Chapter 13
Teaching the Practical Skill of Correct Inhaler Use: Knowing and Being Able to Do

Garner Faulkner II and Christopher J. Moore

Introduction

Patients with pulmonary disease (such as COPD and asthma) are often prescribed inhaled medications, since this is the most effective route for specific delivery to the lungs and airways [1–6]. Medication via the inhalation route allows for direct delivery, with faster response times (helping to alleviate symptoms/exacerbations), and decreased systemic effects compared with oral or intravenous routes [1, 2, 6].

The inhalation of medication has been dated back as far as the mid-1700s. The common inhaler we know and think of today, the metered dose inhaler (MDI), was introduced in the 1950s by Dr. George Maison [7, 8]. Dr. Maison had an asthmatic daughter. She told her dad that the asthma medication should be more convenient and easier to use than the bulb nebulizer that was available at the time (which leaked in her school bag when she attempted to carry it with her). In 1956, the modern-day MDI was developed by Dr. Maison, Charles Thiel, and Irving Porush [8]. With the development of the MDI, it made delivery of medication and use a lot easier. MDIs are the most common aerosolized medication dose administration device used in the treatment of respiratory disease today. Since the launch and popularity of the MDI, other medication inhalation device types have emerged, most notably that being the dry-powder inhaler (DPI). In very recent years, the soft mist inhaler has emerged and has gained popularity. Today, there are so many devices available and in varying types of medications that it is even easier today for a patient with pulmonary disease to get their inhaled medication than it was just 60 years prior.

G. Faulkner II (✉)
Pulmonary Diagnostic Lab, UPMC Comprehensive Lung Center, Pittsburgh, PA, USA
e-mail: faulkneriig@upmc.edu

C. J. Moore
Respiratory Care Services, Geisinger Medical Center, Danville, PA, USA
e-mail: cjmoore@geisinger.edu

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However, ease of use in aerosolized medication dosing does not necessarily equal effective medication delivery to the patient. Many factors affect proper medication delivery to the patient such as age, disease type/severity, administration technique, design, temperature, and humidity. One of the biggest factors may just be that patients often do not take/use their inhalers properly. Studies have shown that errors in inhaler technique may be common, frequent, and repetitive [3, 9–16].

Another factor that can interfere with proper management of lung and airways diseases is the nonadherence to prescribed inhaler therapy [10, 13, 17–19]. Improper inhaler technique and intermittently following prescribed medication usage are common causes of poor respiratory disease control [5, 12, 14, 17, 20]. It has been reported that over 85% of patients may misuse their inhalers either technically or with improper adherence to prescribed dosing [9, 12, 14, 15]. Poor adherence to inhaled medications (underuse, overuse, and improper use) can be nearly 50% in patients with COPD [21]. Poor adherence and poor technique have been significantly linked to poor asthma control [10]. This is, in particular, seen with inhaled steroids since they need to be used consistently to build up to a therapeutic dose. It is common for patients to discontinue steroid therapy on their own because they are feeling better. There have also been studies showing the lack of adherence and poor inhaler technique to be significantly associated with increased rates of admission to the hospital and even a higher risk of death [22]. Today, there are many guidelines for the management of chronic respiratory disorders promoting the use of inhaled medications (such as asthma, chronic obstructive pulmonary disease, and cystic fibrosis). Because delivery of inhaled medications to the lung is so very important in patients with pulmonary disease, we will review several important topics in this area including: examining metered aerosolized inhalation, the various types of delivery devices available, proper techniques, adherence to therapy, barriers to successful medication administration, and what the healthcare professional can do/needs to do to help.

Why Proper Technique Is Important

In typical aerosol deposition in the lungs, medication can be deposited into lung tissue by way of three processes. These include: (1) inertial impact, (2) sedimentation, and (3) Brownian motion [23].

Turbulent airflow created by increased inspiratory flow rates may cause inertial impaction in which much of the inhaled medication dose is lost in the oropharynx and large conducting airways. Although this is more commonly seen with aerosols with particles >10 μm, the throat is the first major site of inertial impaction when medications are given by mouth. Up to 90% of aerosolized medications can be lost due to inertial impaction [23].

Once remaining medications pass the oropharynx and larger conducting airways, medication particles settle in airways due to gravity which is known as sedimentation. Commonly, particles 1–5 μm, which are common to that found in most MDIs and are in the desired therapeutic range for aerosols, are deposited in the lungs due to sedimentation. Since medication particle size is ideal, lung tissue response occurs

when medication is deposited via this method. On average, 9% of the total medication dose is deposited by sedimentation [23].

The remaining 1% of inhaled medication enters the lung by way of Brownian motion colliding with adjacent particles as they are free floating. Particles inhaled via this method are <1 μm in size. Due to particle size, they are often exhaled as they are suspended in gas or liquid within the lungs [23].

In vitro studies have shown, even if performed correctly, a maximum of 40% of the medication reaches the intended target of the lower airways [24]. However, most patients with very good technique would fall into about 20–25% range [24, 25]. Those with poor technique drop into the range of under 10% [24]. As discussed previously, most patients perform with some errors, so it likely most patients are getting about 10–20% of the medication from an inhaler to the lung/airways. Since much of medication is lost during a patient's inhalation process, proper administration technique is vital to deliver as much medication as possible to the patient and the lower airways.

The abovementioned medication deposition values are based upon normal anatomy and physiology in healthy lungs. Another consideration is to look at differences in the disease process as well. Studies show patients with severe COPD are likely get a significantly lesser drug deposition in the lung than someone with a mild form of the disease due to inability to generate sufficient inspiratory flow [26]. Therefore, selection of a device that a patient can and will use as well as one with appropriate dosing might be an even further consideration.

Pulmonary disease can lessen medication delivery further due to increased airway resistance, decreased inspiratory volume and muscle strength, airway remodeling, and inflammation [6]. With these added hurdles of pulmonary disease, it makes proper technique vital to deliver inhaled medications.

Medication Dosing Device Overview

Pressurized Metered Dose Inhalers (pMDIs)

Pressurized metered dose inhalers (pMDIs) are the most commonly used MDIs to treat patients with respiratory disease [7]. Their design includes a pressurized metal canister of nonreactive metal, glass, or plastic that allows the medication to remain in liquid form, a metering valve, actuator, dose counter, and a mouthpiece which delivers a precise medication dose (Fig. 13.1). The canister is actuated by the patient to discharge the medication while the patient is inhaling [27]. Particles delivered with a pMDI range from 1 to 5 μm, which is in therapeutic range for aerosol particle size for lung administration.

