Respiratory Medicine (2013) **107**, 37–46

Available online at www.sciencedirect.com

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Inhaler competence in asthma: Common errors, barriers to use and recommended solutions

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Received 14 May 2012; accepted 26 September 2012
Available online 23 October 2012

KEYWORDS
Asthma;
Inhalers;
Chronic obstructive pulmonary disease (COPD)

Summary
Whilst the inhaled route is the first line administration method in the management of asthma, it is well documented that patients can have problems adopting the correct inhaler technique and thus receiving adequate medication. This applies equally to metered dose inhalers and dry powder inhalers and leads to poor disease control and increased healthcare costs. Reviews have highlighted these problems and the recent European Consensus Statement developed a call to action to seek solutions.

This review takes forward the challenge of inhaler competence by highlighting the issues and suggesting potential solutions to these problems. The opportunity for technological innovation and educational interventions to reduce errors is highlighted, as well as the specific challenges faced by children. This review is intended as a policy document, as most issues faced by patients have not changed for half a century, and this situation should not be allowed to continue any longer. Future direction with respect to research, policy needs and practice, together with education requirements in inhaler technique are described.
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http://dx.doi.org/10.1016/j.rmed.2012.09.017

What is known about the problem?

Inhalers are the most common type of medication devices used in asthma treatment. However, they are often used sub-optimally leading to uncontrolled asthma and increased costs, either as a result of uncontrolled disease, or increased drug utilization for relief medication or preventative therapy.[1] This remains a common problem in asthma and COPD.[2,3]

The recent ADMIT (Aerosol Drug Management Improvement Team) series discussed current knowledge of asthma management, its components, factors that may limit patients' ability to achieve optimal asthma outcomes and instruments to measure asthma control, and attempted to raise awareness that correct device use is crucial for successful treatment.[4–9] A call for action to the medical community recently published in the European Respiratory Journal laid out how this might be practically implemented.[10] The present paper goes further by considering all aspects of the misuse of inhalers and aims to provide an overview of the problem and recommend solutions.

The worldwide costs associated with the management of asthma in adults and children are substantial, from both the healthcare payer and the societal perspective. In the US, the total direct annual cost of asthma has been estimated to be as much as $1.48 billion.[11,12] In Europe, the estimated average cost for a child with asthma ranged from €883[12] to €2202[13] per year; for adults these costs ranged from €632[13] to €2745.[14]

Pharmaceutical expenditure represents an increasing share of total direct medical costs. A UK review estimated the annual cost of asthma to be £752.6 million, of which 8% was due to hospital admissions, 13% to general practice consultations and 79% to community prescriptions.[15] Indirect costs represent 40–50% of the total societal burden of asthma.

Research findings show that costs increase significantly with increasing asthma severity.[16] In the US TENOR study, healthcare expenditure for an uncontrolled patient is more than double that of a controlled patient.[12]

Improper inhalation technique can lead to decreased efficacy through reduced deposition of medication in the lungs. Critical inhaler handling errors, likely to significantly impair delivery of adequate medication, that are associated with different inhaler devices are listed in Table 1. In a review of 21 studies looking at misuse of metered dose inhalers, poor technique was estimated to be prevalent in 14–90% (with an average of 50%) of cases.[17] It is perhaps not surprising that patients often use their device incorrectly since healthcare professionals' understanding of the correct use of these devices is also poor. In a study of medical interns, only 5% were found to be able to correctly use an MDI device.[18] The same study showed that a substantial increase in correct use occurred after a one-on-one training session.[18] In a systematic review of educational programs for self-management of asthma in children and adolescents, education was associated with improved lung function, reduced school absenteeism, decreased numbers of days with restricted activities and fewer visits to emergency departments.[19] Switching patients from inhalers to other inhalers requiring technical training can reduce control, if not accompanied by a GP consultation, due to increased levels of misuse caused by confusion over appropriate inhaler technique for different devices.[20] In an observational study of prospectively recruited consecutive patients, asthma instability was associated with inhaler misuse.[17] In one of the few studies in this area, patients randomized to a short, pharmacy-led, training program in the use of their inhaler achieved significantly improved clinical and quality of life outcomes compared to a control group who received no training.[21]

