulizer

The nebulizer part is connected to the compressor with a short (2–3 feet) piece of plastic tubing. The compressor part may not be needed in the hospital because pressurized air or oxygen is widely available from outlets at the head of each hospital bed. But the compressor is needed for the home to provide the pressurized air.

The liquid medication is put into the medication cup in the jet nebulizer and the nebulizer reassembled. The compressor then is plugged into an electrical outlet and turned on. To take your aerosol treatment, you put the mouthpiece into your mouth and breathe in the mist or aerosol from the nebulizer.

It is very important that any type of hand-held jet nebulizer be kept in the upright position during use. Otherwise, the medication might not come into contact with the jet part of the nebulizer, and there will be no mist created.

After a few minutes, the nebulizer will start to make a sputtering noise. This indicates that the treatment is nearly over. (See “When is my treatment over?” at the end of this chapter.)

As previously mentioned, there are now newer models of compressors that can be operated by a rechargeable battery. This is a very convenient feature, especially when there isn’t an electrical outlet available. However, battery-powered compressors are more expensive, so insurance companies rarely pay for them.

SVNs are easy devices to use because they do not require any special coordination, such as that needed for other aerosol inhalers. You simply put the medication into the jet nebulizer, turn on the compressor, and breathe!

How do electronic nebulizers work?

There are 2 ways electronic nebulizers work. For the ultrasonic nebulizer, the key part is a small ceramic disc, over which the liquid medication is placed. When the electronic charge is applied, the ceramic disc vibrates at a high speed. The vibration creates sound waves that travel through the liquid medication, breaking it into very fine particles that can be inhaled.

For the vibrating mesh electronic nebulizer, the liquid is pumped through a small mesh

screen that vibrates at a very fast rate. The mesh screen has thousands of tiny holes in it. So when the liquid medication hits it, it is changed into very fine particles that can be inhaled.

Unfortunately, even though they are very convenient, electronic nebulizers are much more expensive (even more than the battery-powered compressors), so insurance companies do not pay for them.

What are the advantages and disadvantages of SVN's?

Small-volume nebulizers are the oldest devices used to administer aerosol treatments in the hospital. When patients arrive in the emergency department short of breath and struggling to breathe, respiratory therapists will sometimes use an SVN to quickly deliver medication to the airways. In fact, you may have had your first experience with a breathing/aerosol treatment with a small-volume nebulizer.

Because of their ease of use, SVN's are chosen for infants, small children, and the elderly. SVN's are especially useful for people who are unable to operate or correctly use an MDI or dry-powder

inhaler (DPI). Also, most insurance plans will cover the cost of an SVN.

While these are some of the advantages, there are a few disadvantages as well. SVN's can be quite noisy, and they are time consuming to use. Furthermore, SVN's are a little difficult to travel with since access to an electrical outlet is needed for the compressor. Some of the new portable SVN's have a rechargeable battery; but unfortunately, this type of SVN is not usually covered by insurance.

Table 2 below shows the advantages and disadvantages of small-volume nebulizers and will be helpful in determining whether they are the best choice for you.

Table 2. Advantages and disadvantages of SVN's



ADVANTAGES

- ✓ Ability to aerosolize many drug solutions.
- ✓ Ability to aerosolize drug mixtures (more than 1 drug) if drugs are compatible.
- ✓ Minimal patient cooperation or coordination is needed.
- ✓ Useful in very young, very old, debilitated, or distressed patients.
- ✓ Drug concentrations and dose can be modified.
- ✓ Normal breathing pattern can be used, and a breath-hold is not required for it to be effective.



DISADVANTAGES

- ✓ Treatment times may range from 5–25 minutes.
- ✓ Equipment required may be large and cumbersome.
- ✓ Need for a power source (electricity, battery, or compressed gas).
- ✓ Potential for drug delivery into the eyes with face mask delivery (see page 20).
- ✓ Variability in performance characteristics among different types, brands, and models.
- ✓ Assembly and cleaning are required. Contamination is possible with improper handling of drug and inadequate cleaning.

When using any SVN, the following hints will help you get the best medication delivery possible during an aerosol treatment.

You should:

1. Read and follow all written instructions and handouts.
2. Pay attention and ask questions during all training sessions. Ask for additional training if necessary.
3. Make sure that the nebulizer is cleaned, dried, and put away between uses.
4. Make sure that the nebulizer parts are properly assembled.
5. Make sure that the nebulizer is in the upright position during use.

How do I use these SVNs?

Adults and adolescents

So, as we have seen, there are a number of different types of small-volume nebulizers. The proper use of these devices is crucial to your success in treating your symptoms of obstructive airways disease. In addition to the amount and size of mist particles produced by the SVN, your breathing pattern has a big influence on the amount of aerosol that reaches your airways.

For best results in using this device, you should be sitting in an upright position. Try to breathe normally during your treatment. But every once in awhile, take a slow, deep breath and then try to hold the breath for 5–10 seconds before you exhale. This helps deposit more medication into your lungs.

You can take your aerosol treatment using either a mouthpiece or a facemask. However, the mouthpiece is considered the best connection to use and it is a lot more comfortable. With a facemask, aerosol can be deposited on the face. That means it sometimes may get into the eyes. However, proper mask fit and design can reduce the chance of getting it into your eyes.

Infants and small children

If you are trying to give an aerosol treatment to an infant or small child, you will not be able to use a mouthpiece. In this case, you will need an infant or pediatric facemask attached to the SVN. Giving aerosol treatments to infants and smaller children can sometimes be difficult, especially if the child is uncooperative or is crying. Crying significantly reduces the amount of medication that gets into the lungs, so forcing a facemask on an uncooperative, crying child does not do any good.

Some folks have recommended holding the aerosol device close to the face of the squirming/crying infant or child (this is called *blow-by*) as a way to get some medication into the lungs. However, we know that *blow-by* is not effective and its practice is *strongly* discouraged.

Instead, try to turn the aerosol treatment session into a game. Spend extra time with the infant or small child, letting them play with the nebulizer parts. Let them see an older sibling or parent or favorite stuffed animal “use” the SVN. Also, several manufacturers now have SVNs and face masks especially designed and decorated for pediatric patients. Chapter 7 of this Guide, called Special Applications, provides additional suggestions for giving an aerosol treatment to children and infants.

Technique Box 1 lists the steps for correct use of jet, mesh, and ultrasonic nebulizers. Helpful hints for using all types of SVNs are shown in the sidebar at left.

Technique Box 1

Steps for Correct Use of Small-Volume Nebulizers

Technique for jet nebulizers

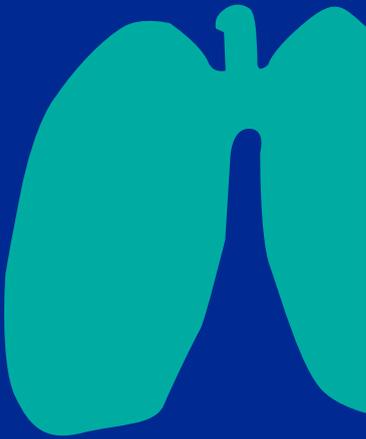
When a jet nebulizer is used, you should:

1. Wash and dry your hands thoroughly.
2. Gather the compressor (with tubing), jet nebulizer, and mouthpiece (or mask).
3. Remove the medication cup from the jet nebulizer.
4. Twist the top off the unit dose medication container and empty the contents into the medication cup.
5. Re-connect medication cup to jet nebulizer.
6. Connect the nebulizer to the compressor with the plastic tubing.
7. Check to see that your compressor is plugged in and then turn it on.
8. Sit in a relaxed, upright position and put the mouthpiece into your mouth and breathe normally. Remember to also keep the jet nebulizer in the upright position during use.
9. Occasionally take a deep breath and try to hold it for 5–10 seconds.
10. If the treatment must be interrupted, turn off the compressor to avoid medication waste.
11. Continue these steps until the jet nebulizer starts to sputter.
12. Give the nebulizer a gentle shake or tap to knock the droplets on the inside back into the bottom of the cup.
13. When the nebulizer sputters again, the treatment is done even though some liquid may remain in the cup. Total treatment time is usually 6–10 minutes, depending on the quantity of medication.
14. Take the jet nebulizer apart and rinse all parts under warm running water; allow the parts to air dry. When dry, reassemble and store in a clean place until the next treatment.
15. At least once a week (or more frequently), wash and disinfect your nebulizer parts. First, after rinsing the jet nebulizer parts under warm running water, wash all nebulizer parts in a mixture of liquid dish soap and warm water. Using a small bottle brush helps get all nebulizer parts clean. Rinse under warm running water. Next, disinfect all parts by soaking for at least 60 minutes in a mixture of 1 cup of white vinegar to 3 cups of warm water.
16. After soaking, rinse the parts again under warm running water and let them air dry.
17. When dry, reassemble everything and store it in a clean place until the next treatment.

Technique for electronic nebulizers

When an ultrasonic or vibrating mesh nebulizer is used, you should:

1. Wash and dry your hands thoroughly.
2. Correctly assemble the electronic nebulizer. It is important that you read and learn about your particular model of electronic nebulizer because there are different types.
3. Follow manufacturer's instructions in performing a proper function test prior to the first use of a new nebulizer to verify proper operation.
4. Twist the top off the unit dose medication container and empty the contents into the medication cup. Do not exceed the volume recommended by the manufacturer.
5. Turn on the electronic nebulizer. You should see the mist coming out of the mouthpiece, even though you will **not** hear any noise.
6. Sitting in a relaxed, upright position, put the mouthpiece into your mouth and breathe normally.
7. Hold the electronic nebulizer in the position recommended by the manufacturer.
8. Occasionally some devices may require you to take a deep breath and try to hold it for 5–10 seconds. Read the specific instructions for your type of device.
9. If the treatment must be interrupted, turn off the unit to avoid medication waste.
10. Continue these steps until you no longer see any mist. Electronic nebulizers do **not** make a sputtering sound.
11. At the completion of the treatment, disassemble and clean as recommended by the manufacturer. NOTE: Electronic nebulizers are more delicate than jet nebulizers, so use caution when handling and cleaning.
12. When cleaning a vibrating mesh nebulizer, do not touch the vibrating mesh as this will damage the unit. Replacement parts are very expensive.
13. Several times a week, disinfect the nebulizer parts by following the manufacturer's instructions.



