

Mask Use with Spacers/Valved Holding Chambers and Metered Dose Inhalers among Children with Asthma



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Abstract

Inhaler misuse is highly prevalent and associated with high morbidity and costs. For metered dose inhalers, proper use can be supported with devices such as spacers/valved holding chambers (VHCs) and masks to effectively deliver inhaled medication to the lungs. However, guidelines are vague about which children with asthma should use spacers/VHCs with masks to deliver medication from metered dose inhalers as well as when they should transition to spacers/VHCs with mouthpieces. In this paper, we provide a focused review of the evidence for mask use, highlighting unclear and conflicting information in guidelines and studies. We synthesize the

differences in recommendations and practice. Based on these findings, we call for future research to determine the appropriate age and necessary skills for transitioning children from using metered dose inhalers with spacers/VHCs and masks to using spacers/VHCs and mouthpieces. Guidelines about mask use should be standardized to help ensure optimal medical delivery for patients, provide consistent inhaler prescriptions and education across settings, and support team-based care to help lower pediatric asthma morbidity and costs.

Keywords: child; metered dose inhalers; nebulizers and vaporizers; spacers; valved holding chambers

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Asthma affects 8.4% of children in the United States, and the associated exacerbations lead to approximately 80,000 hospitalizations and 550,000 emergency department (ED) visits annually among youth (1). Asthma can be effectively managed with respiratory inhalers, which deliver medication directly to the lungs when used correctly (2). Specifically, metered dose inhalers (MDI) are most commonly prescribed to provide quick-relief and controller medications.

Studies estimate that more than half of children who use MDIs without devices, such as spacers and valved holding chambers (VHCs) with mouthpieces or masks, gain little to no clinical benefit from their medication because of incorrect inhaler technique (3, 4). Previous research has defined correct inhaler technique based on a patient performing a series of steps, ranging from 5 to 14, that are necessary for the inhaled medication to be effectively deposited into the lungs (4). Although MDIs allow for some forgiveness in medication

delivery even when misused, because of the fine particles they contain (5), inhaler misuse is cited as one of the key reasons for failure of inhaled therapies (6–9). The implications of inhaler misuse are broad, not only for patients but also for health systems as a whole. Patients with incorrect inhaler technique are more likely to have poorly controlled asthma, which is associated with increased exacerbations and healthcare utilization (7, 10–12). Individuals with inhaler misuse may also lose confidence in their treatment regimen and subsequently

have poor adherence, thereby contributing to asthma morbidity (12). Furthermore, the cost of inhaler misuse is estimated at \$7–15 billion, which constitutes a sizable proportion of the total \$50 billion spent on inhalers for all respiratory conditions each year (13).

Given the significant impact of inhaler misuse on both patients and health systems, it is critical to find solutions that facilitate correct inhaler technique. These solutions must address both the variation in clinical guidelines and the inadequate education about inhaler technique to successfully decrease inhaler misuse among patients with asthma. Proper MDI use can be supported with appropriate devices, such as spacers and VHCs with mouthpieces or masks. Current asthma guidelines show general agreement that younger children should use an MDI and spacer/VHC with a mask, whereas older children should use an MDI and spacer/VHC with a mouthpiece (2, 14, 15). However, these guidelines provide vague and conflicting information about the age that children should be directed to stop using masks with their spacers/VHCs, leading to wide variation in practice. Such variation creates confusion for patients, families, and clinicians and reduces opportunities to teach children proper inhaler technique, thus missing the chance to support effective medication delivery, reduce acute care utilization, and improve health outcomes. This review aims to discuss the evidence about mask use with spacers/VHCs in children, synthesize recommendations and practices, and call for future studies to determine standardized best practices.

A focused review of the literature on spacer/VHC and mask use in children with asthma was performed using combinations of the keywords mask, spacer, valved holding chamber, inhaler, mask attachments, asthma, pediatric, and children. The methods sections of relevant studies were used to determine whether the studies should be included or excluded. Specifically, studies were excluded if they did not test a pediatric age range, investigated the use of spacers/VHCs with mouthpieces but not spacers/VHCs with masks, or mentioned masks peripherally without providing substantive evidence on the use of masks.