The potential economic advantages of improving inhalation technique are likely to be compelling. Poor inhaler technique leads either to worse asthma control than could otherwise be achieved, or to stepping up to higher doses or prescribing of additional therapies such as fixed dose combinations in patients who could manage well with inhaled steroid therapy alone. Hence there is tremendous potential for improved inhaler technique to lead to better asthma control and reduced prescription costs. While it is important to consider the costs of interventions to improve inhaler technique, given the financial and health burden of poor asthma control, it is likely that a program which effectively shows the impact of improved inhaler technique on asthma management would be considered cost effective and should be cost saving. Real-life research either in terms of pragmatic trials or observational research are needed to confirm the true economic advantages of improving inhalation technique. In principle, pragmatic studies can be undertaken to evaluate the advantages of improving inhaler technique as an alternative to increasing the dose of existing therapies; however, payers are likely to want to see evidence that improving inhaler technique leads to measureable health outcomes and resource saving benefits in a real-life setting.

Reasons for inhaler errors

Multiple factors impact on inhaler use. These can be grouped into several broad categories, which relate to the device itself, the patient (consumer) or the health care professional.

The device

There are many different types of inhaler devices available to patients and they can differ in terms of:

- The way in which the inhaler dispenses the medication; whether it is passively or actively generated (i.e. the aerosol-generating properties which can be propellant, mechanical, or compressed air)
- The type of formulation (e.g. solution, dry powder etc)
- Whether the inhaler contains medication in a single- or multi-dose, is disposable or refillable, or contains a reservoir
- Dose preparation for DPIs.

Each of the different drug delivery systems demands a certain level of physical skill, manipulation, dexterity, hand strength, lung capacity and/or hand-lung co-ordination in order to ensure optimal/correct inhaler use.[22–26]

Often, it is the very young and the elderly who experience physical difficulties when using an inhaler device.[27] Therefore, there may be an increased risk of inhaler errors if due consideration is not given to the patients' individual practical abilities when prescribed inhaler devices. The following considerations are suggested:

- Check natural inhaler technique — if the patient tends to breathe in slowly use an MDI or fast and hard use a DPI[10]
- Keep device consistent — don't mix MDI and DPI inhalers[28]
- Check for usage errors — if the patient displays errors of actuation and inhalation use a breath actuated MDI (BAI) or a small particle formulation
- Use training aids for encouraging slow inhalation with MDI devices.

The patient/consumer

In addition to physical capabilities, several other patient-related factors may impact on inhaler use including their health beliefs/beliefs about medications, adherence and patient device preference. While understanding the patient's psychosocial status and the way in which it impacts on health behavior is complex, some key criteria need to be considered in terms of inhaler use.

In order to optimize disease management, patients are required to demonstrate correct inhaler technique, both at the outset of treatment and as they continue to use their inhaler over time.[21] However, studies indicate that between 40 and 60% of people with asthma are non-adherent to their medication.[29–31] Patients' beliefs about their condition and medications impact on their level of adherence to regular medication.[23,32–40] Patients who believe using their inhaler is an important part of their asthma management demonstrate higher levels of correct inhaler use.[32] Another important factor to consider is patient preference for inhalers. This can be classified in terms of operational use (e.g. ease of learning to use, holding and operating, cleaning etc), convenience (e.g. size, color, shape, durability, weight, etc) and oral sensation (e.g. taste and irritation). Evidence indicates that patients do express preference for particular inhaler devices and that this is associated with increased ease of teaching the patient how to use the inhaler as well as increased likelihood of correct use.[41,42]

The healthcare professional

The role of healthcare professionals in inhaler use is critical, both in achieving initial correct inhaler technique and also in maintaining this correct inhaler use over time.