What are common problems and solutions to the use of small-volume nebulizers?

There are potential problems you might face when using a small-volume nebulizer. The most common problem is the low output or absence of any aerosol. Or the unit simply does not operate. Below is a basic troubleshooting guide that lists potential causes and solutions to common problems. Be certain to use the manufacturer's instructions as well as seek assistance from your respiratory therapist, home care equipment provider, or health care provider.

Troubleshooting

Problems with Jet Nebulizers: Absent or Low Aerosol Output

Causes

Loose or unattached connections.

Obstruction in the opening of the jet nebulizer.

The compressor does not operate.

The output of the compressor is low.

The nebulizer does not make any aerosol.

Solutions

Check the connections and make sure that they are properly attached.

Check the opening of the jet nebulizer and clear obstructions when needed.

Make sure the compressor is plugged in. If it is plugged in and the outlet has power but you still have this problem, you may need a new compressor.

Clean or replace the inlet filter pad. (Consult the manual)

Clean the nebulizer jet or obtain another nebulizer.

Troubleshooting

Problems with Vibrating Mesh and Ultrasonic Nebulizers: The Unit Does Not Operate

Problems	Solutions
Incorrect battery installation (seen in both vibrating mesh and ultrasonic nebulizers)	Check the battery installation and reinstall if needed.
External power source connection (seen in both vibrating mesh and ultrasonic nebulizers)	Check the connections with the AC adapter and the electrical outlet.
Overheated unit (seen in ultrasonic nebulizers)	Turn off the unit, wait until it cools down, and restart the unit.
Incorrect connection of the control module cable (seen in vibrating mesh nebulizers)	Check the connections with the control module cable and reattach them properly, if needed. Consult the owner's manual.
Malfunctioning electronics (seen in both vibrating mesh nebulizers and ultrasonic nebulizers)	Replace the unit.
Mesh holes blocked with medication due to poor cleaning.	Clean according to the manufacturers instructions.

When is my treatment over?

Your aerosol treatments should be scheduled on a regular basis (at a particular time of the day, or in advance of a particular situation). For example, your doctor may want you to take a treatment at 8:00 each morning, and another one at 8:00 in the evening. Your doctor may also want you to take a treatment before you do any exercise. Depending on the type of nebulizer used and the amount of medication, aerosol treatments generally take about 5–10 minutes.

When using a jet nebulizer, you will know that the treatment is coming to an end when you hear a sputtering sound. Sputtering happens when there is only a tiny bit of medication left in the medication cup.

Once the nebulizer starts to sputter, lightly tapping the side of the medication cup a few times will extend the treatment for another minute or so. When the nebulizer sputters again, the treatment is over. There may still be a small amount of liquid left in the cup.

There is no sputtering with electronic nebulizers. Instead, the absence of any mist and an empty medication cup will be your signal that the aerosol treatment is finished. With some electronic devices, a buzzer sounds to signal the end of treatment.

4

Aerosol Drug Delivery Devices: Inhalers

What are inhalers?

The term “inhaler” describes self-contained devices that are used to generate aerosolized drug for a single inhalation or breath. There are 2 general types of inhalers — pressurized metered-dose inhalers (pMDIs) and dry-powder inhalers (DPIs). Both types of inhalers are very convenient and may be carried around in your purse or pocket and used anywhere.

There are a large variety of inhaler designs. Several types of inhalers may be prescribed for you, with each having different operating instructions. Confusion about what each of them does and how to use them correctly can result in a less effective dose. So we will discuss the different types and address these possible problems. You should also consult your health care provider as well as the manufacturer’s instructional materials.

What common inhalers are available in the United States?

Currently available inhalers are illustrated in Figure 4. The list of aerosol drugs is similar to that provided in previous chapters of this Guide and are as follows: anticholinergics, beta-2 agonists (we call these 2 groups SABAs and LABAs), anticholinergic/beta-2 agonist combinations, inhaled corticosteroids, beta-2 agonist/inhaled corticosteroid combinations, and other drugs. You should always use your device and drug as prescribed by your doctor. Remember that each drug has a different action, and any adverse (bad) effect should be brought to the attention of your doctor or health care provider.

Anticholinergics

Spiriva®
Handihaler®
(tiotropium bromide)
Inhalation Powder
Boehringer Ingelheim
Pharmaceuticals, Inc.



Atrovent® HFA
(ipratropium bromide HFA)
Inhalation Aerosol
Boehringer Ingelheim
Pharmaceuticals, Inc.



Tudorza™
Pressair™
(aclidinium bromide)
Inhalation Powder
Forest Pharmaceuticals, Inc.



Anticholinergics/ β₂-Agonist Combination

Combivent®
Respimat
(ipratropium bromide and albuterol sulfate)
Inhalation Aerosol
Boehringer Ingelheim
Pharmaceuticals, Inc.



β₂-Agonists

Foradil® Aerolizer®
(Formoterol fumarate)
Inhalation Powder
Novartis Pharmaceuticals



Maxair™ Autohaler™
(pirbuterol acetate)
Inhalation Aerosol
Graceway Pharmaceuticals



ProAir® HFA
(albuterol sulfate)
Inhalation Aerosol
Teva Specialty
Pharmaceuticals



Proventil® HFA
(albuterol sulfate)
Inhalation Aerosol
3M Pharmaceuticals Inc.



Arcapta™ Neohaler™
(indacaterol)
Inhalation Powder
Novartis Pharmaceuticals



Xopenex® HFA
(levalbuterol tartare)
Inhalation Aerosol
Sepracor Inc.



Ventolin® HFA
(albuterol sulfate HFA)
Inhalation Aerosol
GlaxoSmithKline



Corticosteroids

Alvesco®
(ciclesonide)
Inhalation Aerosol
Nycomed



Asmanex
Twisthaler®
(mometasone)
Inhalation Powder
Schering Corporation



Flovent® Diskus®
(fluticasone propionate)
Inhalation Powder
GlaxoSmithKline



Flovent® HFA
(fluticasone propionate)
Inhalation Aerosol
GlaxoSmithKline



Pulmicort®
Flexhaler®
(budesonide)
Inhalation Powder
AstraZeneca LP



QVAR®
(beclomethasone dipropionate)
Inhalation Aerosol
Teva Specialty Pharmaceuticals



β₂-Agonist/Corticosteroid Combination

Advair Diskus®
(fluticasone propionate and salmeterol)
Inhalation Powder
GlaxoSmithKline



Advair® HFA
(fluticasone propionate and salmeterol xinafoate)
Inhalation Aerosol
GlaxoSmithKline



Dulera®
(mometasone furoate/formoterol fumarate dihydrate)
Inhalation Aerosol
Merck



Symbicort®
(budesonide and formoterol fumarate dihydrate)
Inhalation Aerosol
AstraZeneca



Other

Relenza®
(zanamivir)
Inhalation Powder
GlaxoSmithKline



Dulera®
(mometasone furoate/formoterol fumarate dihydrate)
Inhalation Aerosol
Merck



Symbicort®
(budesonide and formoterol fumarate dihydrate)
Inhalation Aerosol
AstraZeneca



TOBI Podhaler
(tobramycin)
Inhalation Powder
Novartis Pharmaceuticals



Figure 4. Common inhalers available in the United States

5

Aerosol Drug Delivery Devices: Pressurized Metered-Dose Inhalers

What are pMDIs?

The first pressurized metered-dose inhaler (pMDI) was developed in 1955 by Dr. George Maison. He came up with the idea for the device as a result of a request by his teenage asthmatic daughter for a better way to take her breathing treatment.

A pMDI is designed to deliver a precise (metered) amount (dose) of medication in a fine mist (an aerosol) that can be inhaled directly into the lungs (airways) for treatment of a respiratory disease, such as asthma or COPD.

How do pMDIs work?

The pMDI is now considered one of the most popular ways to deliver aerosol medication. Regardless of manufacturer or the medication included, the basic components of the pMDI include the canister, drug/propellant, metering valve, actuator (or boot), and sometimes a dose counter.

Figure 5 is an illustration of a pMDI with each component labeled and the medication spraying from the boot. Table 3 provides an explanation of each part of a pMDI.