Development of Masks

Spacers/VHCs and masks were introduced after the development of the MDI. The first

MDI was manufactured in 1955 to provide inhaled medication for asthma. However, MDIs have proven largely ineffective, as it is physically impossible for individuals to breathe a significant amount of the medication released during actuation of the inhaler into their lungs before the medicine coats the throat and mouth. Thus, when MDIs are used without devices (such as spacers or VHCs), most of the medication is deposited prematurely in the mouth and throat and does not reach the individual's lungs (16).

To help overcome the potential challenges of medication delivery to the lungs, the first commercially available spacer was released nearly two decades later (1976). The spacer was developed in an attempt to reduce the oral deposition of prescribed medications and to overcome poor hand-breath coordination of children. Spacers allow for more effective delivery of MDI medication in children who are young, experiencing breathlessness, or unable to hold their breath (17). Although a spacer is a reservoir that separates the MDI from the patient's mouth to allow for slow inhalation of the medicine, a VHC is a type of spacer that also has a one-way valve that allows for air to flow into, but not out of, the patient's mouth (18). When VHCs were first developed (1983), it was believed that the addition of valves to spacers did not confer any clinical advantage. After a series of revisions were made to the initial design of the VHC (by 1998), it was found that valves can mitigate poor coordination (17).

Soon after the development of spacers and VHCs, the first mask to be used with a spacer/VHC and MDI was produced for commercial sale (1986) (17). Masks were developed to allow for better medication delivery, specifically for infants and children who are too young to hold their breath or to follow instructions (19). Masks are most effective when there is a tight seal around the child's face (3) and when used with sleeping or calm patients (20–22).

Children who use a spacer/VHC with a mask often use the tidal breathing technique, whereas those who use a spacer/VHC with a mouthpiece often use a breath-hold technique when administering their MDI medication (23). It has been demonstrated that the breath-hold technique leads to greater lung deposition of medication across individuals of all ages (24).

Studies of Mask Use

No studies have systematically documented the prevalence of mask use among children.

Rather, research that examines the use of a spacer/VHC and a mask with an MDI has primarily focused on its efficacy in children under 5 years of age (Table 1).

A study by Tal and colleagues demonstrated that in children 3 months to 5 years of age, inhaled medication administered via MDI, spacer, and mask is effectively delivered to the lungs, as measured by imaging that assesses deposition of radiolabeled medication. The authors state that older children should use a spacer with a mouthpiece for better lung deposition of medication, but they do not cite specific evidence to validate their opinion nor specify what criteria children should meet before the transition from a spacer with a mask to a spacer with a mouthpiece (22).

Additionally, in a double-blind study by Conner and colleagues, researchers demonstrated that a holding chamber with a mask can effectively deliver inhaled medication to children aged 6–36 months, as measured by patients' symptom relief. However, the study did not investigate the effectiveness of spacers/VHCs with masks in children over 3 years of age (25).

A more recent study by Ditcham and colleagues showed no significant difference in the lung deposition of radiolabeled albuterol when administered to 3- to 5-year-old children using an MDI and spacer with mouthpiece versus an MDI and spacer with mask (26). The study did find, however, that there was significantly less head and neck deposition of albuterol when administered using a spacer with a mouthpiece than with a spacer with a mask. Notably, medication was administered by the staff. Thus, it is important to note that these results may not persist if patients or family members administered the medication instead of healthcare professionals because of the importance of the mask seal (27, 28).