Inhaler technique training delivered to patients by healthcare professionals is important in terms of the nature, frequency and skill level demonstrated. Only 15–69% of healthcare professionals (across all disciplines) can demonstrate correct inhaler use,[43–47] a low proportion of patients receive inhaler use education[48] and an even smaller proportion of patients have their inhaler technique reviewed over time.[48] Consequently, approximately half of patients who initially learn how to use their inhalers properly, do not maintain this correct technique over time.[49] As is becoming normal for spirometry testing, a system of validation of training ability and inhalation assessment is proposed, for healthcare professionals who prescribe inhalers.

Another critical concept is the nature of the education delivered. The most effective patient training technique in correct inhaler use has been found to be verbal instruction combined with physical demonstration.[38,48,50] Repeating this education over time increases the proportion of patients returning to follow-up visits who maintain the correct technique.[21,49]

Cultural barriers and inhaler use in asthma

Barriers including religious and cultural beliefs may impact on the use of inhalers and reduce the impact of educational interventions.[51] In some populations, the use of an inhaler is seen as improper or impolite and oral drugs may be favored. Moreover, healthcare professionals need to be aware that some CFC-free inhalers contain alcohol, since certain populations may have religious and/or cultural concerns regarding the use of such preparations.[52]

Improvement of inhaler technique from a technology perspective

There are two major compliance issues for patients using medication: intentional and unintentional non-compliance.

Unintentional non-compliance occurs when a patient makes inadvertent mistakes using the device. This issue can be addressed with technology by making devices more 'self explanatory'. The number of possible errors should be investigated by conducting handling studies. The more complex an instruction and the more handling steps needed to start the inhalation process, the greater the chance of an error occurring. For example, if the activation of a device is needed as a separate step, this step could be combined with another, resulting in a simpler instruction such as, 'on removing the cap, the device is activated'.

A patient's breathing capacity is a key factor as it determines the amount of drug reaching the lungs.[10] Technical developments can help patients to breathe in correctly by providing instructions on potential errors.

Intentional non-compliance exists when the patient decides to refrain from taking the medication, to only take it from time to time or to knowingly use the wrong inhalation technique. This issue is more difficult to address with device developments. As an important first step, the reasons for the patient's behavior should be determined. In some cases, electronic compliance monitoring and motivation by (automated) reminders might be a helpful solution. The patient should understand the benefits of using the medication on a regular basis and appreciate the importance of each handling step. With modern information technology it should be possible to give instructions and to explain likely errors and mishandling.

In cases of severe or uncontrolled disease,[1] patients should be offered a self-monitoring system and/or a tool which enables a professional instructor (nurse, MD,

Table 1 Critical inhaler handling errors associated with specific inhaler devices. Critical errors are defined as when a patient performs an error, displays imperfect technique or lacks knowledge on usage or maintenance of the inhaler device that is likely to significantly impair the delivery of adequate medication on all occasions.