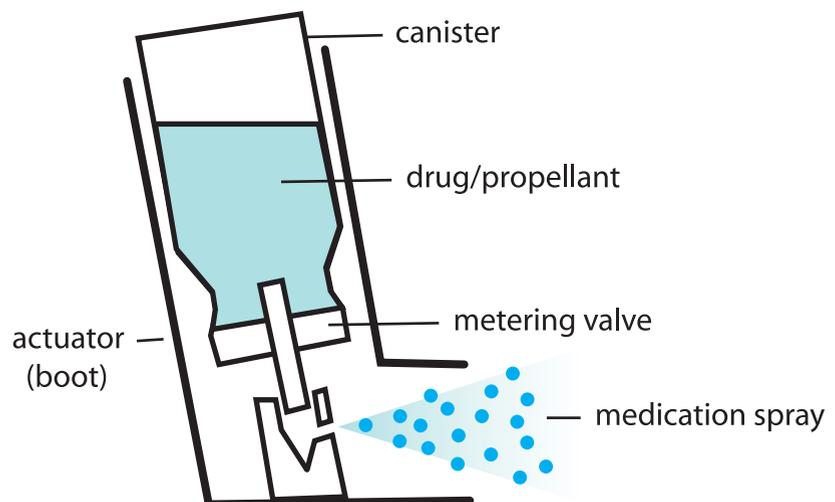


Figure 5. Standard components of pMDIs

Table 3. The basic components of the pMDI

COMPONENT	EXPLANATION
Canister	A metal container, able to withstand high internal pressures.
Propellant	Liquefied compressed gas in which the drug is dissolved or suspended.
Drug	Particulate suspensions or solutions, in the presence of surfactants or alcohol, that allocate the drug dose and the specific particle size.
Metering Valve	Most critical component that is crimped onto the canister and is responsible for metering a reproducible volume or dose.
Actuator	Frequently referred to as the “boot,” partially responsible for particle size based on the length and diameter of the nozzle for the various pMDIs. Each boot is unique to a specific pMDI/drug.

The medication is released from the pMDI by pressing the canister into the boot. This is called *actuation*. Note in the illustration that the canister is in the boot upside down so that the valve sits inside the nozzle.

When the canister valve is pressed into the nozzle, the pressurized propellant forces a dose of the medication through the nozzle. The liquid medication is immediately turned into an aerosol, which you inhale into your airways. The same amount of medication is released with each actuation.

The most important step when using a pMDI is to know when to inhale. For best effect, you need to inhale the medication from the pMDI as soon as it is released from the nozzle. Otherwise, the dose will evaporate into the air and be lost. This means that you must place the pMDI into your mouth and coordinate your inhalation with actuation. For those too young or too old to coordinate breathing and actuation, there are other devices that can help. We will discuss these later in this section.

As noted previously, a newer delivery device called a *Respimat* is also available to deliver your medication. While this device also uses pressure to deliver the medication, there are a few differences between this and the pMDIs previously discussed. The major difference is the use of a spring instead of a propellant to push the medication out of the device and into

your airways. An illustration and simplified explanation follows.

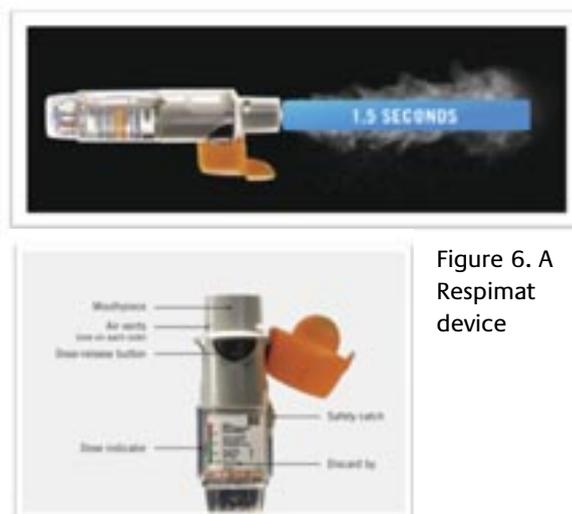
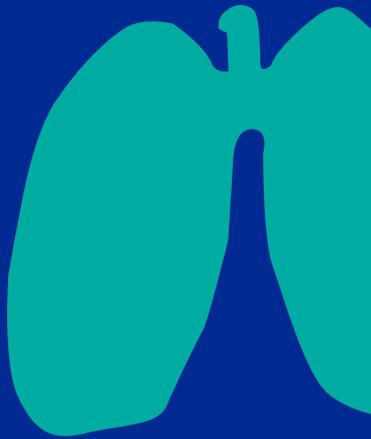


Figure 6. A Respimat device

The components are similar to the basic components of the pMDI, with the cartridge serving in place of the canister and the upper housing and transparent (clear) base substituting for the actuator (boot). A dose-release button is located on the side of the device and is pushed instead of depressing the canister into the actuator. The spring is housed in the cartridge within the transparent container. When the dose button is depressed, a dose of medication is released. A more detailed explanation of how it is used will be addressed later in this section.



What are the advantages and disadvantages of pMDIs?

Pressurized metered-dose inhalers have many advantages. But, like anything else, there are a few disadvantages as well. Perhaps the greatest advantage is their small size, ease of use, portability, and ability to provide multiple doses. They can very easily fit into your purse or pocket and can be pulled out and used very quickly wherever you happen to be.

There is also no need to mix, handle, or prepare any medications. It is not necessary to handle any nebulizer parts. Also, because pMDIs are self-contained, there is minimal to no fear of contamination.

However, pMDIs do require some coordination when pressing down (actuating) the canister and controlling and synchronizing your breathing. Coordinating the activation, inhaling properly, and holding your breath all at the same time can be tricky. In fact, the Respimat pMDI was developed to address the propellant problem and uses a spring-mechanism to deliver the medication and thus avoid the propellant problem. And, finally, there can be a significant loss of medication to the mouth and back of the throat, and it is difficult to determine how many doses are left in the device if it does not have a built-in dose counter. Table 4 lists the advantages and disadvantages of the pMDI.

Table 4. Advantages and disadvantages of the pMDI



ADVANTAGES

- Portable, light, and compact
- Multiple dose convenience
- Short treatment time
- Reproducible doses
- No drug preparation required
- Difficult to contaminate



DISADVANTAGES

- Hand-breath coordination is required.
- Patient activation, proper inhalation pattern, and breath-hold are required.
- Fixed drug concentrations and doses.
- Foreign body aspiration from debris-filled mouthpiece.
- High deposit of medicine in mouth and back of throat (oropharyngeal area) instead of the lungs.
- Difficult to determine the dose remaining in the canister without a dose counter.

What factors affect pMDI performance and drug delivery?

When you depress (activate) your pMDI, you receive a dose of medication. But remember that only about 10–15% of the total dose is delivered to your airway when done with perfect technique. Thus, you can see that using your device properly is extremely important. So you need to know what factors can further affect performance and delivery of your medication. What follows is a list and explanation of these factors.

Storage Temperature: For best results, pMDIs should be stored at or near room temperature. If a pMDI is left in a cold car overnight, it might not work until it returns to room temperature.

Shaking the Canister: If your pMDI is left sitting for an extended period of time between uses, the medication and the propellant can separate. So you will need to shake the canister before you use the pMDI. Not shaking the pMDI canister before use can reduce the delivered dose of medication by as much as 25%.

Nozzle Size and Cleanliness: The amount of medication delivered to you is dependent upon nozzle size, cleanliness, and the lack of moisture. The actuator nozzle is specific for your pMDI — meaning you should not mismatch one actuator with another. The nozzle size determines both the inhaled dose and size of the particle. If you notice any buildup on the nozzle

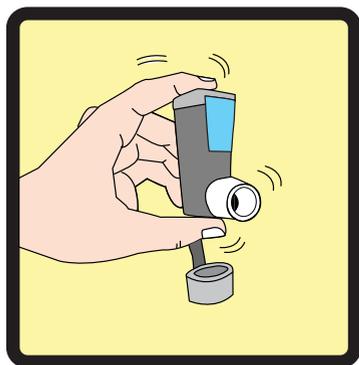
(such as a white and crusty residue), you should clean the device, which we will discuss in Chapter 8.

Timing of Actuation Intervals: When you take your treatment, you should allow for a pause between each puff from the inhaler. It is recommended that you wait approximately 30-60 seconds between each puff as this may improve the action of the drug.

Priming: You will recall that whenever you use a pMDI, you should begin by shaking the canister. This is done to mix the propellant and the medication. But what about the dose that is already sitting in the metering chamber and is about to be inhaled into the airway with the next actuation?

This dose may not be mixed, and the drug may have separated from the propellant. This uncertain dose should be released into the air. This is called *priming*. So, pMDIs that are brand new or have not been used for an extended period of time should be primed. Simply shake the pMDI and prime the canister (squirt that first dose into the air). Also, be certain to follow the manufacturer's recommendations for priming.

Table 5 provides the recommended guidelines for priming the various pMDIs available on the market.



Shake



Prime



Depress and Inhale

Table 5: Priming requirements for commercially available pMDIs

GENERIC NAME	BRAND NAME	TIME TO PRIME	# SPRAYS
Short-Acting Bronchodilators			
Albuterol Sulfate HFA	ProAir HFA	New & when not used for 2 weeks	3
	Proventil HFA	New & when not used for 2 weeks	4
	Ventolin HFA	New & when not used for 14 days	4
Pirbuterol	Maxair Autohaler	New & when not used for 2 days	2
Levalbuterol HCl	Xopenex HFA	New & when not used for 3 days	4
Ipratropium Bromide HFA	Atrovent HFA	New & when not used for 3 days	2
Ipratropium Bromide/ Albuterol Sulfate Combination	Combivent HFA	New & when not used for 24 hours	3
	Combivent Respimat	New & when not used in 3 days	1-4
Inhaled Corticosteroids			
Beclomethasone Propionate HFA	QVAR	New & when not used for 10 days	2
Ciclesonide	Alvesco	New & when not used for 10 days	3
Flunisolide Hemihydrate	Aerospan™ HFA	New & when not used for 2 weeks	2
Fluticasone Propionate	Flovent HFA	New	4
		Not used more than 7 days or if dropped	1
Combination Drugs			
Budesonide in combination with Formoterol	Symbicort HFA	New & not used more than 7 days or if dropped	2
Fluticasone in combination with Salmeterol		New	4
		Not used more than 4 weeks or if dropped	2
Mometasone & Formoterol	Dulera	New & not used more than 5 days	4

Characteristics of the Patient: The amount of aerosol medication delivered to the airways will vary from patient to patient. Infants and children will receive less medication, which is due primarily to the smaller size of their airways and faster breathing rates. There is also the issue of infants and small children not being cooperative (see chapter 7).

