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Using A Metered Dose Inhaler (Mdi) With Spacer or Nebulizer for Managing Children Under 5 Years of Age with Exacerbation of Wheezing or Asthma

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Abstract

Childhood asthma presents burdens on the child with asthma, their families, society, and healthcare. Inhaled short acting bronchodilators are the most common first line medications used to treat exacerbation of wheezing or asthma. Nebulizers and metered dose inhalers (MDIs) with spacers are among the most widely used devices to deliver these medications. Although evidence supporting MDIs as an efficient, more convenient and cost-effective way to administer inhaled medications to children, nebulizers continue to be seen as the gold standard for managing children under 5 years of age with exacerbation of wheezing or asthma. .

Keywords: Asthma exacerbation; Wheezing; Management; Preschool; Metered dose inhaler with spacer; Nebulizer

Abbreviations: MDI: Metered Dose Inhaler; MDI-spacer: Metered Dose Inhaler with Spacer

Introduction

Asthma is the third leading cause of hospitalization in children [1]. It is estimated that approximately 6 million children in the United States have asthma. Children under the age of 5 years have the highest rate of potentially preventable hospital stays for asthma [2]. The yearly direct healthcare cost of asthma care in the United States is estimated to be $50.1 billion [3]. Hospital stays demonstrate the largest portion of that cost. Indirect costs (e.g. loss of productivity-missed school days, parents missed workdays) make up another $5.9 billion for a total of $56 billion dollars per year. While the CDC (2018) reports that asthma exacerbations have gone down in children of all races and ethnicities from 2001 through 2016, emergency department and urgent care visits related to asthma exacerbations continue to be high among Non-Hispanic black children ages 0-4 years. Childhood asthma presents burdens on the child with asthma, their families, society, and healthcare [4]. Inhaled short acting bronchodilators are the most common first line medications used to treat wheezing or asthma exacerbations [5]. Nebulizers and metered dose inhalers (MDIs) are among the most widely used devices to deliver these medications. Although administration of bronchodilators via MDI is the most preferred and widely used for older children and adults, nebulizers continue to be seen as the "gold standard" for delivering bronchodilators in office and hospitals for treatment of wheezing or asthma exacerbations in children under 5 years of age [6-8]. In the past it was presumed by the medical community that infants and young children were unable to use MDIs effectively because they were unable to coordinate inhalation with medication administration [9]. The introduction of spacers, plastic tubes that hold inhaled medications in a chamber and allows a patient to inhale medications while taking normal breaths through a facemask or mouthpiece, helped solve this problem [10-12]. Adding a spacer onto an MDI increases the amount of inhaled drug that reaches the lung by 20% and reduces local and systemic side effects of inhaled medications [13]. In addition, MDIs used with spacers (MDI-spacers) are easier to use, less expensive, are portable, require less time and effort, do not require medication preparation or electricity, and require lower medication doses compared to nebulizers. In contrast, nebulizers are more expensive, inconvenient to use, require a power source and longer time for administration, require maintenance, and have been shown to have imprecise dosing. Additionally, nebulizers potentially pose a risk of infection [14]. In 2003 nebulizer use was associated with an outbreak of severe acute respiratory syndrome (SARS). Transitions from nebulizer to MDI-spacers in older children and adults have been found to decrease supply and labor costs and total number of treatments necessary to manage wheezing or asthma exacerbations [15,16]. Most recently [17] conducted a meta-analysis to compare the efficacy of pediatric

asthma exacerbation and wheezing treatment in the emergency department by nebulizer and MDI-spacers and identified no differences in cardiorespiratory frequency, O2 saturation, and asthma scores upon between inhalation the two treatment techniques. Additionally, most current pediatric wheezing and asthma management guidelines recommend the use of MDI-spacers and age-appropriate masks or holding chambers for all children [18]. Despite evidence identifying MDI-spacers as at least as effective as nebulizers in the delivery of short acting bronchodilators to manage children under 5 years of age with exacerbation of wheezing or asthma, nebulizers are still widely used as the modality of choice to administer bronchodilators to children under the age of five.

The purpose of this article is to identify and discuss literature identifying the use of a MDI-spacer as at least as effective as nebulizers in the delivery of short acting bronchodilators to manage children under 5 years of age with exacerbation of wheezing or asthma.

Literature search

English language publications (2000 to 2019) randomized clinical trials were retrieved from CINAHL, Scopus, and Cochrane databases. Seven journal articles met the specific criteria for this systematic review (2 meta-analysis and 5 randomized control trials). The primary outcome measure was efficacy of asthma exacerbation management in children under 5 years of age.