Device	Critical error
Metered dose inhalers (MDIs) without a spacer	Failure to remove the cap
	Not holding the inhaler upright
	Actuation not corresponding to inhalation; actuation before inhalation
	Actuation not corresponding to inhalation; actuation is too late (Puff 1)
	Failure to actuate
	Failure to inhale
	Inhale too fast
	Inhalation through the nose
	When asked — patient does not know how to tell that their device is empty
Metered dose inhalers (MDIs) with a spacer	Failure to ensure a tight seal when mouthpiece is inserted into spacer. There should be a click heard with the Volumatic and with the AeroChamber device. It should be inserted with tight seal and the inhaler should be vertical at 90°
	Failure to hold spacer with inhaler upright
	Failure to actuate just one dose into the spacer (either no dose actuated or actuates more than one dose)
	Spacer mouthpiece is inserted correctly but failure to seal lips
	Failure to inhale through mouthpiece within 2 s of discharging one dose
	Failure to actuate a dose into the spacer
	Failure to inhale
	Inhalation through the nose
	Failure to hold breath (or to hold for $<$3 s)
	When using two doses, starting to inhale through mouthpiece within 2 s of discharging the first dose
	Coughing during the inhalation
	If prescribed Fostair, failure to know that they should use their inhaler within 20 weeks/5 months after receiving it from the pharmacy
	Spacer has faulty parts, valves, or cracks in the plastic
	Having washed the device in soapy/detergent water
	Failure to air dry the device
	Failure to remove the cap
Dry powdered inhalers (DPI): Accuhaler	Failure to slide cover as far as possible
	Failure to slide lever fully to open mouthpiece
	Holding in a downward position after dose preparation (before inhalation)
	Shaking after dose preparation
	Blowing into the device before inhalation
	Failure to put in mouth and seal lips around mouthpiece
	Inhalation is not forceful from the start
	Failure to inhale through mouthpiece
	Inhalation through the nose
	Failure of the patient to know when the device is empty
Dry powdered inhalers (DPI): Turbohaler	Failure to remove cap
	Shaking during preparation
	Device not held upright (mouthpiece skywards) when the base is twisted during dose preparation (within 45°)
	Dose not prepared correctly — twisting the base until it clicks
	Dose not prepared correctly — turning it back to the original position
	Device not held upright (mouthpiece skywards) after the base is twisted until inhalation (within 45°)
	Shaking after dose preparation
	Failure to put in mouth and seal lips around mouthpiece
	Inhalation is not as fast as the patient can achieve (defined as a very fast suck)
	Inhalation is not forceful from the start
	Failure to inhale through mouthpiece

	Inhalation through the nose
	Failure to slide cover as far as possible and then lever to open mouthpiece
	Failure to breathe out slowly to empty the lungs
	Breathing out into the device before inhalation
	Failure to tilt head such that the chin is slightly upwards
	Inhalation is not as long as the patient can achieve
	Failure to hold breath (or to hold for <3 s)
	Failure to replace cap after second inhalation

physiotherapist) to provide feedback. The benefit of simple systems which monitor and give feedback to patients with asthma has been shown.[53] In the future electronic monitoring and feedback systems, used in combination with inhalation devices, may make this much easier to achieve. However, it remains undetermined whether patients and healthcare professionals are in favor of routinely using such monitoring. Compliance monitoring has been attempted in the clinical trial setting, but even in this situation it is of limited value. Furthermore, compliance monitoring does not confirm that the prescribed treatment is regularly reaching the patient's airways. The identification of biomarkers which could determine the dose of medication received by the target tissues is a potential future research objective.

Another aspect which should be considered is the age of the patient. Children will need different devices to those used with adolescents and adults. In addition, elderly patients will also have different device requirements and may need special features incorporated. Younger patients typically prefer smaller, more technical delivery systems. In contrast, elderly or disabled patients might benefit from larger devices which can be handled easily and which have clearer displays and larger actuators.

To summarize, technical solutions exist for both types of non-compliance. The age of the patient using the device should always be considered.

Educational interventions to reduce inhaler technique errors

Few studies have rigorously examined interventions to improve and maintain skill in inhaler use and reduce error. Inadequate inhaler technique decreases the effective delivery of drugs, thus interventions which reduce inhaler error may improve patient outcomes.[17,27,54] Although multiple studies suggest that new "improved" inhaler devices reduce errors and improve outcomes, a review of controlled trials demonstrated that a broad range of inhaler devices are equally effective in delivering therapy when patients use them appropriately.[55]

Improving healthcare professional inhaler knowledge and skills

While virtually all comprehensive patient education programs include some level of education about the correct use of inhalers, most patients do not participate in such formal programs and instead rely on instruction received from healthcare professionals in the clinic. However, these healthcare professionals typically lack the appropriate knowledge and skills in using different inhaler devices.[56] For this reason, studies have examined educational interventions designed to "train the trainer" and improve healthcare professional inhaler competence. It has been demonstrated that a single education session improves medical residents' inhaler knowledge and skills.[57] Another study demonstrated that pharmacists who participated in a single-session education workshop showed significantly better knowledge and skills than a control group, and that this knowledge was retained at a high level.[58] Internet-based, interactive, multimedia tutorials represent a promising, new low-cost mechanism for educating healthcare professionals. It has been shown that a small-group lecture format with web-based tutorial significantly improved pharmacy students' knowledge of MDI technique.[59] Similar effectiveness of a web-based inhaler tutorial designed for healthcare professionals has also been reported.[60]