Breathing Techniques: When you use your pMDI, you should only use what is called the “closed mouth technique.” This breathing technique is now recommended when using a pMDI

with the newer HFA propellant. With the closed mouth technique, (1) the mouthpiece of the boot is placed between your lips, and (2) while taking in a deep breath, the canister is depressed (actuated) to release the medication directly into your mouth and the airways.

All of the steps for using the closed-mouth technique are covered in the next section of the Guide and is labeled Technique Box 2. The Respimat delivery device is slightly different and it, too, will be addressed in the Technique Box that follows.

How do I use my pMDIs?

Technique Box 2

Steps for Correct Use of Pressurized Metered-dose Inhalers

Technique for pMDIs

When using the closed-mouth technique, you should:

1. Wash and dry your hands thoroughly.
2. If necessary, warm the pMDI canister in your hand.
3. Remove the mouthpiece cover and make sure there aren't any loose parts inside the mouthpiece.
4. Shake the pMDI several times.
5. Prime the pMDI into the air if it is new or has not been used for several days.
6. Sit up straight or stand up.
7. Exhale fully and hold the pMDI so the mouthpiece is at the bottom and the canister is sticking out of the top of the pMDI.
8. Place the pMDI between your lips. Make sure that your tongue is flat under the mouthpiece and does not block the pMDI.
9. Seal your lips.
10. Actuate the pMDI as you begin to slowly take in a breath.
11. Hold your breath for 10 seconds. If you cannot hold your breath for 10 seconds, then for as long as possible.
12. Wait 30–60 seconds if another dose of medicine is needed.
13. Repeat steps 2–11 until the dosage prescribed by your doctor is reached.
14. If taking an inhaled corticosteroid, rinse your mouth after the last puff of medicine and spit the water out — do not swallow.
15. Replace the mouthpiece cover on the pMDI after each use.

Technique Box 2 (continued)

Steps for Correct Use of Respimat Pressurized Metered-dose Inhalers

Technique for Respimat pMDIs

When using the Combivent Respimat, you should:

1. Wash and dry your hands thoroughly.
2. With the orange cap closed, press the safety catch while pulling off the base. (Be careful not to touch the piercing element located at the bottom of the clear base.)
3. Write the discard by date on the label of the inhaler. (The discard by date is 3 months from the date the cartridge is inserted.)
4. Take the cartridge out of the box. Push the narrow end of the cartridge into the inhaler. The base of the cartridge will not sit flush with the inhaler. About 1/8 of an inch will remain visible when the cartridge is correctly inserted.
5. Put the clear base back into place.
6. Hold the inhaler upright with the orange cap closed to avoid accidental release of dose.
7. Turn the clear base in the direction of the white arrows on the label until it clicks (half a turn).
8. Flip the orange cap until it snaps fully open.
9. Shake the pMDI several times.
10. Prime the pMDI by pointing the inhaler toward the ground. Press the release button. Close the orange cap. Repeat the process until a spray is visible.
11. Sit up straight or stand up.
12. Exhale fully and hold the pMDI so the mouthpiece is horizontal to the ground.
13. Place the pMDI between your lips and point your inhaler to the back of your throat.
14. Make sure that your tongue is flat under the mouthpiece and does not block the pMDI.
15. Seal your lips.
16. While taking in a slow breath through your mouth, depress the dose-release button and continue to breathe in slowly as long as you can.
17. Hold your breath for 10 seconds or for as long as comfortable.
18. Wait 30–60 seconds if another dose of medicine is needed.
19. Rinse your mouth after the last puff of medicine and spit the water out — do not swallow.
20. Replace the mouthpiece cover on the pMDI after each use.

What are common problems and solutions to the use of my pressurized metered-dose inhaler?

Occasionally you may experience a problem when using your pMDI. The most common problem is low aerosol output or no mist following actuation. Below is a troubleshooting chart that will help you identify the cause as well as the solution of several problems. You should also follow the instructions provided in the manufacturer's literature as well as consult with your respiratory therapist or health care provider.

Troubleshooting

Problems with the pMDI: Absent or Low Aerosol Output

CAUSES	SOLUTIONS
Incorrect pMDI assembly	Assure that the canister/cartridge is correctly seated in the actuator.
Incorrect pMDI & spacer assembly	Assure that the pMDI mouthpiece is properly attached to the spacer inlet.
pMDI is empty	Check the dose counter or daily log sheet to make sure there is enough medicine in the canister/cartridge. Otherwise, replace the pMDI.

How do I know my pMDI is empty?

When pMDIs were first released onto the market, there was no way to know how many puffs of medication were left in the canister. Many people thought that as long as they heard or felt something inside the canister when it was shaken, then there was medication left.

However, there is not an exact 1-to-1 ratio of medication to propellant. There is always slightly more propellant than medication. So even if you still feel/hear something inside the canister when shaken, it may only be propellant.

So, the only reliable method to determine the number of doses remaining in a pMDI is to manually count and record in a log every individual puff (actuation) given, including both priming and therapy doses. This tally is then subtracted from the total number of puffs (actuators) listed on the product label until all have been used.

For example, if a new pMDI has 200 actuations when full, the canister would need to be replaced when the total number of actuations (including priming) start to reach 200. At that time the pMDI should be properly disposed of. Unfortunately, the manual counting of doses may not be practical and/or dependable, especially if you are using your medication as a quick reliever and are always on the go.

Fortunately, the U.S. Food and Drug Administration (FDA) now requires all new pMDIs to have dose counters built into the boot. The dose counter is set to the total number of actuations. With each actuation, the number is decreased until no more doses are left. Figure 7 shows what these pMDI boots look like.



Figure 7. Examples of built-in dose counters

The FDA also now recommends that all pMDIs not having a dose counter be used with an external dose-counting device. There are 2 types of external dose counters. In one type, the canister of the pMDI is inserted into a new boot that has the dose counter built-in. The other type fits over the end of the canister. Both types record each actuation. Figure 8 shows an example of each type of external dose counter.



Figure 8. Examples of external dose counters for a pMDI

You should be sure that if you use an external dose counter that it can be used and will work effectively with your particular pMDI. Improper attachment or a poor fit with the canister can result in improper actuation. This could lead to little or no medication being released, as well as an incorrect count of remaining doses.

Obtaining an external dose counter will be an added expense. But it is a one-time investment and has some great benefits. With any external dose counter, you must follow the guidelines and instructions provided in the manufacturer's literature.

When attempting to keep track of the number of puffs remaining in the pMDI, the following steps should be taken daily.

Without Dose Counter:

1. Check the product label or literature and determine the number of puffs that the pMDI has when it is full.
2. When using medications on a daily basis, calculate how long the pMDI will last by dividing the total number of puffs in the pMDI by the total puffs used per day. For example, if used twice a day with 2 puffs per treatment and primed with each use, this would calculate to a total of 6 puffs per day. If you divide this by the number of puffs available (200 divided by 6), the canister will last 33 days. Also, you must remember that the medication will run out sooner if the pMDI is used more often than planned.
3. Identify the date that the medication will run out and mark it on the canister or on the calendar.
4. Keep track of how many puffs of medicine are administered on a daily log sheet and subtract them to determine the amount of medication left in the pMDI.
5. Keep the daily log sheet in a convenient place.
6. Replace the pMDI when all of the puffs have been administered.

With Dose Counter:

1. Check the product label or literature and determine the number of puffs that the pMDI has when it is full.
2. Track the pMDI puffs (actuations) used and determine the amount of medication left in the pMDI by checking the counter display.
3. Learn to read the counter display. Each dose counter has a specific way of displaying doses that remain in the canister. For example, some devices will turn red as an indication that the number of puffs (actuations) is less than 20 puffs and it is time to replace the pMDI. Again, be certain to read the manufacturer's guidelines to interpret the counter display and to follow the recommendations before its use.
4. Recognize that when the last dose is given (dispensed), the pMDI should be properly disposed of.

What are spacers and valved holding chambers?

Spacers and valved holding chambers are devices used to overcome many of the difficulties in using a pMDI alone. These devices come in different forms and sizes.

A spacer is a plastic or metal tube that adds space (and volume) between the pMDI and your mouth. The pMDI is actuated (squirted) directly into the spacer where the aerosol mist (plume) is temporarily held. A spacer gives the speed of the aerosol (plume) time to slow down before it is inhaled.

Spacers will also reduce the amount of aerosol particles that are deposited into the mouth and throat. Spacers can also help with the hand-breath coordination problem since the metered medication is inhaled from the spacer within 1–2 seconds following actuation of the pMDI.

Sometimes clinicians or patients construct homemade spacers from plastic containers (e.g., soda bottle) or cardboard tubes (e.g., empty toilet paper roll). Depending on how well a pMDI fits into a homemade spacer, these may work for a little while. However, their performance is variable and hence should not be considered as a suitable replacement for a true medical spacer.

A valved holding chamber is actually a spacer with a built-in one-way valve to help contain the aerosol until it is inhaled. However, you need to inhale as closely to the depression of the actuator as possible as time delays longer than 2–3 seconds can significantly alter the amount of medication delivered.

Some valved holding chambers also have an audible signal to alert you that you are inhaling too quickly. If you do hear the signal, then you are inhaling too fast and need to slow down your breath into your lungs. Remember, pMDIs work best when you take a **slow, deep** breath.

Children with small lung volumes may need to take several breaths from the valved holding chamber with a face mask to deliver a single pMDI puff (actuation).