In contrast to the 0- to 5-year-old population, there is a paucity of research about the use of masks in children over 5 years of age. None of the published studies identified and reviewed for this paper compared the effectiveness of an MDI with a spacer and a mask with the effectiveness of an MDI with a spacer and a mouthpiece in children over 5 years of age. It is possible that this study has not been conducted because mask use is not recommended in this age group within the guidelines. However, in our experience, the use of an MDI with a spacer/VHC and a mask is common in children over 5 years of age; thus, research is

Table 1. Studies of the use of masks with metered dose inhalers and spacers/valved holding chambers

Author, Year, Reference Number	Population	Device	Imaging or Measurement	Results	Conclusion
Tal and colleagues, 1996 (22)	13 males, 3 mo–5 yr	MDI, spacer with mask	Imaging of deposition of radioactive salbutamol administered via spacer with mask	Lung imaging after MDI inhalation via a spacer showed deposition of the drug in both the central and peripheral intrapulmonary airways	Infants and toddlers can be reliably and safely given inhaled medication with an MDI and spacer with a mask
Conner and colleagues, 1989 (25)	29 children, 6–36 mo	MDI, spacer with mask	Administration of salbutamol or placebo via a spacer with mask followed by a double-blind symptom questionnaire	A holding chamber with mask is effective in delivering medication to the lungs	Young children can effectively receive respiratory therapy via an MDI and spacer/VHC with a mask
Häselbarth and Svedmyr, 2020 (28)	Face models, mimic 1 yr and 4 yr	MDI, spacer with mask, spacer with mouthpiece	Amount of fluticasone propionate deposited on a face model with a pressurized MDI connected to a VHC with a mouthpiece, VHC with a sealed facemask, or VHC with an unsealed facemask	There was better drug output without a facemask and amount of medication delivered was dependent on the seal of the facemask	Facemasks should have a tight seal and children should shift to using a VHC with a mouthpiece as early as possible
Ditcham and colleagues, 2014 (26)	12 males, 3–5 yr	MDI, spacer with mask, spacer with mouthpiece	Anterior and posterior planar scintigraph taken after administration of albuterol with a spacer with a mask or a spacer with a mouthpiece	Lung deposition was 9.1% with a facemask and 7.9% with a spacer mouthpiece, and head and neck deposition was 10.6% with a facemask and 5.3% with a spacer mouthpiece	Lung deposition of albuterol through a MDI and a spacer with a mask is high, but is not significantly different from deposition through an MDI and a spacer with a mouthpiece
Zar and colleagues, 2000 (16)	40 children, 3–7 yr	MDI, spacer with mask, spacer with mouthpiece	Measurement of lung deposition of aerosolized technetium-99 m DTPA inhaled during the sequential use of two randomly assigned spacers (two spacers had facemasks, one spacer had a mouthpiece, one spacer was a 500-ml bottle)	No difference in lung deposition when patient used a spacer with a mask or a spacer with a mouthpiece and higher lung deposition when patient used a bottle instead of a spacer with a mouthpiece	There is no difference in lung deposition between a mask and a mouthpiece with a spacer

Definition of abbreviations: DTPA= diethylenetriamine pentaacetate; MDI= metered dose inhalers; VHC= valved holding chamber.

needed to compare the effectiveness of a spacer/VHC with a mask versus a spacer/VHC with a mouthpiece.

In addition, while research has looked at the use of spacers/VHCs with masks in younger children and the use of spacers/VHCs with mouthpieces in older children, no studies have evaluated the specific age or factors associated with a successful transition from a

spacer/VHC with a mask to a spacer/VHC with a mouthpiece. Furthermore, the child's ability to do the tidal breathing technique versus the breath-hold technique has not been studied as a part of the transition from spacer/VHC with a mask to spacer/VHC with a mouthpiece. These gaps in the research have inevitably contributed to the variation present in current guidelines for mask and spacer use.

Recommendations for Mask Use

In the more than 30 years since the invention of spacers, VHCs, and masks, guidelines from various professional organizations have differed in terms of recommendations about the use of masks

and spacers/VHCs in clinical care. Many guidelines instruct clinicians, including physicians, nurses, and respiratory therapists, to use MDIs with spacers/VHCs and masks in young children, although some do not specify the age range for which mask use is appropriate.