Improving patient inhaler knowledge and skills

Focused educational interventions designed to improve inhaler skills of adults and children with MDIs, pMDIs and DPIs can result in significant reduction in patient inhaler error.[21,49,61–66] Written and verbal instructions alone improved patient technique, but the addition of a physical demonstration delivered by a pharmacist resulted in markedly better retention of inhaler skills.[49] Another study showed that a simple 2.5 min inhaler education intervention delivered by trained community pharmacists not only significantly improved patient inhaler technique but also resulted in improved asthma outcomes.[21] Other educational strategies for improving the efficacy of inhaler technique include the use of multimedia computer presentations,[64,65] use of a training aid (2Tone Trainer),[1] and telepharmacy counseling combined with an interactive video.[66]

Specific challenges for pediatric inhaler use

Patients of all ages can demonstrate problems when using their inhalers. Each inhalation method and age group presents specific problems but most children can be successfully trained to effectively use their inhalation device, no matter which method it utilizes.[5] The choice of inhaler device for preschool children is limited to either nebulizers or a pMDI plus a spacer. In school children all inhalation methods can be used and the choice depends on the child's ability and preference.[67]

Preschool children

In pre-school children the choice between pMDI and spacer or nebulizer is an individual choice. It is important that a facemask is used, and that this fits tightly and the child is not crying whilst using the inhaler.[67] Nasal breathing provides sufficient lung deposition in these patients. The percentage of lung deposition is correlated to age and weight[68,69] and the inhaled dose therefore increases with age or weight.[70] Even the low deposition values reported in babies[68] should be sufficient to manage their disease.

School children and adolescents

Lung deposition

In older children inhalation through the mouth provides better lung deposition than nasal breathing.[68] As soon as the child can cope they should be switched from a mask to a mouthpiece, and use a single deep inhalation instead of tidal breathing.[67] When using tidal breathing in 2–7 year olds, 2 and 3 breaths with a small and a large spacer are sufficient for adequate dosing.[71] For the concomitant treatment of allergic rhinitis and asthma, exclusive nasal inhalation through a facemask (mouth closed) attached to a large volume valved spacer may be as effective as the dual (intranasal plus inhaled corticosteroid) conventional treatment.[72]

Spacers

Spacers are useful in children and other patients that have problems using a pMDI or DPI. A variety of spacers, ranging from small to large volume, are available.[67] Conflicting reports claim[70] or deny[73] that differences exist between spacers. Plastic spacers with antistatic properties appear to provide better lung deposition than those without,[67] even when compared with metal ones.[74] Each spacer has its own particular recommended washing and use procedures and so it is important to follow the instructions in the Patient Information Leaflet.[67] Static delays in inhalation and multiple actuations decrease the dose emitted and use is restricted due their bulk.[67] In developing countries home-made non-valved spacers provide equivalent efficacy to the commercially available spacers.[75]

DPI and pMDI use

Changing children to portable inhalers is age-dependent and DPIs can be introduced successfully at an earlier age than a BAI or a pMDI.[5] However, children may have problems achieving the DPI and pMDI recommended techniques.[5] It is important, therefore, that they are reviewed regularly by those who have received inhalation technique training and can themselves competently use these devices.