Result

Castro-Rodriguez JA et al. [19] conducted a meta-analysis to compare the efficacy of a bronchodilator given by MDIs with spacers or nebulizers in children under 5 years of age with exacerbations of wheezing or asthma in an emergency department setting. Castro-Rodriguez JA et al. [19] analyzed databases published (1966 to 2003) randomized, prospective, controlled trials with a primary outcome measure of hospital admissions and identified six trials (n = 491) that met criteria for inclusion. Patients who received a bronchodilator by MDI with spacer showed significant decreases in hospital admission rates compared with those treated with nebulizers (OR, 0.42; 95% CI, 0.24-0.72; P = .002); decreases were noted to be more significant among children with moderate to severe exacerbations (OR, 0.27; 95% CI, 0.13-0.54; P = .0003). Finally, measured severity (eg, clinical score) and identified significant improvement in the group who received a bronchodilator by MDI with spacer in comparison to those who received nebulizer treatments (standardized mean difference, −0.44; 95% CI, −0.68 to −0.20; P = .0003).

Niki Mitselou et al. [20] compared administration of bronchodilators by nebulizers to MDIs with spacers and evaluated the clinical effect of thesss treatment of acute asthma in preschool children. A prospective randomized clinical trial in a pediatric emergency department (PED) was employed. Preschool children who were admitted for virus induced wheezing or acute asthma exacerbation were randomly allocated to receive bronchodilator treatment by nebulizer or by MDI with spacer. Their parents completed questionnaires. Identified no differences in parents' views of ease of use and device acceptance, length of stay in the pediatric emergency department, and rates of hospitalization rates. Additionally, significant differences were not seen in respiratory rates, oxygen saturations, or heart rate at baseline or after treatment. Parents reported that 40% of the young children had a diagnosis of asthma while up to 66% were taking some type of asthma medication. Sought, to examine if efficacy of administration of albuterol, a bronchodilator, by MDI with a spacer vs. nebulizer to treat wheezing in children aged 2 years and younger. Double blind, randomized, placebo-controlled clinical trial was employed. A convenience sample of wheezing children aged 2 to 24 from a pediatric emergency were studied. Eighty-five patients were enrolled in the nebulizer group and 83 in the spacer group (N=168). The nebulizer group received a placebo MDI with a spacer followed by nebulized albuterol. The spacer group received albuterol by a MDI with a spacer followed by nebulized isotonic sodium chloride solution. Treatments were given every 20 minutes by a single investigator blinded to group assignment. Admission rate was the primary outcome measured. Pulmonary Index score and oxygen saturation were measured initially and 10 minutes after each treatment. Delgado, Chou, Silver, and Crain (2003) found that the nebulizer group had a significantly higher mean (SD) initial Pulmonary Index score compared with the spacer group (7.6 [2.5] vs. 6.6 [2.0]; P = .002). With the initial Pulmonary Index score controlled, children in the spacer group were admitted less (5% vs. 20%; P = .05). Analyses revealed an interaction between group and initial Pulmonary Index score and lower admission rates in the spacer group were found primarily in the children experiencing severe asthma exacerbations. Mandelber et al. [21] sought to determine the efficacy of MDIs with spacers compared to nebulizers in the treatment of a population of babies and small children with exacerbation of asthma. The design of the study was a randomized, double blind, placebo-controlled trial. Forty-two children referred to the PED (median age ± SD, 16 ± 15 months) with exacerbation of asthma received either placebo MDI with spacer (four puffs) and salbutamol 0.5 mL (2.5 mg) as a nebulizer (group I, n = 19), or salbutamol MDI and 0.5 mL of saline solution administered in the same manner as above (group II, n = 23). This treatment was repeated three times every 20 min. Found that respiratory rates (RRs) at baseline were as follows: group I, 45 ± 11.2 breaths/min; and group II, 52.3 ± 11.3 breaths/min (p = not significant [NS]). After the first, second, and third interventions, the percent fall from baseline of the RR were as follows: group I, 8.9, 13.1, and 17.9%, respectively; group II, 8.6, 14.6, and 18.6%, respectively. There was no significant difference at any time in the results between the two groups. The clinical scores (CSs) at baseline were as follows: group I, 6.6 ± 1.3; group II, 6.8 ± 1.49 (p = NS). After the first, second, and third interventions, the percent fall from baseline of the CS were as follows: group I, 9.1, 17.9, and 23.2%, respectively;