Current guidelines make conflicting recommendations. The National Heart, Lung, and Blood Institute asthma guidelines recommend that children under 5 years of age should use a “spacer or valved holding chamber or mask” with an MDI (2). Later in that section, it states those under 4 years of age should use a VHC with a mask, whereas children 4 years or older should use a spacer or VHC. The National Heart, Lung, and Blood Institute guidelines do not make recommendations about the use of spacers or masks in children over 5 years old, even though studies indicate all children should use spacers/VHCs with MDIs (29). In addition, the Global Initiative for Asthma guidelines recommend that children less than 3 years old should use a pressurized MDI with a spacer/VHC and a mask, and most 3- to 5-year-old children should use an MDI with a spacer/VHC and a mouthpiece (14). Elsewhere in the guideline, a table indicates that children 0–3 years of age should use a mask, whereas 4- to 5-year-old children should use a mouthpiece for the MDI and a spacer. The Global Initiative for Asthma guidelines do not discuss spacer use after 5 years of age. The respiratory therapist guidelines state that children under 4 years of age should use a spacer/VHC and a mask with an MDI, children over 4 years of age should use a spacer/VHC with an MDI, and children over 5 years of age should use an MDI alone (15). None of these guidelines make specific recommendations about the developmental stage at which children should stop using a mask with their spacer and instead state that children should use a mask until they are comfortable using a spacer/VHC and a mouthpiece with an inhaler (15) or they can demonstrate good technique (14).

When considered together, the guidelines lack clarity and offer conflicting recommendations about mask and spacer/VHC use. They specify different ages at which youth should use masks with spacers/VHCs, sometimes providing inconsistent recommendations within the same guideline. For those children using masks, the recommendations indicate that the transition from a spacer/VHC with a mask to a spacer/VHC with a mouthpiece

should occur sometime between 3 and 6 years of age. This recommendation about the transition stems from evidence that young children cannot create a tight seal around the mouthpiece of a spacer (6) and cannot control their breathing to coordinate inhalation with the actuation of the inhaler (23); until they are able to, children should instead use a mask with the spacer/VHC. However, the age range at which children should ultimately be transitioned to using a spacer with a mouthpiece is quite large and does not account for other factors that may influence the ability of a child to use an MDI with a spacer/VHC and a mouthpiece rather than with a mask (23, 30).

Variability in Clinical Practice

In our experience in both clinical and research settings, clinicians and families describe that some children older than 5 years of age are using an MDI with a spacer/VHC and a mask. There is also a great deal of variability in practice surrounding the transition of patients from a spacer/VHC with a mask to a spacer/VHC with a mouthpiece. Clinicians in various settings and institutions have cited that many patients over 5 years of age are not transitioned to the use of an MDI with a spacer/VHC and a mouthpiece to deliver medication despite having the coordination to do so. Currently, no empirical evidence exists to highlight this variability in clinical practice or discuss its origin.

Physicians, nurses, pharmacists, and respiratory therapists whom we have encountered have expressed a desire for clearer and more specific guidelines about the actions that they should take to ensure that patients are using the correct device(s) on the basis of their age and skill levels. These clinicians have shared that some of their patients have not been transitioned from a spacer/VHC with a mask to a spacer/VHC with a mouthpiece because it is unclear which medical professional is responsible for telling patients to stop using masks and for providing inhaler technique education. Furthermore, clinicians have explained that families describe receiving mixed messages from healthcare professionals about which devices to use for MDI administration. As a result, patients and their families may have reduced confidence in their medical teams and the plan of care, potentially contributing to reduced adherence to recommended treatments.