Propellants are used with the pMDI to deliver the medication dose once actuated by the patient. Before their ban by way of the Montreal Protocol due to negative effects toward the ozone, chlorofluorocarbons (CFCs) were used as propellants. Hydrofluoroalkanes (HFAs) are now commonly used in pMDIs for medication delivery [27].

Fig. 13.1 An example of a pressurized metered dose inhaler

One of the biggest disadvantages of using a pMDI alone is the speed at which medications are discharged. One actuation can discharge medications at a velocity of up to 30 m/sec [28] resulting in more medication lost in the oropharynx. Impaction of the medication often occurs in the cheeks, tongue, or back of the throat. To remedy this problem, valve holding chambers or "spacers" are used to capture medication in a compartment. The medication can then be inhaled slowly allowing more medication to reach lung/airways effectively. Another problem that may arise with use of pMDIs is the need for manual dexterity. Patients with poor manual dexterity and or coordination such as children, elderly, and patients with arthritis may have difficulty actuating the pMDI.

Valved-Holding Chambers

There are many valved-holding chambers (VHCs) or "spacers" available today for use in conjunction with pMDI. To effectively use a VHC, a patient must be able to generate an inspiratory flow rate of 20–60 L/min to effectively distribute medication within the lungs. Lower flows tend to lessen the amount of medication that is drawn from the VHC while higher flows tend to increase medication that is lost in the oropharynx. VHCs are often equipped with a valve that can whistle or hum, indicating too strong of an inspiratory force [27].

As mentioned above, without a VHC, the total amount of medication delivered to the lungs at best is only around 25% [25]. With errors though, the percentage of medicine delivered to the airways drops to half of that. Data that suggests valve-holding chambers enhance pMDI medication delivery is lacking in current medical literature. However, holding chambers may correct for poor pMDI technique [29]. The VHC often can take the guesswork and coordination needed for proper MDI use/administration. It is suggested that VHC be used with anyone using MDIs. Specifically, though, VHCs should be strongly encouraged in the following [2, 30]:

1. Infants/children
2. People prescribed corticosteroids
3. People whom have difficulty with coordinating/timing

In young children (usually 6 and under), a mask is often used in combination with a valve holding chamber, especially when pediatric patients are discharged from the hospital and back into the home setting.

Breath-Actuated Metered-Dose Inhaler

A type of pMDI developed to aide in overcoming the problem with poor actuation and timing, and for use when a VHC is not available, is the breath-actuated metered-dose inhaler (BA-pMDI) [31]. BA-pMDIs actuates at inspiratory flow rates of about 20–30 L/min [2]. By using this method, the patient does not have to time out when to actuate the inhaler. VHCs should not be used with BA-pMDI [2]. Currently, though there are not many medications formulated in this delivery device.

Dry-Powder Inhaler (DPI)

Dry-powder inhalers (DPIs) are becoming more common among maintenance medications in metered dose inhalers as the variety of inhaled medications available continually increase. DPIs use fine particle powder medication formulations that are commonly 1–5 μm in size [27]. DPIs can be seen in single drug types or multiple

drugs combined in one inhaler. Medication delivery is created when the patient opens the device to expose the mouthpiece. At that same time as when DPI is opened, a premeasured dose is accessed which is delivered when the patient places the device in the mouth and inhales at a sufficient inspiratory flow rate.

Effective DPI medication delivery is dependent on medication formulae which must be optimized. Inactive excipients are commonly used with DPI medications to decrease medication variability secondary to cohesive forces, most notably, van der Waals forces. Second, DPI device configuration is essential to achieve therapeutic particle range. DPI devices constructed with high internal resistance achieve greater lung deposition of medication [32].

Dry-powder medications, when packaged, are clustered into various sized particles. Medications in this form are not suitable for proper and effective medication deposition in the lungs. Therefore, DPIs must incorporate methods during inhalation to create both uniform and effective medication particle size. DPIs achieve respirable medication particles by way of deagglomeration.

DPIs achieve respirable medication particles by way of deagglomeration. Deagglomeration is a process where these variable size medication clusters are broken down into uniform effective inhalation particles. Deagglomeration can occur in DPIs using 2 methods. First, deagglomeration can occur when medication particles collide with one another or the medication particles can impact the DPI device. Second, optimum medication particles can be created during inhalation by airflow shear to achieve desired particle size [27, 33].

Since no medication holding chamber is needed with DPIs, it is essential that a patient can follow commands and generate an inspiratory flow of 30–90 L/min for optimum delivery. Inspiratory flow greater than 90 L/min can lead to drug deposition in the oropharynx alone. Patients that have inspiratory flows less than 30 L/min may not receive a full and effective medication dose. Some literature questions the effectiveness of inspiratory flow rates from 30–60 L/min [34, 35]. Secondary to this, it has been suggested that maybe greater than 60 L/min to ensure enough inspiratory flow to deliver the powder to the targeted airways [36]. As such, DPIs are not for use with smaller children and these patients are better suited for pMDIs with a valve holding chamber. Many patients are unable to generate the inspiratory flow needed to ensure proper pulmonary deposition and proper drug release [37]. In addition to children, the elderly and those patients with significant airflow limitations will often lack the inspiratory flows needed [37]. Secondary to the flow requirements, these devices are associated with increased resistance during inhalation [16]. Inhalers with decreased resistance have been found to be important to patients and more likely to adhere to therapy [16, 18].

Furthermore, humidity and moisture can adversely change DPI functionality by causing medication to clump preventing deagglomeration during inhalation [7].

DPIs tend to leave a bit more residue in the patient's mouth. This often may cause either a bad taste in their mouth or loss of taste altogether. Some patients also report a dry throat or causing them to get hoarse. All of the above-mentioned can lead to the patient stopping the use of their DPI. There are several types of DPIs out

there in use today. In general, though, they come in two formats: single dose or multiple doses. The single type is a where a single dose is placed into the device (Fig. 13.2) and taken each time it is prescribed (for example Spiriva®). The single dose is typically some sort of capsule.

The multiple dose DPI, (Fig. 13.3), is more common and contains several doses (usually enough medication for 1 month of use), for example, Diskus®, Ellipta®, and Pressair®. With the multiple dose DPIs, there is typically some sort of action that opens up a capsule or causes a dose to release. This may be opening/locking of a device, twisting/locking of the device, or releasing a trigger/button.

Soft Mist Inhalers (SMIs, "Respimat®")

Soft mist inhalers (SMIs) eliminate the need for propellants and excipients used in pMDIs and DPIs. Rather, SMIs use spring-loaded canisters that release a predetermined medication dose for the patient, but at a much lower discharge speed when compared to a pMDI. Discharged medications are often referred to as a medication "cloud," which creates a larger window for the patient to properly inhale the medication [28] with decreased oropharyngeal deposition.