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group II, 8.6, 18.9, and 24.7%, respectively. These results, also, did not differ significantly at any time between the two groups. Hospitalization rate and side effects did not differ between the two groups. Deeronjanawong J [22] aimed to compare the efficacy of bronchodilator therapy administered via MDI with spacer and nebulizer in wheezing children up to 5 years old. A prospective randomized, double blind, placebo-controlled trial was employed. Patients were randomly divided into two groups. The first group received 2 puffs of placebo via MDI-spacer, followed by 0.15 mg/kg salbutamol respiratory solutions via jet nebulizer. The second group received 2 puffs (100μg/puff) of salbutamol via MDI-spacer, followed by placebo via jet nebulizer. Clinical scores and tidal breathing pulmonary function test were evaluated before and after treatment. Pulmonary function parameters included those derived from flow volume loops (volume to peak tidal expiratory flow over total expiratory volume, VPTEF/VE; time to peak tidal expiratory flow over total expiratory time, TPTEF/TE; and ratio of tidal expiratory flow at 25% remaining expiration to peak expiratory flow, 25/PF), compliance (Crs), and resistance (Rrs) of the respiratory system. The efficacy of both methods was compared using analysis of covariance. Forty-seven wheezing children were studied (24 received salbutamol via MDI-spacer, and 23 received it via nebulizer). No statistical differences were noted in clinical scores and pulmonary function between the two groups. However, heart rates were noted to significantly increase after treatment in the nebulizer group when compared to those in the MDI-spacer group (P = 0.004).

Cates CJ [23] conducted a meta-analysis to assess the effects of MDI with spacers compared to nebulizers for the delivery of bronchodilators for acute asthma. Cochrane Airways Group Trial Register and reference lists of articles were searched. Randomized trials in adults and children (from two years of age) with asthma, where spacer bronchodilator delivery was compared with wet nebulization. Two review authors independently applied study inclusion criteria (one review author for the first version of the review), extracted the data and assessed risks of bias. Results are reported with 95% confidence intervals (CIs). A total of 1897 children and 729 adults in 39 trials were included in this review. Thirty-three trials were conducted in the emergency room and equivalent community settings, and six trials were on in patients with acute asthma (207 children and 28 adults). Methods of delivery of bronchodilators did not show significant differences in hospital admission rates. In adults, the risk ratio (RR) of admission for spacer versus nebulizer was 0.94 (95% CI 0.61 to 1.43). The risk ratio for children was 0.71 (95% CI 0.47 to 1.08, moderate quality evidence). Length of stay in the emergency department was significantly shorter for children when the spacer was used (mean duration in the emergency department for children given nebulized treatment was 103 minutes, and for children given treatment via spacers 33 minutes less) (95% CI -43 to -24 minutes, moderate quality evidence). No significant differences were noted in length of stay in the emergency department, or peak flow and forced expiratory volume between the two devices. Pulse rates were noted to be lower in children who used spacers (mean difference -5% baseline (95% CI -8% to -2%, moderate quality evidence), as was the risk of developing tremor (RR 0.64; 95% CI 0.44 to 0.95, moderate quality evidence).

Leversha [24] sought to compare the costs and effectiveness of albuterol by MDI and spacer versus nebulizer in young children with moderate and severe acute asthma. Randomized, double blind, placebo-controlled trial was conducted in an emergency department at a children's hospital. Children 1 to 4 years of age with moderate to severe acute asthma participated in this study. Children assigned to the spacer group received albuterol by MDI with spacer (Aero Chamber) followed by placebo by nebulizer (n = 30). The nebulizer group received placebo MDI with spacer followed by 2.5 mg albuterol by nebulizer (n = 30). Treatments were administered at 20-minute intervals until their status improved and they did not need further doses, or a total of 6 treatments were administered. Baseline clinical score, heart rate, respiratory rate, auscultatory findings, and oxygen saturation were recorded at the beginning, after each treatment, and 60 minutes after the last treatment. Both groups had similar characteristics and asthma severity. The spacer was found to be as effective as the nebulizer for clinical score, respiratory rate, and oxygen saturation but produced a greater reduction in wheezing (P =.03). Heart rate increased to a greater degree in the nebulizer group (11.0/min vs. 0.17/min for spacer, P <.01). Fewer children in the spacer group required admission (33% vs. 60% in the nebulizer group, P =.04, adjusted for sex). No differences were seen in rates of tremor or hyperactivity. The mean cost of each emergency department presentation was $825 for the spacer group and $1282 for the nebulizer group (P =.03); 86% of children and 85% of parents preferred the spacer.