This variability in mask use among children with asthma may be the result of several factors. First, clinicians may be wary of transitioning their patients from using a spacer/VHC with a mask to a spacer/VHC with a mouthpiece because there is an increased risk of misuse when patients use a new device and/or new technique to administer their medication (31). To ensure clinical stability and prevent adverse side effects, particularly with corticosteroids, careful oversight by the clinician is needed each time a device and/or technique is changed. As a result, clinicians may choose not to transition devices for patients who are unable to receive consistent care. Second, because of the intermittent nature of asthma, patients may not seek medical care until they experience significant symptoms or an exacerbation, leading to inconsistent care over time. These gaps in care may occur across months or years, which may mean that a child has had significant changes in their development and coordination, thus impacting their ability to properly use an inhaler. Third, clinicians may have different educational foundations or beliefs about when the transition from a spacer/VHC with a mask to a spacer/VHC with a mouthpiece should occur and who is responsible for starting and overseeing this transition. These differences lead to inconsistencies regarding when and how clinicians advise their patients about transitioning the inhaler devices. Even among patients who receive guidance and education about the transition from a spacer/VHC with a mask to a spacer/VHC with a mouthpiece, children and parents may not feel comfortable with the change. In addition, patients may see many different clinicians, and, without continuity, healthcare professionals may not remember to address the manner in which the patients are using their inhalers or be aware of whether the child has transitioned their inhaler devices. Finally, financial and/or insurance restrictions may limit the ability of patients to obtain new medication delivery devices, creating a logistical barrier to the transition from a spacer/VHC with a mask to a spacer/VHC with a mouthpiece.

Proposals for Future Studies

Given the limited evidence about the optimal age for mask use, the variation in current clinical guidelines, and the range of implementation of these measures in clinical

practice, further research is needed to determine the most appropriate age and the necessary skills for the transition from a spacer/VHC with a mask to a spacer/VHC with a mouthpiece. Additional research is needed to determine the impact of transitioning the inhaler devices used by a child too early or too late to understand how it affects immediate medication delivery, short-term asthma morbidity, and long-term asthma outcomes. This research is critical to optimize inhaled medication administration and to inform guidelines for care of children with asthma.

Studies must first be conducted to understand how masks are currently used across care settings and to determine the consequences of older children using masks. Indeed, it is possible that if masks are proven to be effective in all children, regardless of age, that mask use should be investigated in adults given that poor inhaler technique is evident across all MDI users (8). In addition, work is needed to identify the criteria necessary for children to transition from using a spacer/VHC with a mask to a spacer/VHC with a mouthpiece. This research will inform the creation of specific recommendations to standardize clinical practice for mask use in children among diverse healthcare professionals and across varied clinical settings.

It is critical that we obtain a better understanding of current real-world practices related to mask use among children of various ages. This quantification can be conducted using retrospective data collected from insurance claims or the electronic medical record. Alternatively, these data can be gathered from observational studies in clinical or community settings. These results can provide insights about the types of devices that are prescribed to or used by children with asthma across various states, urban/rural communities, clinical settings, racial/ethnic backgrounds, and socioeconomic levels.

Furthermore, healthcare professionals should be surveyed to better understand the causes and effects of clinical variability in spacer/VHC and mask prescription and usage. This approach can help to determine 1) current practices for spacer/VHC and mask use among children, 2) perceived age and skills needed for patients to stop using a spacer/VHC with a mask and transition to a spacer/VHC with a mouthpiece, 3) clinicians' knowledge of correct inhaler technique with various devices, and 4) clinicians' responsibility for educating patients and subsequently transitioning

them from a spacer/VHC with a mask to a spacer/VHC with a mouthpiece.

Although some research suggests that children should be transitioned from using spacers/VHCs with masks to spacers/VHCs with mouthpieces as early as possible to maximize delivery of medication from an MDI (32), studies should test the effectiveness of a spacer/VHC with a mask versus a spacer/VHC with a mouthpiece in delivering inhaled medication to youth over 5 years of age. These studies could mirror prior research focused on children under 5 years of age to examine process measures, such as medication deposition in the lungs (22). In addition, patient outcomes, such as asthma-related exacerbations, ED visits, and hospitalizations should be evaluated through randomized trials.