Spacers and valved holding chambers can be purchased from a pharmacy or from your home care company. Figure 9 shows one example of the wide variety of spacers and valved holding chambers that are available.



Figure 9. Example of a pMDI attached to a valved holding chamber

Why would I use a spacer and/or holding chamber?

The use of an accessory device (a spacer or holding chamber) with a pMDI improves the effectiveness of aerosol therapy and reduces the amount of aerosol deposited into the nose and back of the throat (what is called oropharyngeal deposition). It does this by adding volume and space between the meter-

ing valve and the patient's mouth. Additionally, a spacer or holding chamber will help overcome problems with hand-breath coordination. Table 6 lists both advantages and disadvantages seen with spacers and valved holding chambers used with pMDIs.

Table 6. Advantages and disadvantages of the holding chambers or spacers ("add-on" devices) used with pMDIs



ADVANTAGES

- Reduces mouth/throat drug impaction and loss.
- Increases inhaled drug by 2–4 times than the pMDI alone.
- Allows use of pMDI when the patient is short of breath.
- No drug preparation required.
- Simplifies coordination of pMDI actuation and inhalation.



DISADVANTAGES

- Large and cumbersome compared to the pMDI alone.
- More expensive and bulky than a pMDI alone.
- Some assembly may be needed.
- Patient errors in firing multiple puffs into chamber prior to inhaling or delay between actuation and inhalation.
- Possible contamination with inadequate cleaning.

How do I use a spacer and/or valved holding chamber?

As noted in Table 6, spacers and valved holding chambers provide many benefits for optimal drug delivery when using a pMDI. However, one of the major problems with the use of these devices is improper technique. Improper technique may decrease drug delivery or, in some cases, cause the dose to be lost completely.

As mentioned, small children pose some unique and special prob-

lems when administering an aerosol treatment with a pMDI. These include: improperly fitted mask, too large a spacer volume, and children or infants who are crying. It is important to stress the importance of proper technique, and Technique Box 3 provides the proper steps to follow in using a spacer and holding chamber with a mouthpiece or mask.

Technique Box 3

Steps for Correct Use of pMDI with Spacer/Valved Holding Chamber

Technique for pMDIs with spacer/valved holding chamber

When using a spacer or valved holding chamber, you should:

1. Wash and dry your hands thoroughly.
2. Warm the pMDI canister to hand or body temperature.
3. Remove the mouthpiece cover and make sure there aren't any loose parts inside the mouthpiece.
4. Shake the pMDI several times.
5. Prime the pMDI into the air if it is new or has not been used for several days.
6. Attach the pMDI to the spacer/valved holding chamber.
7. Keep the canister in an upright position.
8. Sit up straight or stand up.
9. Exhale fully.
10. Follow the instructions below based on the type of device interface being used:

With the mouthpiece:

- Place the mouthpiece of the spacer between your lips. Make sure that your tongue is flat under the mouthpiece and does not block the pMDI, and seal your lips around the mouthpiece.
- Actuate the pMDI as you begin to breathe in slowly. If the device produces a “whistle,” this indicates that you are breathing in too rapid. (Some devices use a “whistling” sound to indicate excessively high inhalation, so hearing this “whistling” noise is a sign for you to inhale more slowly.)
- Move the mouthpiece away from your mouth and hold your breath for 10 seconds or for as long as you are comfortable.

With the mask

(used primarily for infants, children, or those unable to use the mouthpiece):

- Place the mask completely over the nose and mouth and make sure it fits firmly against the face.
 - Hold the mask in place and actuate the pMDI as the child begins to inhale slowly. If the device produces a “whistling” sound, be aware that the child is breathing in too rapidly.
 - Hold the mask in place while the child takes 6 normal breaths (including inhalation and exhalation) and remove the mask from the child's face.
11. Wait 30–60 seconds if another puff of medicine is needed.
 12. Repeat steps above until the dosage prescribed by your doctor is reached.
 13. If taking a corticosteroid, you should rinse the mouth after the last puff of medicine and spit the water out. Do not swallow it.
 14. Replace the mouthpiece cover on the pMDI after each use.

General Steps to Avoid Reduced or No Dosing for pMDIs with Spacer/VHC

When using pMDIs with a spacer or valved holding chamber, the following steps should be taken to avoid reduced or no dosing during the aerosol treatment. You should:

1. Assure proper fit of the pMDI to the spacer or valved holding chamber.
2. Remove cap from the pMDI boot.
3. After use, clean and reassemble the pMDI spacers and valved holding chamber according to manufacturers' instructions.

6

Aerosol Drug Delivery Devices: Dry-Powder Inhalers

What are DPIs?

A dry-powder inhaler (DPI) is another type of portable device that can be used to deliver aerosol medications to the lungs. DPIs are a little different from small-volume nebulizers (SVNs) and pressurized metered-dose inhalers (pMDIs). DPIs deliver the medication to the lungs as a very fine powder.

Also, DPIs are breath actuated. This means that DPIs **do not** contain propellant (the stuff in the pMDI that produces the force to change liquid medication into an aerosol). Instead, the fine powder is drawn from the DPI when you take a fast, deep breath through the DPI. This is a very important distinction from the two previously mentioned devices. So, it is *the patient* using the DPI who provides the force to get the medication out of the device and into his/her airways.

What are the different types of DPIs?

Currently, there are 3 types of dry-powder inhalers: single-dose DPIs, multiple unit-dose DPIs, and multiple dose DPIs. We will discuss each individually, but you should know that they all have the same essential components within the inhaler.

Single-Dose DPIs: There are different types of single-dose dry-powder inhalers, but the way they all work is pretty much the same. You place a capsule containing the powdered medication into the drug holder. Next, the drug capsule is pierced so that when air is drawn into and through the device, the powdered drug becomes part of the airflow and is carried into the lungs. While this is fairly simple, the primary disadvantage of single-dose DPIs is the time needed to load a dose for each use. Examples of drugs using this type of DPI include formoterol (Foradil[®]) and tiotropium (Spiriva[®]).

Multiple Unit-Dose DPIs: The multiple unit-dose DPI holds a number of doses (called blisters) of medication on a rotating wheel. Each blister of powdered medication is punctured when a cover is lifted. This allows the powdered medication to be inhaled through the mouth. These devices require a relatively high inspiratory flow (meaning a quick breath) for an adequate amount of drug to be delivered to the lungs. An example of a drug using this type of DPI is the anti-flu drug zanamivir (Relenza[®]).

Multiple-Dose DPIs: The multiple-dose DPI either takes a measured dose from a reservoir of powdered medication or it provides several individual doses on a blister strip. There are multiple examples of these devices — each having unique features, designs, and doses. You should read and follow the instructions on the manufacturer's label. Drugs using this type of DPI include fluticasone plus salmeterol (Advair[®]), mometasone (Asthmanex[®]), and fluticasone (Flovent[®]).

Figure 10 provides examples of some of the currently available dry-powder inhalation drugs.



Figure 10. Currently available dry-powder aerosol formulations in the U.S. categorized by design features

How do DPIs work?

DPIs were developed to overcome the difficulties of using metered-dose inhalers, specifically the problem of poor coordination of actuation and inhaling. While there are several types of DPIs available, they all have the same basic components. These components consist of: an air inlet, a drug chamber for the medication, a pathway to separate smaller particles from larger ones, and a mouthpiece. Figure 11 diagrams the function of a DPI.

With a DPI, the powdered medication is contained in a small capsule that is contained in a medication chamber. The capsule is then punctured to allow the fine powder to be

released. When you take in a quick deep breath through the mouthpiece of the DPI, the fine powdered medication is separated from the larger carrier particles and drawn into the lungs.

DPIs do not have the problem of coordinating actuation with inhalation. However, in order to work properly, a DPI does require you to breathe a certain way. The proper way is to take in a quick, fast breath through the mouthpiece. If the breath is not fast or strong enough, the fine powdered medication will not be separated from the larger carrier particles and will stay inside the DPI.

For example, note the drawing of a DPI’s function in Figure 11. It shows on the left side that the smaller drug particles are attached to larger particles of lactose (the lactose is there to simply help carry the drug). As the combined particles are pulled through the screen mesh, the smaller drug particles are separated from the larger lactose particles. This process is called *deaggregation*. If the inhaled breath is not strong enough, the fine medication particles are not separated from the larger carrier particles. This results in poor or no drug delivery. So, the breathing technique you use for a DPI is very important.

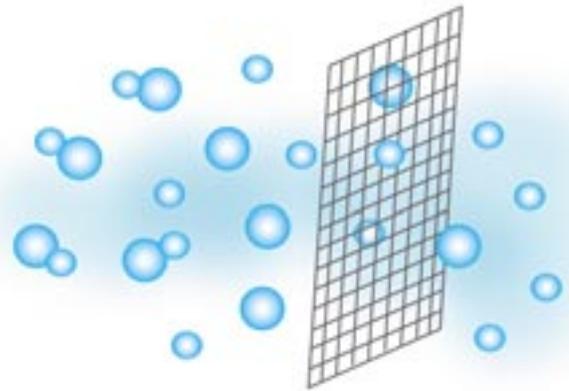


Figure 11. Diagram of a DPI’s function

What are the advantages and disadvantages of DPIs?

Much like all aerosol devices, dry-powder inhalers have both advantages and disadvantages. Because they do not use a propellant (as does the pMDI), they do not require hand-breath coordination. What ultimately delivers the medication to your lungs is your own inspiratory effort. So you need to have a strong enough breath to inhale the powdered drug from the device.

This is a very important point — you bring medication from a DPI into your airways by tak-

ing in a quick, deep breath from the DPI. It is also very important that you do not exhale into any DPI. This will result in moisture getting into the device. Moisture will make the powdered medication clump like wet flour and will limit its effectiveness.