Discussion

The primary objective of this article was to identify and discuss literature identifying the use of MDI-spacer as at least as effective as nebulizers in the delivery of short acting bronchodilators for managing children under 5 years of age with exacerbation of wheezing or asthma. All seven studies in this review compared the use of MDI-spacers and nebulizers for managing children under 5 years of age with wheezing or asthma exacerbations. The two meta-analysis reported results with 95% confidence intervals. Overall, all of the studies identified that MDIs used with spacers were at least as effective if not better than nebulizers in the delivery of bronchodilators to treat children under the age of 5 years with exacerbations of wheezing or asthma. Among these studies, one revealed that the use of an MDI-spacer decreased hospitalization and improved clinical scores, decreases were noted to be more significant among children with moderate to severe exacerbations. Lower admission rates were also noted in one of the studies in an MDI with spacer group. Length of stay in the emergency department was found to be significantly shorter

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in one of the studies when an MDI-spacer was used. Three studies showed that bronchodilator therapy via nebulizer increased the heart rate when compared to the MDI-spacer and amongst them one noted decrease in risk of developing tremors. Another study revealed that although the MDI-spacer was as effective as the nebulizer for clinical score, respiratory rate, and oxygen saturation, the MDI-spacer significantly reduced wheezing. This review also identified that an MDI-spacer was a more cost-effective alternative to a nebulizer in the delivery of inhaled medication. Interestingly, one study found that 40% of the preschool children who participated in the study had a diagnosis of asthma however, 66% of them were on some type of asthma medication. This finding speaks to the continued mismanagement of pediatric asthma. One of the studies also noted that 86% of the preschool children and 85% of parents preferred the MDI-spacer to the nebulizer. One of the studies noted the importance of understanding that parents may underestimate the gravity of their children's asthma and recommended that adequate education be provided to staff and parents in order to treat pediatric exacerbations of asthma successfully (Table 1).

Table 1:

Author, Date, and Article Title	Objective	Methods/Research Design	Statistics and Confidence Intervals	Significant Findings
1.Castro-Rodriguez JA, Rodrigo GJ. (2004) Beta-agonists through metered-dose inhaler with valved holding chamber versus nebulizer for acute exacerbation of wheezing or asthma in children under 5 years of age: a systematic review with meta-analysis.	To compare the efficacy of β-againsts given by metered-dose inhaler with a valved holding chamber (MDI+VHC) or nebulizer in children under 5 years of age with acute exacerbations of wheezing or asthma in the emergency department setting.	N=491 Published (1966 to 2003) randomized, prospective, controlled trials were retrieved through several different databases. The primary outcome measure was hospital admission	Six trials (n = 491) met criteria for inclusion. Patients who received β-agonists by MDI+VHC showed a significant decrease in the admission rate compared with those by nebulizer (OR, 0.42; 95% CI, 0.24-0.72; P = .002); this decrease was even more significant among children with moderate to severe exacerbations (OR, 0.27; 95% CI, 0.13-0.54; P = .0003). Finally, measure of severity (eg, clinical score) significantly improved in the group who received β-agonists by MDI+VHC in comparison to those who received nebulizer treatment (standardized mean difference, −0.44; 95% CI, −0.68 to −0.20; P = .0003).	The use of an MDI+VHC was more effective in terms of decreasing hospitalization and improving clinical score than the use of a nebulizer in the delivery of beta-agonists to children under 5 years of age with moderate to severe acute exacerbations of wheezing or asthma.
2. Mitselou, N., Hedlin, G., & Hederos, C. (2016). Spacers versus nebulizers in treatment of acute asthma – a prospective randomized study in preschool children. Journal of Asthma, 53(10), 1059-1062. doi:10.1080/02770903.2016.1185114	To compare administration of bronchodilators by nebulizers with delivery by metered dose inhalers (MDIs) with spacers and to evaluate the clinical effect of the treatment of acute asthma in preschool children.	N=18 A prospective randomized clinical trial in a pediatric emergency department (PED). Preschool children who were admitted for virus induced wheezing or acute asthma exacerbation were randomly allocated to receive bronchodilator treatment by nebulizer or by metered dose inhaler. The accompanying parents completed a questionnaire.	The length of stay in the PED and the hospitalization rate were similar and no difference was seen in the parents' view of ease of use and device acceptance. Baseline data were similar for both groups apart from the family history of asthma and atopic disease that was greater in the nebulizer group. No significant differences were seen in heart rate, respiratory rate and oxygen saturation at baseline and after the treatment. According to the parents 40% of the participants had asthma diagnosis though up to 66% had some kind of asthma medication.	· MDIs with spacers are at least as effective as nebulizers in the delivery of beta agonists to treat preschool children with virus induced wheezing or acute exacerbations of asthma in the PED. · Parents may underestimate the gravity of their children's asthma. It is mandatory to provide adequate education to the staff and parents in order to treat pediatric acute asthma successfully