A DPI should be used with an inhalation that is as forceful as the patient can achieve and this should be continued for as long as possible.[67] The inhalation should be forceful from the start rather than build gradually. These inhalation maneuvers with a DPI are necessary to provide sufficient turbulent energy to de-aggregate the metered dose during an inhalation so that the emitted dose has the potential for lung deposition.[76] A pMDI should be used with a slow inhalation, continued for as long as possible, and the actuation of the dose should be made when the subject starts to inhale.[67]

Inhalation flow with DPI

Using an inhalation that is as fast as possible from the beginning and continued for as long as possible is important.[67] De-aggregation of the formulation in the metered dose of a DPI occurs as a result of the turbulent energy generated by the interaction of the patient's inhalation flow with the DPI's resistance.[76] The peak inhalation flow of children through a DPI increases with age[77] and decreases during acute exacerbations.[78–80] The peak inhalation flow achieved through each type of DPI is related to its internal resistance and the patient.[76] This leads to children achieving lower flows when the resistance of the DPI is higher.[79–81] Lung deposition[69] and clinical response in children[77] is probably related to an insufficient turbulent energy leading to inefficient de-aggregation. For a medium/high resistance DPI, this de-aggregation is reduced when the inhalation flow is less than 30 l/min.[82] However if the DPI's resistance is higher, then usually the minimum threshold turbulent energy will occur at a lower flow to provide an effective clinical response.[83]

Coordination with pMDI

Coordination between dose actuation and the start of an inhalation, as well as using a slow inhalation, are important to ensure good penetration into the lungs.[67] Inhalation technique errors are more common in children using a pMDI.[84–86] Fast inhalation is a common error[86] but training children to inhale slowly may be difficult.[5] Although BA-pMDIs would help and should be easier to train children how to use,[5] the range of drugs is limited and the licensing of BA-pMDI corticosteroids does not generally extend to children. Extra-fine particles may be less dependent on an optimal inhalation technique[67] and provide good, lung deposition in children.[87,88] However, the range of these products is limited and is mainly restricted to off-label prescribing in children.

Training in inhaler technique

In all age groups training in inhaler technique is useful for each type of inhaler[84,85,89,90] and should be repeated at regular intervals.[84,85] A lower inhaled corticosteroid dose and improved asthma control occurs in children when the inhalation technique improves.[91]

The need for policy change

There is clearly a need for policy makers to grasp the importance of improving inhaler technique through the strategies discussed in this paper. By instituting programs to address inhaler technique assessment and training in all health care settings, substantial health gain could be achieved. Health care costs for asthma would be decreased and future increases in expenditure reduced. The recent call for action published in the European Respiratory Society Journal[10] which emphasized the importance of correct inhaler choice, proper training and ongoing education to maintain technique merits support at the policy level to achieve its desired outcomes.

Conclusions and recommendations for next steps

Asthma control and COPD outcomes are clearly sub-optimal and inferior in clinical practice to those obtained in clinical trials. A major contributing factor appears to be poor inhaler technique and all of its consequences. Extensive studies are required on the impact of the inhalation technique in achieving optimal asthma control.[92] These studies could identify the most effective training methods, tools or inhalers.

At a time of increasing prevalence of obstructive lung disease against a background of restricted health care spending, making the most effective use of inhaler devices has now become a priority for all involved, whether they are health care providers, governmental bodies, researchers, health care professional groupings or patient organizations. Key aspects of this issue are shown in Table 2 which summarizes the research, policy, educational and pharmacoeconomic needs. We are clearly at the point where the problem of inhaler misuse can no longer be ignored but should be fully embraced by all parties involved in providing care for patients with obstructive lung disease.

Acknowledgments

The Inhaler Error Steering Committee is a consortium of specialists with expertise in inhalation therapy and inhaler compliance. Members of the Inhaler Error Steering Committee receive a small honorarium from Teva Pharmaceuticals and Mundipharma International Corporation Limited for attending meetings, and travel expenses are reimbursed.

Conflict of interest statement

Sinthia Bosnic-Anticevich has no shares in any pharmaceutical companies. In the past five years she has provided consulting on the topic of inhaler device use to Pharmaceutical Society of Australia and the Pharmacy Guild of Australia. She has received research funding from the Australian Commonwealth Government Department of Health and the Australian Research Council.

Andrew Briggs has no shares in any pharmaceutical companies. He has received sponsorship to carry out studies, together with some consultancy agreements and honoraria for presentation, from several pharmaceutical companies that market inhaled products. These include AstraZeneca, Boehringer Ingelheim, GlaxoSmithKline, Meda, Nycomed, Teva, and UCB. Research sponsorship has also been received from grant awarding bodies (UK MRC).