Designed to prevent better lung deposition due to lower discharge velocity, there are advantages using SMIs [28]. First, dosing is often cut by half when compared to pMDI. Second, patients with lower inspiratory flow rates can effectively use SMIs. Finally, SMIs can be used in combination with a VHC or a mask can be added to a VHC when used with children.

Fig. 13.2 An example of a single dose DPI

Fig. 13.3 Examples of multiple dose DPIs

Unfortunately, there are limited medications currently in SMI format. SMIs that are on the market at present are approved for COPD use only, although their use in asthma has shown some benefit. Some patients with poor coordination or difficulty with finger dexterity may have difficulty loading the cartridge of the SMI. If a patient shows difficulty with this, it may be important for education of a family member, caregiver, or selection of a different device. Another problem reported about these devices is that it is sometimes difficult to read the dial indicator of how many doses are left. Unlike a counter type of dosing reminder, the SMIs use a number line with an arrow that points to it. Not all the numbers are listed so at times some patients have difficulty reading how many doses may be left.

Which Devices Are More Problematic for Patients to Correctly Use?

Most studies have shown a greater amount of errors among the MDI format compared to the DPI. This is likely due to many more steps required to properly administer an MDI. However, most of these studies have been observational. Some other studies have shown equal observed errors between MDIs and DPIs [4, 38], while others state patients using DPIs made less crucial errors as compared to MDIs [16]. Even some others state that the misuse of DPIs is common, but the significance on clinical outcomes has yet to be shown [12]. There are very few studies looking at the effect of minor errors. For MDIs, there have been problems seen when the medication canister is not properly seated in the "boot" (the plastic device that holds the medication cartridge). When educating patients on use of MDIs, it is important to ensure they have it properly seated in the "boot." If the MDI canister is not properly seated in the boot, a large amount of medication may be lost [39].

It may be very difficult for a patient to determine how many actuations are left on a pMDI. Clinicians should really favor a pMDI with a built-in counter. This will help to ensure the patient knows exactly how much medication is left [20]. Another factor that should be reiterated is for the patient to monitor when a medication will expire. This tends to particularly be true for rescue pMDIs. Patients may not be using them as often as routine controller types of medications.

Patients should be reminded to store DPIs in a dry environment. Also, because moisture/humidity (as mentioned above) may cause the powder to clump, the patient should be instructed to not breathe/exhale back into the device [20].

Checking Proper Inhaler Technique

As mentioned earlier, the inhaler technique and adherence is vital in the management of respiratory disorders (see Chap. 3). One very important part to ensure proper use is to check the patient's technique of their prescribed device. One mistake often made is asking the patient "Do you know how to use your inhaler?" This type of open-ended question without follow-up questions can be deceiving. Often, the answer will be "yes," but without observing the patient to use their device, how does one really know for sure? Or we presume with very simple one-time explanations (and never rechecking) the patient will follow very detailed steps to accurately take inhaled medications and adhere to prescribed therapy [2, 12, 40]. Studies have shown a higher link to inhaler misuse when there has been a lack of quality instruction on correct inhaler technique [4, 38]. Often, healthcare professionals will reiterate the time of dosing without further detail. For example, "Take 1–2 puffs every 4 hours as needed." With this instruction, there are no details of how to inhale the medication (fast or slow), on letting air out first, on a breath hold (and for how long), and no details on how long between each puff. Lastly, one of the most common lack of details was the definition of "as needed." We have frequently been told by patients

Table 13.1 Steps needed to correctly use a pMDI with a VHC

1. Prime inhaler if first use with new MDI or if MDI has not been used in about a week
2. Make sure the canister is properly inserted into the "boot"
3. Remover cap/cover from both VHC and MDI boot
4. Insert the MDI into the back of the VHC
5. Shake the pMDI several times
6. Exhale fully, away from VHC/MDI
7. Place the VHC and attached MDI into mouth (past teeth, above tongue and create tight seal with lips)
8. Press down on the medication container once and release
9. Breathe in slowly as deeply as possible
10. Hold your breath for a minimum of 5 seconds (preferably 10 seconds)
11. Remove VHC from mouth and exhale slowly/gently

that they really are not sure when they are to use an "as-needed" medication. This leads to the patient not using it for fear of overusing it.

One common and inexpensive way is to have a checklist of proper steps and to check the patient's technique face to face [2, 41]. Placebos are really great to use since each inhaler design can be different and has unique qualities and attributes that may need to be tailored for specific patients [2, 41, 42]. Have the patient use a placebo inhaler and check off each step performed correctly. One major focus during these follow-ups is to support the development of a patient's psychomotor skills [17]. First, conduct a demonstration of the proper use with the placebo, then have the patient repeat what they saw [17].

In general, there are several steps needed to correctly use a pMDI with a VHC [25] (Table 13.1):

If more than one dose is prescribed, wait about 30 seconds and repeat steps 5–11.

As mentioned above, there are different types of DPIs and the way the powder is released can be different in each device. Because of these differences, it is always best for the healthcare professional to review the medication/deliver package that comes with the specific inhaler. But in general, there are several steps for the proper use of a DPI inhaler (Table 13.2) [43].

Another important process is to have the patient verbally describe the proper use of their inhaler. As mentioned above there are key steps for proper use of inhaled devices. Having the patient be able to reiterate these steps demonstrates to the healthcare professional that the patient has learned the correct sequence. When teaching or reassessing technique, this way of reviewing to ensure proper use is known as the "teach back" technique/method. This method ensures reverse demonstration as feedback that the patient understood what you just showed them. If the patient does not show back what they just learned, then the educator knows further instruction is required [44]. If the patient has errors, the instructor should identify the problems with the technique, reinstruct, and have the patient demonstrate again [10, 17]. Common errors in technique for the pMDI and DPI are described in Tables 13.3 and 13.4, respectively. The instructor should also have the patient verbally reiterate when/how often the inhaler should be used. *Teach-back* is discussed in further detail in Chap. 5.