Table 7 below lists the advantages and disadvantages of dry-powder inhalers. You should discuss these with your respiratory therapist or clinician at the time the DPI is prescribed.

Table 7. Advantages and disadvantages of DPIs



ADVANTAGES

- Small and portable
- Built-in dose counter
- Propellant free
- Breath actuated
- Short preparation and administration time



DISADVANTAGES

- Dependence on patient’s inspiratory flow.
- Patient may be less aware of delivered dose.
- Vulnerable to room humidity or exhaled humidity into mouthpiece.
- Limited range of drugs.
- Different DPIs with different drugs.
- Easy for patient to confuse “Directions for Use” with other devices.

How do I use my DPI?

Each DPI device has a different level of built-in resistance to a patient's ability to inhale. This means that for each DPI you have to inhale at a different speed or rate to draw in the correct amount of drug to your lungs. Therefore, very young children, the elderly, and patients with severe airflow obstruction may not be able to generate adequate air flow when using a certain DPI. A respiratory therapist can easily determine if you can use a certain type of DPI.

Since they all use dry powder, all DPIs are adversely affected by humidity and moisture. Moisture causes clumping of the powder. It also reduces the separation of smaller powdered particles from larger ones. All DPIs need to be kept dry. DPIs should not be stored in bathrooms, shower areas, and areas with little or no air conditioning. This also means you should **never** exhale into any DPI. Be certain to exhale away from the DPI prior to taking your deep breath from the DPI. After you take in your deep breath, remove the DPI from your mouth and slowly exhale away from the DPI. NEVER breathe into the DPI device.

Because of the many differences in the design and operation of DPIs, the correct technique for best lung deposition varies. You should therefore carefully review the device instructions (manufacturer's product literature) of each DPI. You can also speak with a respiratory therapist prior to using your dry-powder inhaler.

Technique Box 4 contains the steps for correctly using the most popular DPIs.

Technique Box 4

Steps for Correct Use of Each Model of Dry-Powder Inhalers

Technique for using the Foradil Aerolizer single-dose dry-powder inhaler



1. Wash and dry your hands thoroughly.
2. Remove the mouthpiece cover from the Aerolizer.
3. Hold the base of the Aerolizer and twist the mouthpiece counterclockwise.
4. Remove capsule from foil blister immediately before use.
5. Place the capsule in the chamber in the base of the Aerolizer.
6. Hold the base of the Aerolizer and turn it clockwise to close it.
7. Simultaneously press both buttons in order to pierce the capsule.
8. Keep your head in an upright position.
9. Hold the Aerolizer in a lateral position (parallel to the floor), with the buttons on the left and right.
10. Exhale away from the Aerolizer.
11. Place the mouthpiece into your mouth and close lips tightly around the mouthpiece.
12. Breathe in quickly and as deeply as possible.
13. Remove the mouthpiece from your mouth and hold your breath for 10 seconds (or as long as comfortable).
14. Exhale slowly away from the Aerolizer.
15. Open the chamber and examine the capsule. If there is powder remaining, repeat the inhalation process.
16. After use, remove and discard the capsule. Do not store the capsule in the Aerolizer.
17. Close the mouthpiece and replace the cover.
18. Store the Aerolizer device in a cool, dry place.

Technique Box 4 (continued)

Technique for using the Spiriva HandiHaler single-dose dry-powder inhaler

1. Wash and dry your hands thoroughly.
2. Peel back the aluminum foil and remove a capsule immediately before using the HandiHaler.
3. Open the dust cap by pulling it upward.
4. Open the mouthpiece.
5. Place the capsule into the center chamber (it does not matter which end is placed in the chamber).
6. Close the mouthpiece firmly until you hear a click (leave the dust cap open).
7. Hold the HandiHaler with the mouthpiece up.
8. Press the piercing button once and release. (This makes holes in the capsule and allows the medication to be released when you breathe in).
9. Keep head in an upright position.
10. Exhale away from the HandiHaler.
11. Place the mouthpiece between your lips and close tightly around the mouthpiece.
12. Breathe in at a rate sufficient to hear the capsule vibrate, until the lungs are full.
13. Remove the mouthpiece from your mouth and hold breath for 10 seconds or as long as comfortable.
14. Exhale slowly away from the HandiHaler.
15. Repeat the inhalation from the HandiHaler.
16. Open the mouthpiece, remove the used capsule and dispose of it. (Do not store capsules in the HandiHaler).
17. Close the mouthpiece and dust cap for storage of the HandiHaler.
18. Store the HandiHaler in a cool, dry place.



Technique for using the Diskhaler multiple unit-dose dry-powder inhaler

1. Wash and dry your hands thoroughly.
2. Remove the cover and check that the device and mouthpiece are clean.
3. Extend tray and push ridges to remove tray.
4. Load medication disk on the rotating wheel.
5. Pull the cartridge all the way out and then push it all the way in until the medication disk is seen in the dose indicator. (This will be the first dose you will receive).
6. Keep the device flat and lift the back of the lid until it is lifted all the way up to pierce the medication blister.
7. Click back into place.
8. Exhale away from the Diskhaler.
9. Place the mouthpiece between your lips, making sure the air hole on the mouthpiece is not covered.
10. Inhale as quickly and deeply as possible.
11. Move the Diskhaler away from the mouth and hold breath for 10 seconds or as long as comfortable.
12. Exhale slowly away from the Diskhaler.
13. If another dose is needed, pull the cartridge out all the way and then push it back in all the way in order to move the next blister into place. (Then repeat Steps 4–12.)
14. Place the mouthpiece cover back on after the treatment. (Make sure the blisters remain sealed until inspiration in order to protect them from humidity and loss).
15. Store the Diskhaler in a cool, dry place.



Steps for Correct Use of Each Model of Dry-Powder Inhalers

Technique for using the Advair, Serevent or Flovent Diskus multiple-dose dry-powder inhalers



1. Wash and dry your hands thoroughly.
2. Open the device.
3. Slide the lever from left to right.
4. Exhale away from the Diskus.
5. Place the mouthpiece into your mouth and close your lips tightly around the mouthpiece.
6. Keep the device horizontal while inhaling the dose with a rapid and steady flow.
7. Remove the mouthpiece from your mouth and hold breath for 10 seconds or as long as comfortable.
8. Exhale slowly away from the Diskus.
9. Store the Diskus in a cool dry place.
10. Observe the counter for the number of doses remaining and replace the device when appropriate.
11. After each dose of Flovent or Advair, rinse your mouth with water to reduce the risk of developing a fungal infection. Do not swallow the rinsing water.

Technique for using Asmanex Twisthaler

1. Wash and dry your hands thoroughly.
2. Hold the inhaler straight up with the pink portion (the base) on the bottom.
3. Remove the cap while it is in the upright position to make sure the right dose is dispensed.
4. Hold the pink base and twist the cap in a counter-clockwise direction to remove it.
5. As the cap is lifted off, the dose counter on the base will count down by 1. This action also loads the dose.
6. Make sure the indented arrow located on the white portion (directly above the pink base) is pointing to the dose counter.
7. Exhale away from the Twisthaler.
8. Place the mouthpiece into your mouth with the mouthpiece facing toward you, and close your lips tightly around it.
9. Inhale the dose with a rapid and steady flow while holding the Twisthaler in a lateral position (parallel to the floor).
10. Remove the mouthpiece from your mouth and hold your breath for 5–10 seconds or as long as comfortable.
11. Exhale slowly away from the Twisthaler.
12. Immediately replace the cap, turn in a clockwise direction, and gently press down until you hear a click.
13. Firmly close the Twisthaler to assure that the next dose is properly loaded.
14. Be sure that the arrow is in line with the dose-counter window.
15. Store the Twisthaler in a cool dry place.
16. After each dose, rinse your mouth with water to reduce the risk of developing a fungal infection. Do not swallow the rinsing water.



Technique Box 4 (continued)

Technique for using Pulmicort Flexhaler:

1. Wash and dry your hands thoroughly.
2. Twist the cover and lift it off the Flexhaler.
3. Hold the Flexhaler in the upright position (mouthpiece up) to load a dose.
4. Make sure that the mouthpiece is not held when the dose is being loaded into the Flexhaler.
5. Twist the brown grip fully in one direction as far as it goes. (It does not matter which way you turn it first.)
6. Twist it back in the other direction as far as it will go.
7. Make sure you hear a click sound during each of the twisting movements.
8. Exhale away from the Flexhaler.
9. Place the mouthpiece in your mouth, seal the mouthpiece with your lips, and inhale deeply and forcefully through the Flexhaler.
10. Remove the mouthpiece from your mouth and hold your breath for 5–10 seconds or as long as comfortable.
11. Exhale slowly away from the Flexhaler.
12. If more than 1 dose is required, repeat Steps 2–11 above.
13. Put the cover back on the Flexhaler and twist it shut.
14. Store the Flexhaler in a cool dry place.
15. After each dose, rinse your mouth with water to reduce the risk of developing a fungal infection. Do not swallow the rinsing water.



Technique for using the Tudorza Pressair multi-dose dry-powder inhaler:

1. Wash and dry your hands thoroughly.
2. Remove the protective cap by gently squeezing the marked arrows on each side of the cap and pulling outward.
3. Hold the inhaler with the mouthpiece facing toward you and the green button on top. DO NOT place in your mouth yet.
4. Press the green button all the way down and release it. DO NOT hold the button down.
5. Check the control window on the device (above the mouthpiece) to ensure the color has changed from red to green, indicating the dose and device are ready for use.
6. Exhale away from the device before placing the mouthpiece into your mouth.
7. Place the mouthpiece into your mouth and breathe in quickly and deeply.
8. You will hear a CLICK when the dose is delivered, but continue with your deep breath until your lungs are filled.
9. Remove the device from your mouth and breathe out.
10. Check the control window on the device (above the mouthpiece) to ensure the color has changed from green to red. IF NOT, repeat Step 7.
11. Replace the protective cap on the mouthpiece.