Jean Bousquet has received honoraria from the following organizations for his participation in scientific advisory boards, lectures and press conferences: Stallergènes, Actelion, Almirall, AstraZeneca, Chiesi, GSK, Merck, MSD, Novartis, OM Pharma, Sanofi-Aventis, Schering Plough, Teva, and Uriach. Member of GA^{2}LEN (Global Allergy and

Table 2 Proposed research, policy and practice needs in inhaler technique.

Research needs	
To understand the gaps in education and knowledge	DELPHI-based research to explore the relationship between inhaler technique and asthma control identifying gaps in education and knowledge
Health economic and clinical outcomes associated with optimal inhaler technique	Assess the value of training in terms of clinical outcome. Measured by two matched groups of primary care physicians, one trained in optimum inhaler technique, the other not
Review of the impact of cultural beliefs on inhaler use	Measure the significance of cultural beliefs and why non-compliance is more prevalent in some populations
Policy needs	
Leverage the importance of inhaler technique within the health policy framework	Identify the impact of critical inhaler errors and poor inhaler technique and present a stepwise approach to change
Practice/education needs	
Current education on inhaler technique is inconsistent and not always accurate	Develop 5 key messages with supporting references to be widely communicated to HCPs and patients 1. Prepare the device • Check orientation • Actuate the device • Shake the device if it is an MDI 2. Prepare the body • Breathe out fully away from the mouthpiece • Consider differences between MDI and DPI devices 3. Place mouthpiece in mouth — ensure a good seal and make sure that the teeth are not in front of the device 4. DPI — breathe as fast and as hard as you can from the beginning 5. MDI — start breathing slowly and actuate, breathe in over 5 s. Hold the breath for at least 5 s
Develop a pharmacoeconomic rationale for change	Inform HCPs and patients that with improved inhalation technique less drug will be required to achieve the same or better control

Asthma European Network), supported by the Sixth EU Framework program for research, contract n° FOOD-CT-2004-506378.

Henry Chrystyn has no shares in any pharmaceutical companies. He has received sponsorship to carry out studies, together with some consultant agreements and honoraria for presentation, from several pharmaceutical companies that market inhaled products. These include Abdi Ibrahim, Almirall, AstraZeneca, Boehringer Ingelheim, Chiesi, GlaxoSmithKline, Innovata Biomed, Meda, Mundipharma, Orion, Sandoz, Teva, Truddell and UCB. Research sponsorship has also been received from grant awarding bodies (EPSRC and MRC).

David Price has consultancy arrangements with Boehringer Ingelheim, GlaxoSmithKline, Merck, Mundipharma, Novartis, Chiesi and Teva. He or his research team have received grants and support for research in respiratory disease from the following organizations in the last 5 years: UK National Health Service, Aerocrine, AstraZeneca, Boehringer Ingelheim, Cipla, GlaxoSmithKline, Merck, Mundipharma, Novartis, Nycomed, Pfizer, Chiesi and Teva. He has spoken for: AstraZeneca, Boehringer Ingelheim, Chiesi, Cipla, GlaxoSmithKline, Merck, Mundipharma, Pfizer and Teva. He has shares in AKL Ltd which produces phytopharmaceuticals. He is the sole owner of Research in Real Life Ltd.

Cindy Rand has no shares in any pharmaceutical companies. In the past five years she has served on Scientific Advisory Boards and/or provided consulting on the topic of patient adherence to the pharmaceutical companies Teva, Merck, Schering-Plough and GlaxoSmithKline. She has received research sponsorship from the National Institutes of Health (US).

Gerhard Scheuch has no shares in pharmaceutical companies. He is founder and shareholder of Activaero GmbH a private drug delivery company and has provided consulting for different pharmaceutical companies including Teva, GlaxoSmithKline, Boehringer Ingelheim, Novartis, Grifols, Bayer, Sandoz.

Medical writing and editorial support for the publication was provided by IMC Healthcare Communication.

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