Table 13.2 Steps for proper use of a DPI inhaler

1. Open the device (usually some sort of mouthpiece cover/ guard)
2. Load/activate the powder medication dose (varies with each device)
(a) Slide the lever away until it clicks – Diskus®
(b) Opening the device until a click – Ellipta®
(c) Twisting base of device until click – Turbuhaler®
(d) Pressing down the button of the device – Pressair®
(e) Loading a single pill – Handihaler®, Neohaler®
2. Keep device level while inhaling
3. Exhale fully, away from the mouthpiece
4. Put mouthpiece between teeth and close lips around
5. Inhale deeply and forcefully
6. Hold breath for 10 seconds
7. Remove inhaler from the mouth without exhaling into it
8. Breathe out slowly

Table 13.3 Common pMDI and soft mist inhaler errors

No spacer is used with pMDI
Device is not primed prior to initial use
Propellants are not mixed with medication properly (pMDI is not shaken)
Device is not actuated prior to inhalation
Failure to inhale
Inhalation is too fast
Inhaling through nose
Improper length of breath hold (common in asthma)
Unable to tell if medication canister is empty
Medications are not taken consistently as prescribed
Failure to rinse mouth after steroid use

Table 13.4 Common DPI errors

Failure to open slide cover fully to expose mouthpiece / improper cap removal
Poor inspiratory muscle strength to create forceful inhalation
Improper length of breath hold (common in COPD)
Inhalation through nose
Unable to tell if DPI is empty
Improper mouth seal on DPI
Patient exhales into device rather than inhale
Shaking or holding the device mouthpiece downward during preparation
Medications are not taken consistently as prescribed
Failure to rinse mouth after steroid use

The in-check dial type of device is great to simulate to the patient how much inspiratory flow is needed when using an MDI or DPI. Observationally, patients tend to initially inhale too forcefully or fast when using an MDI. With DPIs, the opposite has been observed. Patients tend to not draw in as forcefully as needed to effectively use a DPI.

The Aerosol Inhalation Monitor (AIM) is an electronic MDI training device that can be used to give direct feedback of incorrect inhaler technique. This device can measure key steps needed for effective inhaler use such as inspiratory flow, ongoing flow, and breath-hold [15]. To give visual feedback, the AIM shows a green light to indicate correct inhalation technique. To indicate inaccurate technique, the AIM shows a red light indicator [15]. This device objectively gives real-time feedback to the clinician as well so they do not have to rely solely on subjective analysis [15].

With regard to appropriate inhaler use, a 2011 consensus statement prepared by the European Respiratory Society (ERS) and the International Society for Aerosols in Medicine (ISAM), advised that prescribers check the patient's inhaler technique as well as review the patient's adherence to their treatment plan regularly [2, 12]. Often, the lack of education, with regard to self-management, results in lengthy hospital stays/costly readmissions. It has been estimated that in excess of 25 billion dollars is spent for inhalers annually [40]. Due to misuse of inhalers, it has been estimated that a little over 5 billion dollars annually is wasted [40]. To ensure adherence, it is important the patient be really evaluated so that the prescribed device is something that they are physically able to and will be willing to use [2, 45, 46]. Often, patients prefer something that is easy to handle, small to carry, and is easy to tell how much medication/dosage is remaining [47, 48]. Patient preference and satisfaction with their device should be a consideration when the healthcare worker is determining the best medication/device to use with their patient [48]. Although a patient may be more satisfied with a device and more likely to adhere to the prescribed technique, the technique can still remain poor [2].

Uniformity in Color or Design

In the 1980s, color coding was used among inhalers. Blue was designated for fast-acting (rescue) medications while brown was used for inhaled corticosteroids. All inhaled medications at that time were pMDIs. The obstacle to successfully identify the medication was that the patient had to be able to see the color of the inhaler to confirm it [49]. As new medications emerged, pharmaceutical companies began deviating from color coding. With no uniformity in color coding, a fast-acting inhaler and a combination inhaler might be the same color (because of different manufactures) or a fast-acting inhaler may have three different colors between different manufacturers. Having certain colors/designs universally accepted would be ideal and effective for uniform teaching [50].

There have been proposals that color coding could be successful by using single color decals applied to the medication packaging based upon specific medication type. In MDIs where medication combinations are used, multiple single-color

decals could be used to specify individual medications, but again there is concern of those who are colorblind. However, there have been ideas suggested that the Braille system could be fabricated into the inhaler device [48]. A uniform coloring for specific types of inhalers would certainly be a relatively easy/uniform way of patients to distinguish between maintenance inhalers and fast acting (rescue) inhalers.

Cleaning

Inhalers, since they are taken by mouth, are prone to debris and are potential reservoirs for bacteria [51, 52]. Bacterial infections in patients with chronic respiratory disease such as COPD, may serve as a cause for an exacerbation/trigger [53]. Debris is more likely on inhaler devices and is concerning as it may interfere with the proper delivery of the medication [52]. Patients should be instructed to wipe off the mouthpiece with each use. One area of concern when a patient does clean their inhaler is when cleaning a DPI. Care must be taken to ensure moisture does not get inside the DPI. As mentioned before, moisture in a DPI can cause clumping and ultimately loss of deliverable medication to the airways. On MDI inhalers, cleaning the "boot" is important to ensure proper aerosol is dispensed.

Patients should also be instructed on cleaning their VHCs. These can often be cleaned by disassembling them, using hot/soapy water, rinsing and letting air/drip dry. After completely drying the VHC, it then can be reassembled [29]. Patients should be discouraged from wiping or rubbing the inside of the VHC since that can add to the surface charge of the chamber, thus affecting the amount of aerosol delivered to the lung/airways [20].

Barriers and Challenges to Successful Inhaler Use

Multiple Differing Devices and Techniques Most patients using any form of inhalers long-term usually require at least one rescue medication and one controller medication. Patients who are prescribed more than one inhaler are more likely to misuse them. Patients prescribed two or greater maintenance inhalers have shown higher rates of incorrect administration technique [1, 54].

Age There is a direct relationship between the amount of medication deposited in the lung when compared to both age and body weight. That is, as both age and body weight increase, higher doses of medication are received into the lung [55]. A very large barrier exists in younger children as there are limited medications that can be used due to age. Most DPIs require patients to be at least 4–5 years of age to provide adequate inspiratory flow when using a DPI for adequate lung deposition. It is well known to pediatric clinicians that appropriately delivering inhaled aerosolized

respiratory medications with any device can sometimes be challenging. Often times, when a child is transitioning back to the home setting from the hospital, they will transition to MDIs since they can be quickly given to the child.

pMDIs tend to be the inhaler device of choice with younger children since they can be given in combination with a mask and VHC. In a study conducted by Ditcham et al. in 2013, results of their investigation show that there was similar medication deposition into the lungs in patients 3–5 years of age when MDIs were given by a mouthpiece device in comparison to a mask [56]. Current medical literature recommendations state that a mask should be used with a pMDI until at least age 3 or until the child can use a mouthpiece effectively [57].

Clinically, it was once thought that when babies cried during aerosolized medication administration, there was more medication deposition in the lungs. Research has proven this to be a false finding, as there is more effective medication delivered to children during quiet and nonstressful breathing patterns [57].