General Steps to Avoid Reduced or No Dosing for DPIs

When using DPIs, the following steps should be taken to avoid reduced or no dosing during your aerosol treatment. You should:

1. Read and follow the instructions for proper assembly.
2. Make sure to keep the DPI clean and dry.
3. Keep the DPI in proper position during the treatment.
4. Be sure to puncture the capsule or blister pack (as directed).
5. Never exhale into a DPI.
6. Make sure to inhale quickly and deep enough to get the medicine into your lungs.
7. Track the doses remaining in the DPI.
8. Do not swallow the capsule; it is not a pill.

What are common problems and solutions to the use of my dry powder inhaler?

The problems associated with dry-powder inhalers are generally related to malfunctioning. Below is a troubleshooting chart that will aid you in identifying the cause as well as the solution to common problems. Additionally, be aware that following the instructions provided in the manufacturer's literature, as well as consulting your respiratory therapist or health care provider, also are important when troubleshooting problems.

Troubleshooting

Problems with Dry-Powder Inhalers: Malfunctioning DPIs

CAUSES	SOLUTIONS
Incorrect DPI assembly	Check the assembly and reassemble when needed.
Failure to discharge medicine	Replace the unit.
Empty DPI	Check the dose counter to make sure it is not empty; otherwise, replace the DPI.

How do I know my dry-powder inhaler is empty?

Single-Dose DPI: Single-dose DPIs use a single capsule for each dose, and only full capsules should be used when each dose is given. If there is powder remaining, the capsule should be returned to the inhaler and inhalation should be repeated. Then the capsule should be disposed after treatment. Prescription renewal should be based on the remaining number of intact capsules.

Multiple Unit-Dose DPI: Because there is not a dose counter on most of these DPIs, doses must be tracked manually. Therefore, visual inspection will confirm the use of all the packets. The disk should be disposed of properly when all the doses have been used.

Multiple-Dose DPIs: Most multiple-dose DPIs come with built-in dose counters that indicate the number of doses remaining in the inhaler. The devices give a particular display when the doses are coming to an end so that a new DPI can be ordered from the pharmacy. The dose counters of selected types of multiple-dose DPIs are explained in Table 8.

Table 8. Explanation of dose counters for selected DPI devices

	Flexhaler	Twisthaler	Diskus
Dose Container	Reservoir	Reservoir	Blister strip
Number of Doses	60 or 120	30	60
Type of Dose Indicator	“0”	“01”	Red numbers
Meaning of Dose Indicator	<p>Although the indicator counts down each time a dose is loaded, it is not likely that you will see the dose indicator move with every dose. You can usually see the indicator move each time you use about 5 doses.</p> <p>The indicator is marked in intervals of 10 doses alternating numbers and dashes. When it is down to “0”, it must be thrown away.</p>	<p>The dose display showing “01” indicates the last dose of medicine is in the Twisthaler and the medicine must be refilled.</p>	<p>The numbers turning red in the dose display indicates that there are 5 doses left.</p> <p>When the dose window shows “0”, there is no medicine left and the diskus should be disposed.</p>

7

Aerosol Drug Delivery Devices: Special Applications

How do I care for infants and small children requiring aerosol drug delivery?

Infants and small children will require the assistance of a parent or other care provider. This section is written to address the needs of parents or other caregivers.

Infants are not simply just smaller versions of adults. They are different in many ways that impact aerosol drug delivery. Thinking ability (understanding how and when to use a device and drug), physical ability (coordination to use that device), and age (airway size, respiratory rate, lung volumes) are substantial challenges for effective aerosol drug delivery. You will need to gain a clear understanding of these challenges and get support and guidance from the respiratory therapist or other health care professional to provide the best aerosol drug therapy for your child. Let's talk a little more about some of these unique challenges and issues related to infants and children.

Age and physical ability

The proper selection of an aerosol delivery device is critical to successful aerosol therapy in infants and small children. It is obvious that the very young will have limitations in terms of using any aerosol therapy device. In fact, experience has shown that children under the age of 3 may not reliably use a mouthpiece. This makes the use of a face mask necessary for both small-volume nebulizers and pressurized metered-dose inhalers (pMDIs).

A small-volume nebulizer with a face mask is the easiest aerosol device to use with infants and small children. If you use a pMDI, an infant-size spacer or valved holding chamber with an infant face mask will be essential.

Dry-powder inhalers (DPIs) are usually not effective in children less than 4 years of age. Even healthy children in this age group cannot take in a breath quickly enough for a DPI to work. Thus, alternative devices used under close supervision by a knowledgeable parent or other caregiver is necessary.



Thinking ability

In addition to age, the choice of aerosol drug device should also be tailored to the infant or small child's thinking ability. Table 9 presents the recommended ages for introducing different types of aerosol generators to children. Of particular note is that small-volume nebulizers and pMDIs with valved holding chambers are recommended for infants and small children up to 5 years of age.

Children up to 3 years of age cannot use a mouthpiece, so both small-volume nebulizers and pMDIs with hold-

ing chambers should be administered with a properly fitting face mask. Face masks should be used until the child is old enough to comfortably and effectively use a mouthpiece.

Additionally, a child younger than 5 years of age may not be able to master specific breathing techniques. It is generally accepted that the thinking ability to control breathing and hand/breath coordination develops by age 5 or 6 years. However, once some children reach age 4 and above, they may have a sufficient understanding of how to use a pMDI or DPI successfully.

Aerosol drug delivery in distressed or crying infants

Inhaled drugs should be given to infants when they are settled and breathing quietly. Crying children receive virtually no aerosol drug to the lungs. Instead, most of the inhaled dose deposits in the nose and back of the throat, which is then swallowed. Therefore, it is essential to keep the infant or child calm and without distress while administering aerosol

drugs. Some approaches or strategies could include playing games, comforting babies, and providing other effective forms of distraction. Also, aerosol drugs can be administered while the infant is asleep as long as administration does not wake up or agitate the infant.

Table 9. Age guidelines for use of aerosol delivery device types

AEROSOL GENERATOR	AGE
Small-volume nebulizer with mask	≤ 3 years
Small-volume nebulizer with mouthpiece	≥ 3 years
pMDI with holding chamber/spacer and mask	< 4 years
pMDI with holding chamber/spacer	≥ 4 years
Dry-powder inhaler (DPI)	≥ 4 years
Metered-dose inhaler (MDI)	≥ 5 years
Breath-actuated MDI (e.g., Autohaler)	≥ 5 years
Breath-actuated nebulizers	≥ 5 years

< = less than; ≤ = equal to or less than; ≥ = equal to or more than

Connecting the small child to an aerosol device

Even infants and small children can make their preferences for specific devices known and this should be considered when selecting a particular device. Using a device that is preferred by the infant or child can increase willingness to take the treatment and achieve the desired clinical response. This includes how the selected aerosol delivery device is applied to the infant/small child.

Mouthpiece or Face Mask? A frequently asked question is whether to use a mouthpiece or face mask. A mouthpiece or face mask is commonly used for aerosol drug delivery in children more than 3 years of age. It should be noted that studies suggest that the mouthpiece provides a greater lung dose than a standard pediatric face mask. Therefore, the use of a mouthpiece is encouraged and preferred. However, a mask that is consistently used is better than a mouthpiece that is not.

Importance of a Close-Fitting Face

Mask: Having a good seal (a close fitting mask to face) is a critical factor in making sure your child gets the medication deposited deep into the lungs. Small leaks around the face mask can result in a decrease in the amount of drug that is inhaled. In some cases this could be as much as 50%.

Initially, a small child may refuse to use a face mask. This is especially so when they feel sick or are irritable. However, the parent or caregiver must

be persistent and offer encouragement. The use of games, play activities, or perhaps having the child participate in holding the mask is another trick. Close supervision, creativity in technique, and strong encouragement are essential to improving the child's tolerance of face masks and to improving aerosol drug delivery.

Face Mask or Blow-by? *Blow-by* is a term used to explain the administration of an aerosol drug where the mist that is coming out of the nebulizer is directed toward the patient's face.

Although blow-by has been frequently used in the past for crying babies or uncooperative children, research has shown that it is a less efficient way to deliver the drug compared with a face mask. The reason for this is that the amount of aerosol drug deposited to the airways will decrease significantly as the distance from the device to the child's face is increased. Therefore, the use of blow-by is now strongly discouraged.

Parent and patient education

As children grow, their aerosol device may need to be changed. When this happens, parents and/or caregivers will need to be taught the best techniques for the use and maintenance of the newer devices. After initial training is provided, frequent follow-up demonstration and relearning is essential to optimizing aerosol drug delivery and adherence to prescribed therapy in infants and children.

8

Aerosol Drug Delivery: Maintenance and Problem Solving

How do I clean my aerosol drug device?

Aerosol drug delivery devices can become contaminated with dirt, debris, and even bacteria from you, your caregiver, and/or the environment. If you are not vigilant in the proper care and handling of your aerosol drug delivery device, serious infection-related and cross-contamination problems can occur. It is therefore essential to follow strict cleaning and maintenance procedures (an infection control plan) to reduce and eliminate the possibility of such problems.

Infection control plan in aerosol drug delivery?