These studies are critical to develop specific recommendations about the criteria needed for children to stop using spacers/VHCs with masks and transition to using spacers/VHCs with mouthpieces, analogous to those used to assess readiness to independently carry and use inhalers (32–34). In addition to age, these criteria should take into account factors such as patient access to care, assistance with medication usage, coordination level, and ability to comprehend and follow instructions. Such recommendations can inform future asthma guidelines to ensure consistency across clinicians and healthcare settings, expanding knowledge in this field and helping to improve patients' inhaler technique and asthma outcomes.

Best Practices

The implementation of several best practices holds potential to improve medication delivery for patients and support coordination among clinicians across healthcare settings. In light of high rates of incorrect inhaler use, regular and repeated inhaler education is crucial to support better asthma outcomes. The potential for gaps in care underscores the importance of clinicians reviewing inhaler technique within 4–6 weeks of introducing a new device. Given the growth of team-based care and value-based models, every individual on a care team is responsible for ensuring that each child has the ideal respiratory devices based on their age and skill level and that the patient is equipped with the knowledge to correctly use their prescribed medications.

Standardized guidelines and clear documentation in the electronic medical record about the use of devices (i.e., spacer/VHC with a mouthpiece or spacer/VHC with a mask) can support this teamwork.

Hospital admissions give clinicians necessary time to review inhaler technique with patients and provide an occasion to transition patients to the appropriate MDI delivery device. The limitations of hospital admission must be considered, including the fact that patients may be asleep, anxious, or coping with a new diagnosis during their hospitalization, all of which may lead clinicians to administer medications via MDI with a spacer/VHC and a mask regardless of which device is appropriate for the patient because it is often the easiest method of delivery. Many patients who seek care at the ED for an asthma exacerbation may not be admitted; however, clinicians in the ED can also use these encounters to transition patients to the appropriate devices by providing prescriptions and education about the appropriate devices. Asthma care in outpatient clinics, both primary care and subspecialty, presents another opportunity for clinicians to assess inhaler technique with children and their parents, transition children from a spacer/VHC with a mask to a spacer/VHC with a mouthpiece as appropriate, and provide tailored inhaler education.

In addition to doctors and nurses, respiratory therapists and pharmacists can further reinforce inhaler education and help transition between devices in these varied clinical settings. Furthermore, school nurses who oversee inhaler administration can play an important role in monitoring inhaler use to ensure effective medication delivery and to support the transition between devices, as appropriate; this can be supported via communication between the child, their parents, and the healthcare professionals who provide their asthma care. Finally, family members of the patient can reinforce this education at home. This inclusion of caregivers is essential given that the patient must be able to consistently perform the technique correctly in all settings in order for medication to be effectively delivered to the lungs. The creation of standardized guidelines supporting team-based care can help to ensure that proper devices are used, and inhaler education is consistently delivered across various settings. These guidelines should avoid using strict, age-based recommendations, which are commonly used in current

guidelines, and instead emphasize the skills that a patient should be able to perform to transition from a spacer/VHC with a mask to a spacer/VHC with a mouthpiece.

Conclusions

Although it has been shown that effective MDI use in younger children requires a spacer/VHC with a mask, it remains unclear what devices are necessary for effective inhaled medication delivery in older children. Significant variability

exists in clinical practice, and thus standardized recommendations are needed across various organizations' guidelines that can be consistently applied to inform decisions about the use of devices with MDIs and transition patients from a spacer/VHC with a mask to a spacer/VHC with a mouthpiece across healthcare settings. These recommendations should ensure personalized care that is based on patients' skill level rather than their age. Ultimately, clinicians should strive to help patients

develop and maintain proper inhaler technique by ensuring use of the appropriate device(s) and by providing repeated inhaler education. These best practices hold the potential to improve asthma outcomes, leading to lower healthcare utilization rates and fewer care-associated costs for children, families, and the healthcare system as a whole. ■

Author disclosures are available with the text of this article at www.atsjournals.org.

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