SMIs are another device option in children due to lower medication discharge velocity, as previously mentioned. However, SMIs tend to be limited by medication selection and variety constraints. Common errors associated with both pMDIs and SMI usage are listed in Table 13.3 [1, 17].

DPIs have a much wider medication selection than SMIs. However, in younger children, these medications tender barriers for their use. First, younger children may not have inspiratory flow rates required for proper medication delivery. Second, some DPIs have age constraints. That is, they are not approved for use until the child reaches a specific age.

There also appears to be a barrier to achieving successful MDI use in the elderly population [58–60]. Often, physical or cognitive disabilities more evident in the elderly may also cause a higher rate poor adherence or poor inhaler technique [58, 59]. Another limiting factor may be due to multiple inhaler use and the elderly patients view/approach on health-related topics. Advanced age may also affect lung function and inability to generate adequate inspiratory flow rates as previously mentioned specifically for DPIs [58]. Common errors associated with DPI usage are listed in Table 13.4 [1, 17, 37].

Health Literacy The healthcare professional is not available to monitor their patients 24/7 to ensure they are using their medications appropriately and understand what they must do when. For effective care, and to ensure patients are able to make educated decisions about their health, they need to be able to obtain, understand, and ultimately be able to follow through with the information about their health [61]. One common mistake made is that we overwhelm patients with educational material that is beyond their comprehension. We assume by giving patients as much information as possible that it will aid them in understanding. Not all people learn the same way. In one study, patients with chronic pulmonary disease who had lower educational levels, showed very poor inhaler technique [61], thus reiterating the need for a more personalized training [5]. In order to ensure effectiveness, educational materials should focus on the patient's knowledge. When needed, the patient's knowledge should be strengthened to ensure confidence and competence to ultimate improve adherence [8]. When providing information/education to

patients/families, the healthcare educator must ensure that the format used is one that the learner (patient and/or family member) can understand. For example, if written materials are provided, the materials should be at a level that they are able to read and understand written instructions [8]. How to support a patient and/or family member learning is further discussed in Chaps. 3 and 4.

Financial Barriers/Insurance Coverage A frustrating, but common, problem is that healthcare professionals may encounter in some countries is insurance coverage and funding for prescriptions, which occur in all age groups. Either it is too expensive for the patient, or what used to be covered is no longer funded, so they are forced to switch to an alternative medication and inhaler that does not work as well for them. This often leads to confusion or the patient just stops taking a prescribed medicine. Medication assistance programs are often available through various manufacturers. However, the patient and or healthcare professional may be unaware of these programs.

Hospital Formularies With new inhalers continually being introduced into the market, it is unrealistic and impractical for each hospital pharmacy to keep every MDI in stock. Hospital formularies were created to control cost, enhance correct medication use, and most importantly, increase patient safety by reducing medication errors [62]. Maintenance or "controller" medications such as long acting bronchodilators and inhaled corticosteroids tend to be the group of MDIs that vary among hospital formularies. Because of this, a patient may be switched to another brand or type of device/medication during their hospital visit. Some institutions allow the patient to take home their medications after being discharged from the hospital. This creates an additional risk of noncompliance and/or confusion. Now which inhaler do they use? Sometimes patients will use both once they are home, increasing the potential risk of over medication.

Following-Up on Technique

Because the majority of patients do not use their inhalers correctly and many factors can contribute to poor adherence, many guidelines recommend inhaler instruction and review of technique frequently and specifically after follow-up from hospitalization [2, 6]. Also, as disease progression occurs, it may become very important that the patient still has the inspiratory capacity to use certain inhaled devices [63]. One way to ensure the proper technique with inhalers is for clinicians to reassess the technique with every visit [2]. Assessing the technique and reviewing the timing of use should be done at clinic visits, while in hospital, in outpatient settings (i.e., pulmonary doctor's office, lung clinic, or pulmonary function lab), and in the home setting, with regularity. Ideally this would be every 3 months initially, and then once proficiency is shown and disease management stabilized, maybe every 6–9 months. Often, a common mistake made is that the healthcare professional assumes the

patient knows what they are doing because they have had their disease for years. Or we teach it once and assume that the patient has the appropriate technique mastered over the long term.

A key to follow-up care is to identify whether the patient is not using inhalers at all due to medication routine noncompliance versus using them incorrectly. Determining why a patient is noncompliant with the medication regimen is just as important as ensuring they are using it appropriately. Education on disease process and how medication affects progression and symptoms may be a key to ensuring compliance with the prescribed regimen.

One of the barriers to education in the hospital or even in clinic visits is the allocation of time and trained staff to do so. An ideal place for patients to get great exposure to follow-up for technique is in pulmonary rehabilitation (PR). PR programs foster opportunities to review medications, their use, and develop ways to implement strategies that focus on supporting adherence [64]. Unfortunately, patients may not always be referred to, be eligible for, or have access to these programs [64]. To aide in this gap, there has been a trend in the last few years toward having specialists such as disease or case managers/coordinators visiting pulmonary patients in settings such as the hospital and then ultimately in the clinic setting to aide in the education process.

Guidelines also recommend that the technique be checked before switching devices/advancing medications [2]. Patients may often have their own idea/beliefs/concerns of how to best care for their lung health. Addressing these through constant following can ensure patient empowerment and improved adherence/better technique [17].

An emerging trend in healthcare today is the utilization of telehealth to provide care/follow-up for patients. Patients utilizing inhaled medication can be interviewed and their technique evaluated from the comforts of their own home. Thomas et al. demonstrated how an inhaler training program that was setup at home using 3 monthly visits through home video conferencing, positively affected inhaler technique, self-efficacy, HRQoL, and adherence to therapy [65]. Patients with COPD would virtually meet with a pharmacist who provided inhaler training using a teach-to-goal method [63]. Participants completed questionnaires to establish disease severity, health literacy, HRQoL, adherence, and satisfaction with the sessions [65]. Although this study was small (only 41 patients), it did show how beneficial such an approach could be to provide another avenue to follow-up care for inhaler technique and adherence to therapy. One obvious problem to video conferencing follow-ups is that patients with lack of resources or access would be unable to utilize this approach. Nonetheless, this approach is definitely an emerging opportunity, since the use of virtual/telehealth is on the rise in the twenty-first century.

Another emerging technology to help healthcare professionals track patients' use and adherence to inhaler therapy is with the use of "smart inhalers" or remote inhaler monitoring devices [17, 66]. Remote monitoring devices are connected to the inhaler and record the information related to medication administration.