Patient Education: Much research has shown that drug-delivery devices used at home are frequently contaminated with bacteria. Therefore, be sure you receive proper instruction from your respiratory therapist or health care provider on how best to clean and maintain your aerosol delivery device. Additionally, it is important that you receive written instructions and that you review them frequently.

Patient Adherence: The hospital provides an environment where diligent and vigilant cleaning and infection control of drug delivery devices can be provided. However, this is less so in the home environment. Many patients at home do not disinfect their nebulizers.

In addition to someone just ignoring the cleaning and disinfecting instructions provided by the manufacturers, adherence can be influenced by personal, social, cultural, and psychological factors. Several factors can increase adherence and minimize the risk of infection, such as periodically changing aerosol drug delivery devices, using disposable equipment, obtaining health insurance approval, and partnering with your respiratory therapist or health care provider.

Cleaning and maintenance of drug delivery devices

You can prevent aerosol drug delivery devices from becoming infected or malfunctioning at home by following the cleaning instructions for the different types of aerosol drug delivery devices given below:

Pressurized Metered-Dose Inhalers (pMDIs): The plastic container (holder or boot) of the pMDI should be cleaned at least once a week as described in the directions in Table 10.

Table 10. Cleaning instructions for the pMDI

CLEANING THE pMDI

- Frequency of cleaning: Once a week and as needed.
- Look at the hole where the drug sprays out from the inhaler.
- Clean the inhaler if you see powder in or around the hole.
- Remove the MDI canister from the plastic container so it does not get wet.
- Rinse the plastic container with warm water and shake out to remove excess water.
- Place it on a clean paper towel and dry it overnight.
- Replace the canister back inside the pMDI and recap the mouthpiece.

Spacers and Holding Chambers: When a spacer is used with an MDI, it should be cleaned before first use and then periodically cleaned based on the manufacturers' suggestions. Table 11 provides the steps for cleaning spacers and holding chambers.

Table 11. Cleaning instructions for the pMDI spacer and holding chamber

CLEANING THE CHAMBER DEVICE

- Frequency of cleaning per manufacturer's recommendation and as needed.
- Disassemble the device for cleaning.
- Soak the spacer parts in warm water with liquid detergent and gently shake both pieces back and forth.
- Shake out to remove any excess water. Air dry the spacer parts in the vertical position overnight.
- Do not towel dry the spacer as this will reduce dose delivery because of static charge.
- Replace the back piece on the spacer when it is completely dry.

Dry-Powder Inhaler (DPI): It is important to note that your DPI should not be submerged in water. Also, it should be kept dry because moisture will decrease drug delivery. You should wipe the mouthpiece of the DPI with a clean dry cloth and also follow the recommendations of the manufacturer for periodic cleaning.

Jet Nebulizers: Your nebulizer should be cleaned after every treatment. The longer a dirty nebulizer sits and is allowed to dry, the harder it is to thoroughly clean it. Rinsing and washing the nebulizer immediately after each

treatment can go a long way in reducing infection risk.

Parts of the aerosol drug delivery device should be washed with soap and hot water after each treatment. Take extra care not to damage any parts of the aerosol generator (compressor unit). Table 12 provides the daily and weekly cleaning instructions for the jet nebulizer. Ultrasonic nebulizers should be cleaned and disinfected based on the manufacturer's recommendations.

Table 12. Cleaning instructions for the jet nebulizer

CLEANING AFTER EACH USE	CLEANING ONCE OR TWICE A WEEK
Wash your hands before handling equipment.	Wash your hands before handling equipment.
Disassemble parts after every treatment.	Disassemble parts after every treatment.
Remove the tubing from the compressor and set it aside. The tubing should not be washed or rinsed.	Remove the tubing from the compressor and set it aside. The tubing should not be washed or rinsed.
Rinse the nebulizer cup and mouthpiece with warm running water.	Wash nebulizer parts in warm water with liquid dish soap.
Shake off excess water.	Disinfect the nebulizer based on the manufacturer's recommendations. The nebulizer parts may be soaked in one of the following solutions:
Air dry on an absorbent towel.	<ul style="list-style-type: none"> • 1-part distilled white vinegar in 3-parts water for 60 minutes (not recommended for cystic fibrosis patients) or • A commercial quaternary ammonium compound (e.g., Control III) for 10 minutes.
Wrap the dry nebulizer in a clean paper towel.	After soaking, rinse all parts with warm running water.
	Shake off excess water and place all parts on a clean paper towel.
	Allow them to air dry completely on an absorbent towel.
	Reassemble the nebulizer and wrap in a clean, dry paper towel.

Disinfection: You should periodically disinfect and replace your jet nebulizer in order to minimize contamination. Each manufacturer suggests a different method of disinfection for its product, and these steps should be followed. It is also important to note that all solutions should be discarded after disinfection. The varied methods for disinfection include:

- Soaking nebulizer parts in a solution of 1-part distilled white vinegar and 3-parts water for at least 60 minutes, or
- Soaking nebulizer parts in a commercial quaternary ammonium compound (e.g., Control III) for 10 minutes.

You should disinfect your nebulizer once or twice a week by using one of these methods. Mixing a concentrate called Control III with water can make a quaternary ammonium solution. Control III can be purchased from your home care company.

Final Rinse: Be sure to use water for the final rinse.

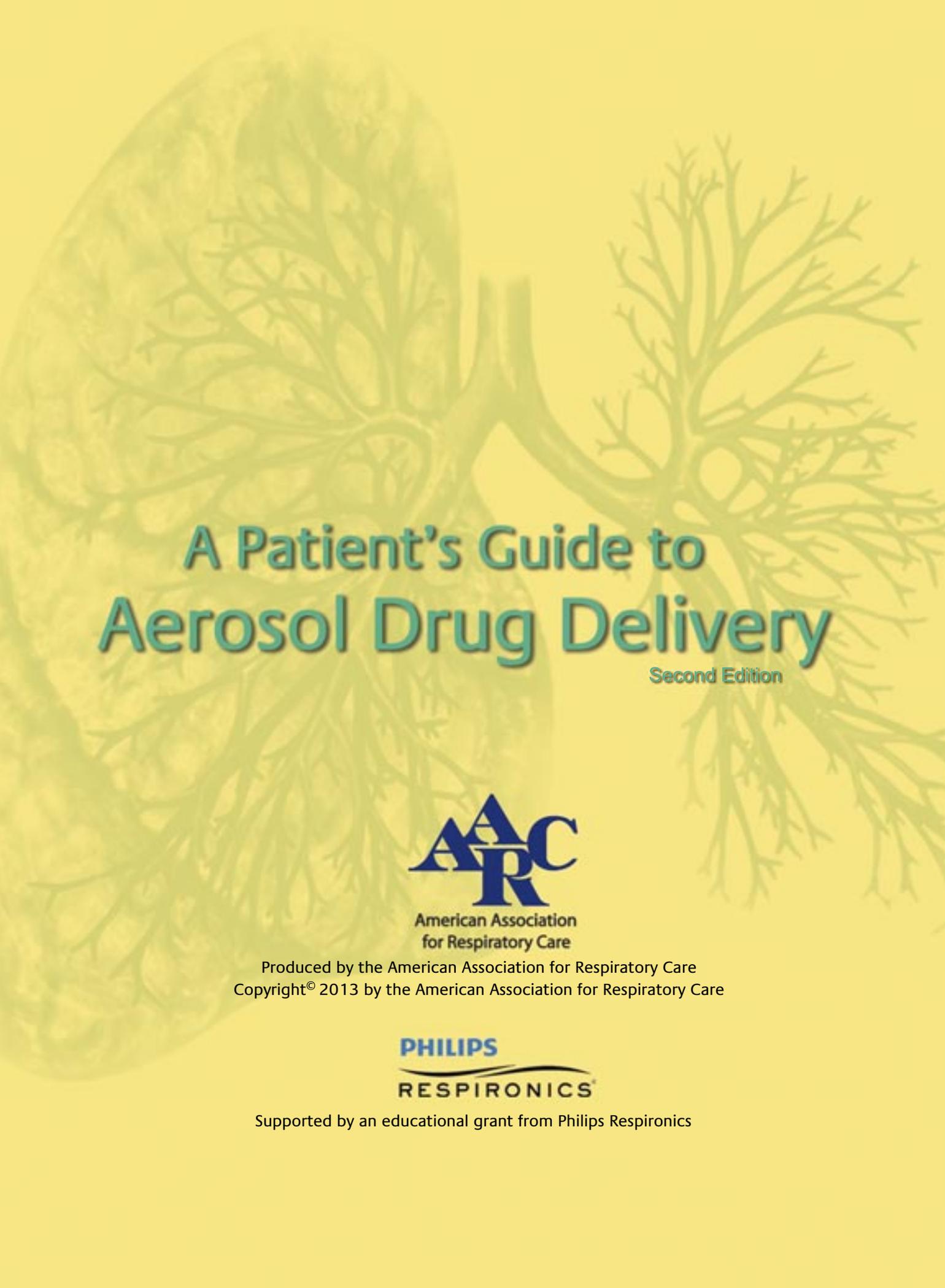
Drying and Maintenance: Because bacteria grow in wet, moist places, nebulizers should be thoroughly dried and stored in a clean, dry place between treatments.

Allowing gas flow from the compressor to the nebulizer for a short time after it is rinsed can reduce drying time. It has been reported that nebulizer performance may change over time due to incorrect cleaning, maintenance, or disinfection procedures. Nebulizers can be kept from becoming contaminated by following the manufacturer's instructions for care and cleaning. This is necessary for all aerosol devices used for inhaled medication.



Reference

Gardenhire DS, Hess DR, Myers TR, Rau JL. A guide to aerosol delivery devices for respiratory therapists (third edition). Dallas, TX: American Association for Respiratory Care; 2013



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