Although these devices are rather expensive, are not available with all types, and require the patient to keep in place when using their inhaler, they do provide accurate data on patient use [17]. Providing healthcare professionals with direct feedback is the biggest advantage of these devices. In a pilot study of COPD patients, Sumino et al. found that over a 3-month period, increased albuterol use captured by the sensor was associated with self-reported episodes of moderate-to-severe exacerbations [66]. This finding can be an extremely important early indicator of an exacerbation, and can be used when following up with patients using inhaler devices.

What Else Can We Do?

Often, patients do not know they are performing their inhaler incorrectly and believe how they use it is the correct way. Reiterating and checking technique in the hospital remains important, but it may not be the best environment to learn and retain vital educational information. As mentioned above, getting involved in the outpatient pulmonary office setting is becoming a greater trend/focus among health systems to ensure patients know how to use, are using, and adhere to their prescribed inhaled therapies. Personalized inhaler technique sheets/labels detailing proper use and highlighting incorrect steps are low-cost interventions that can be used for improved patient education and adherence [17].

At the University of California San Diego COPD/Asthma Education Clinic, one successful solution implemented to help patients with medication adherence was to give them a copy of a common inhalers picture sheet. The inhaler the patient is to use is circled and a brief overview of when it is to be used is written beside it. For example, if the patient is prescribed Albuterol as needed, the picture of the Albuterol inhaler would be circled and beside it is written, "Take for quick relief of symptoms." If the patient is prescribed a maintenance inhaler, that picture is circled and something such as "takes 2 puffs every 12 hours even if feeling better." This way, the patient knows not to take it randomly as needed, but routinely as prescribed. The sheet of pictures is printed out in color and has the names of each medication bedside them. Often, patients stated they would tape this sheet on the inside of their medicine cabinet, so they remember what inhaler was to be used when.

At the UMPC Comprehensive Lung Center in Pittsburgh, pulmonary patients started on new inhalers are taught the correct technique, using placebos by a pulmonary healthcare professional. The healthcare professionals utilize teach-back technique to ensure proper reverse demonstration with placebo inhalers. The technique is checked frequently during return visits as well as when prescribed new inhalers. Also, patients prescribed MDI or DPI devices are checked to ensure that they have accurate inspiratory flow rates by using the In-Check Dial device.

Geisinger Medical Center also utilizes teach back technique during education, and incorporates In-Check Dial to assess patient inspiratory flow rates to ensure proper MDI device for patients.

Other Problems Leading to a Lack of Capability for Inhaler Use

Another issue that dampers appropriate education is that all too often healthcare professionals providing education are not properly trained on the use of devices either. There appears to often be a lack of medical textbooks or chapters even including a simple list of steps to properly use an inhaler [40]. Literature has shown that the overall knowledge and understanding by healthcare professionals is rather low and inadequate [17, 67–69]. Some literature reports that over 60% of healthcare professionals (nurses, doctors, pharmacists, and respiratory therapists) are unable to describe critical steps to proper inhaler use [40]. Poor understanding of the correct use of these devices may prevent healthcare professionals from being able to adequately assess and teach proper inhaler techniques in their patients [67]. This calls for organizations to develop guidelines and/or institutions to develop policies/protocols to formally layout how education should/will be performed. This should include guidelines for the healthcare professional as to what should be covered when teaching patients the correct technique. Another factor that may lead to improper education by the healthcare professional is sufficient time for education is not allocated [69]. In some countries, this may be due to a lack of funding or reimbursement for clinicians to provide education. State and federal lawmakers need to also be educated on this important matter to allow for institution reimbursement/funding and to ensure proper training costs are allocated to healthcare professionals.

Conclusion

The inhalation of medication to treat patients with pulmonary disease is common, as well as efficacious. There are many factors that affect the delivery of medication to the airways and lungs. There is also a variety of devices available to deliver these medications. Although these devices appear simple to use, currently prescribed devices are quite complex after being constantly improved for over 60 years to ensure effective therapy.

Nonadherence to prescribed therapy adversely impacts health outcomes, the HRQoL of the patient, and healthcare costs/reimbursements. There is still room for great improvement since inhaler/medication misuse and errors regarding proper use are very common. It is important for both the patient and healthcare professionals to fully understand how inhalers work, and which device is the best for specific patients and situations. Each device can have equal advantages as well as disadvantages, so it is extremely important for healthcare professionals to work together with the patient to find a device the patient is more likely to use and understand.

Ongoing evaluation and training of proper inhalation technique in patients using inhalers to treat their symptoms and manage their pulmonary disease remain extremely important, if not vital. Evaluating and re-evaluating the patient's

technique and adherence to prescribed therapy as often as possible enhance the likelihood of successful compliance and disease/symptom management.

Ongoing research and data collection are also vital to ensure advanced education on inhaler technique and to maximize adherence to inhaled medications. As important as inhaled medications are to manage patients with pulmonary disease, it should not be considered acceptable that well over three-fourths of these patients continue to inadequately adhere to therapy or use their device [70].

References

1. Braido F, Chrystyn H, Baiardini I, Bosnia-Anticevich S, Van der Molen T, Dandurand RJ, Chisholm A, et al. Clinical commentary review "trying, but failing" – the role of inhaler technique and mode of delivery in respiratory medication adherence. J Clin Immunol Pract. 2016;4(5):823–32.
2. Laube BL, Janssens HM, de Jongh FHC, Devadason SG, Dhand R, Diot P, et al. ERS/ISAM task force report: what the pulmonary specialist should know about the new inhalation therapies. Eur Respir J. 2011;37(6):1308–31.
3. Luczak-Wozniak K, Dabrowska M, Domagala I, Miszczuk M, Lubanski W, Leszczynski A, Krenke R. Mishandling of pMDI and DPI inhalers in asthma and COPD – repetitive and non-repetitive errors. Pulm Pharmacol Ther. 2018;51:65–72.
4. Melani AS, Bonavia M, Cilenti V, Cinti C, Lodi M, et al. Inhaler mishandling remains common in real life and is associated with reduced disease control. Respir Med. 2011;105(6):930–8.
5. Pothirat C, Chaiwong W, Phetsuk N, Pisalthanapuna S, Chetsadaphan N, Choomuang W. Evaluating inhaler use technique in COPD patients. Int J Chron Obstruct Pulmon Dis. 2015;10:1291–8.
6. Rabe KF, Hurd S, Anzueto A, Barnes PJ, Buist SA, Calverley P, et al. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: GOLD executive summary. Am J Respir Crit Care Med. 2007 Sep 15;176(6):532–55.
7. Gardenhire DS, Burnett D, Strickland S, Myers TR. A guide to aerosol delivery devices for respiratory therapists. 4th ed: American Association for Respiratory Care; Irving, Texas; 2017.
8. Rubin BK, Fink JB. Optimizing aerosol delivery by pressurized metered-dose inhalers. Respir Care. 2005;50(9):1191–7.
9. Dalcin Pde T, Grutcki DM, Laporte PP, Lima PB, Menegotto SM, Pereira RP. Factors related to the incorrect use of inhalers by asthma patients. J Bras Pneumol. 2014;40(1):13–20.
10. Giraud V, Allaert FA, Roche N. Inhaler technique and asthma: feasability and acceptability of training by pharmacists. Respir Med. 2011 Dec;105(12):1815–22.
11. Hilton S. An audit of inhaler technique among asthma patients of 34 general practitioners. Br J Gen Pract. 1990;40(341):505–6.
12. Lavorini F, Magnan A, Dubus JC, et al. Effect of incorrect use of dry powder inhalers on management of patients with asthma and COPD. Respir Med. 2008;102:593–604.
13. Molimard M, Raherison C, Lignot S, Depont F, Abouelfath A, Moore N. Assessment of handling of inhaler devices in real life: an observational study in 3811 patients in primary care. J Aerosol Med. 2003;16:249–54.
14. Rootmensen GN, van Keimpema AR, Jansen HM, de Haan RJ. Predictors of incorrect inhalation technique in patients with asthma or COPD: a study using a validated videotaped scoring method. J Aerosol Med Pulm Drug Deliv. 2010 Oct;23(5):323–8.
15. Shealy KM, Paradiso VC, Slimmer ML, Campbell DL, Threatt TB. Evaluation of the prevalence and effectiveness of education on metered-dose inhaler technique. Respir Care. 2017;62(7):882–7.

16. van der Palen J, Klein JJ, Kerkhoff AH, van Herwaarden CL. Evaluation of the effectiveness of four different inhalers in patients with chronic obstructive pulmonary disease. Thorax. 1995;50(11):1183–7.
17. Ari A. Patient education and adherence to aerosol therapy. Respir Care. 2015;60(6):941–55; discussion 955–957.
18. Molimard M, Colthorpe P. Inhaler devices for chronic obstructive pulmonary disease: insights from patients and healthcare practitioners. J Aerosol Med Pulm Drug Deliv. 2015;28(3):219–28.
19. Dudvarski Ilic A, Zugic V, Zvezdin B, et al. Influence of inhaler technique on asthma and COPD control: a multicenter experience. Int J Chron Obstruct Pulmon Dis. 2016;11:2509–17. Published 2016 Oct 6. https://doi.org/10.2147/COPD.S114576.
20. Levy ML, Dekhuijzen PN, Barnes PJ, et al. Inhaler technique: facts and fantasies. A view from the Aerosol Drug Management Improvement Team (ADMIT). NPJ Prim Care Respir Med. 2016;26:16017.
21. Restrepo RD, Alvarez MT, Wittnebel LD, Sorenson H, Wettstein R, Vines DL, et al. Medication adherence issues in patients treated for COPD. Int J Chron Obstruct Pulmon Dis. 2008;3:371–84.
22. Vestbo J, Anderson JA, Calverley PM, et al. Adherence to inhaled therapy, mortality and hospital admission in COPD. Thorax. 2009;649110:939–43.
23. Capstick TGD, Clifton IJ. Inhaler technique and training in people with chronic obstructive pulmonary disease and asthma. 27 Jan 2012. Retrieved from https://www.medscape.org/viewarticle/757312_1.
24. Biswas R, Hanania NA, Sabharwal A. Factors determining in vitro lung deposition of albuterol aerosol delivered by ventolin metered dose inhaler. J Aerosol Med Pulm Drug Deliv. 2017;30(4):256–66.
25. https://www.thoracic.org/patients/patient-resources/resources/metered-dose-inhaler-mdi.pdf. Am J Respir Crit Care Med 2014;190:P5–P6.
26. Farkas A, Lizal F, Jedelsky J, Elcner J, Horvath A, Jicha M. Simulation of airway deposition of an aerosol drug in COPD patients. Pharmaceutics. 2019;11(4):153.
27. Ibrahim M, Verma R, Garcia-Contreras L. Inhalation drug delivery devices: technology update. Med Devices Res. 2015;8:131–9.
28. Hess D, Dhand R. The use of inhaler devices in adults. UpToDate 2018. Retrieved from https://www.uptodate.com/contents/the-use-of-inhaler-devices-in-adults.
29. Moore R. The use of inhaler devices in children. UpToDate 2018. Retrieved from http://www.uptodate.com/contents/the-use-of-inhaler-devices-in-children.
30. https://www.nationalasthma.org.au/living-with-asthma/resources/patients-carers/factsheets/spacer-use-and-care.
31. Newman SP, Weisz AW, Talaee N, et al. Improvement of drug delivery with a breath actuated pressurised aerosol for patients with poor inhaler technique. Thorax. 1991;46:712–6.
32. Demoly P, Hagedoorn P, De Boer AH, Frijlink HW. The clinical relevance of dry powder performance for drug delivery. Respir Med. 2014;108(8):1195–203.
33. Grant AC, Walker R, Hamilton M, Garrill K. The ELLIPTA dry powder inhaler: design, functionality, in vitro, dosing performance and critical task compliance be patients and caregivers. J Aersol Med Pulm Drug Deliv. 2015;28(6):474–85.
34. Broeders MEAC, Molema J, Vermue NA, Folgering HTM. In check dial: accuracy for diskus and turbuhaler. Int J Pharm. 2003;252:275–80.
35. Chrystyn H. Is inhalation rate important for a dry powder inhaler? Using the In-Check Dial to identify these rates. Respir Med. 2003;97:181–7.
36. Mahler DA. Peak inspiratory flow rate as a criterion for dry powder inhaler use in chronic obstructive pulmonary disease. Ann Am Thorac Soc. 2017;14:1103–7.
37. Newman SP, Busse WW. Evolution of dry powder inhaler design, formulation, and performance. Respir Med. 2002;96:293–304.
38. Sestini P, Cappiello V, Aliani M, Martucci P, Sena A, Vaghi A, et al. Prescription bias and factors associated with improper use of inhalers. J Aerosol Med. 2006;19(2):127–36.

39. Wilkes W, Fink J, Dhand R. Selecting an accessory device with a metered-dose inhaler: variable influence of accessory devices on fine particle dose, throat deposition, and drug delivery with asynchronous actuation from a metered-dose inhaler. J Aerosol Med. 2001;14(3):351–36.
40. Fink JB, Rubin BK. Problems with inhaler use: a call for improved clinician and patient education. Respir Care. 2005;50(10):1360–74.
41. Aydemir Y. Assessment of the factors affecting the failure to use inhaler devices before and after training. Respir Med. 2015 Apr;109(4):451–8.
42. Bonini M, Usmani OS. The importance of inhaler devices in the treatment of COPD. COPD Res Pract. 2015;1(1):9.
43. Onyedum C, Desalu O, Nwosu N, Chukwuka C, Ukwaja K, Ezeudo C. Evaluation of inhaler techniques among asthma patients seen in Nigeria: an observational cross sectional study. Ann Med Health Sci Res. 2014;4(1):67–73.
44. Dantic DE. A critical review of the effectiveness of 'teach-back' technique in teaching COPD patients self-management using respiratory inhalers. Health Educ J. 2013;73(1):41–50.
45. Newman SP. Inhaler treatment options in COPD. Eur Respir Rev. 2005;14:102–8.
46. Small M, Anderson P, Vickers A, Kay S, Ferner S. Importance of inhaler-device satisfaction in asthma treatment: real world observations of physician-observed compliance and clinical/patient-reported outcomes. Adv Ther. 2011;28(3):202–12.
47. Jahedi L, Downie SR, Saini B, Chan HK, Bosnic-Anticevich S. Inhaler technique in asthma: how does it relate to patients' preferences and attitudes attitudes towards their inhalers? J Aerosol Med Pulm Drug Deliv. 2017;30(1):42–52.
48. Dekhuijzen PN, Lavorini F, Usamani OR. Patients' perspectives and preferences in the choice of inhalers: the case for Respimat or Handihaler. Patient Prefer Adherence. 2016;10:1561–72.
49. Bottrell J. The color of inhalers: part 2. 20 March 2018. Retrieved from https://asthma.net/living/inhalers-part-2/.
50. Jayakrihnan B, Al-Rawas OA. Asthma inhalers and colour coding. Br J Gen Pract. 2010;60(578):690–1.
51. Borovina LR, Tremellen KE, Walker MP, Hawley TM, Horgan AR, Grant GD, King MA. The microbial contamination of pressurised metered-dose inhalers anonymously sourced from the South-East Queensland Australia community population. Int J Pharm Pract. 2012;20(2):129–33.
52. Levesque KA, Johnson CE. Bacterial contamination of pressurized inhalers. Drug Intell Clin Pharm. 1984;18(9):735–7.
53. Wilson R. Bacteria, antibiotics, and COPD. Eur Respir J. 2001;17:995–1007.
54. Yu AP, Guérin A, de Leon DP, Ramakrishnan K, Wu EQ, Mocarski M, Blum S, Setyawan J. Therapy persistence and adherence in patients with chronic obstructive pulmonary disease: multiple versus single long-acting maintenance inhalers. J Med Econ. 2011;14(4):486–96.
55. Price D, Bosnia-Anticevich S, Briggs A, Chrystyn H, Scheuch G, Bousquet J. Inhaler competence in asthma: common errors, barriers to use, and recommended solutions. Respir Med. 2013;107:37–46.
56. Ditchman W, Murdzoska J, Zhang G, Roller C, Von Holer D, Nikander K, Devadason S. Lung deposition of 99m tc-radiolabled albuterol delivered through a pressureized metered dose inhaler and spacer with a facemask or mouthpiece in children with asthma. J Aerosol Med Pulm Drug Deliv. 2014;27(1):63–75.
57. Ari A. Drug delivery interfaces: a way to optimize inhalation therapy in spontaneously breathing children. World J Pediatr. 2016;5(3):281–7.
58. Barbara S, Kritikos V, Bosnic-Anticevich S. Inhaler technique: does age matter? A systematic review. Eur Respir Rev. 2017;26:170055. https://doi.org/10.1183/16000617.0055-2017.
59. Ferreira EF, Pascoal A, Silva P, Lourenco O, Valente S, Valente MJ, et al. Inhaler training and asthma knowledge are associated with a higher proportion of patients with correct inhaler technique in young but not in elderly asthmatics. J Asthma. 2019; https://doi.org/10.1080/027770903.2019.1582063.
60. Gillman A, Douglass JA. Asthma in the elderly. Asia Pac Allergy. 2012;2(2):101–8.
61. Beatty CR, Flynn LA, Costello TJ. The impact of health literacy level on inhaler technique in patients with chronic obstructive pulmonary disease. J Pharm Pract. 2017;30(1):25–30.

62. Her QL, Amato MG, Seger DL, Gilmore JF, Fanikos J, Bates DW. Review of nonformulary medication approvals in an academic medical center. Jt Comm J Qual Patient Saf. 2017;43(2):89–96.
63. Prime D, de Backer W, Hamilton M, Cahn A, Preece A, Kelleher D, Baines A, Moore A, Brealey N, Moynihan J. Effect of disease severity in asthma and chronic obstructive pulmonary disease on inhaler-specific inhalation profiles through the ELLIPTA dry powder inhaler. J Aerosol Med Pulm Drug Deliv. 2015;28:486–97.
64. Hill K, Vogiatzis I, Burtin C. The importance of components of pulmonary rehabilitation, other than exercise training, in COPD. Eur Respir Rev. 2013;22:405–13.
65. Thomas RM, Locke ER, Woo DM, Nguyen EHK, Press VG, Layouni TA, et al. Respir Care. 2017;62(11):1412–22.
66. Sumino K, Locke ER, Magzamen S, Gylys-Colwell I, Humblet O, Nguyen HQ, et al. Use of a remote inhaler monitoring device to measure change in inhaler use with chronic obstructive pulmonary disease exacerbations. J Aerosol Med Pulm Drug Del. 2018;31(3):191–8.
67. Plaza V, Giner J, Rodrigo GJ, Dolovich MB, Sanchis J. Errors in the use of inhalers by health care professionals: a systematic review. J Allergy Clin Immunol Pract. 2018;6(3):987–95.
68. Basheti IA, Armour CL, Reddel HK, Bosnic-Anticevich SZ. Long-term maintenance of pharmacists' inhaler technique demonstration skills. Am J Pharm Educ. 2009;73(2):32.
69. Leung J, Bhutani M, Leigh R, Pelletier D, Good C, Sin DD. Empowering family physicians to impart proper inhaler teaching to patients with chronic obstructive pulmonary disease and asthma. Can Respir J. 2015;22(5):266–70.
70. Faulkner G II. So that's how you use it: how effective is education on inhaler use? Respir Care. 2017;62(7):1001–3.