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3. Delgado A, Chou KJ, Silver EJ, Crain EF. (2003) Nebulizers vs. Metered-Dose Inhalers with Spacers for Bronchodilator Therapy to Treat Wheezing in Children Aged 2 to 24 Months in a Pediatric Emergency Department.	To determine if administration of albuterol by a metered-dose inhaler with a spacer device is as efficacious as administration of albuterol by nebulizer to treat wheezing in children aged 2 years and younger.	N= 168 Double blind, randomized, placebo-controlled clinical trial. Pediatric emergency department. Patients From a convenience sample of wheezing children aged 2 to 24 months, 85 patients were enrolled in the nebulizer group and 83 in the spacer group. The nebulizer group received a placebo metered-dose inhaler with a spacer followed by nebulized albuterol. The spacer group received albuterol by a metered-dose inhaler with a spacer followed by nebulized isotonic sodium chloride solution. Treatments were given every 20 minutes by a single investigator blinded to group assignment	The primary outcome was admission rate. Pulmonary Index score and oxygen saturation were measured initially and 10 minutes after each treatment.	· Metered-dose inhalers with spacers may be as efficacious as nebulizers for the emergency department treatment of wheezing in children aged 2 years or younger.
4. Mandelber, Tsehor, Houri, Gilad, Morag, & Priel (2000)	To determine the efficacy of MDI with Nebuchamber (Astra AB; Lund, Sweden), a non-electrostatic spacer device (NESD), as compared to NWA in the treatment of an unselected population of babies and small children with AWE.	N=42 Randomized, double blind, placebo-controlled trial. Forty-two children referred to the PED (median age +/- SD, 16 +/- 15 months) with AWE received either placebo MDI through a NESD (four puffs) and salbutamol 0.5 mL (2.5 mg) as a NWA (group I, n = 19), or salbutamol MDI and 0.5 mL of saline solution administered in the same manner as above (group II, n = 23). This treatment was repeated three times every 20 min.	The respiratory rates (RRs) at baseline were as follows: group I, 45 +/- 11.2 breaths/min; and group II, 52.3 +/- 11.3 breaths/min (p = not significant [NS]). After the first, second, and third interventions, the percent fall from baseline of the RR was as follows: group I, 8.9, 13.1, and 17.9%, respectively; group II, 8. 6, 14.6, and 18.6%, respectively. There was no significant difference at any time in the results between the two groups. The clinical scores (CSs) at baseline were as follows: group I, 6.6 +/- 1.3; group II, 6.8 +/- 1.49 (p = NS). After the first, second, and third interventions, the percent fall from baseline of the CS was as follows: group I, 9.1, 17.9, and 23.2%, respectively; group II, 8. 6, 18.9, and 24.7%, respectively. These results, also, did not differ significantly at any time between the two groups. Hospitalization rate and side effects did not differ between the two groups.	· Even in the group of unselected very young children (mean age < 2 years) with AWE, the use of MDI with NESD is at least as effective as the use of NWA. · As opposed to data from an adult population, no plateau was reached in the dose-response curve using the above doses over time.

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5. Deerojanawong, Manuyakorn, Prapphal, Harnruthakorn, Sritippayawan, &Sanransamruajkit. (2005). Randomized controlled trial of salbutamol aerosol therapy via metered dose inhaler-spacer vs. jet nebulizer in young children with wheezing.	The jet nebulizer is a common device used for administering aerosol medication in young children. However, compared to a metered dose inhaler-spacer (MDI-spacer), it takes more time and personnel. This study aimed to compare the efficacy of salbutamol aerosol therapy given via these two devices in young wheezing children.	N=47 A prospective randomized, double blind, placebo-controlled trial was performed in children up to 5 years old who had acute wheezing and were admitted to the Department of Pediatrics, King Chulalongkorn Memorial Hospital. Patients were randomly divided into two groups. The first group received 2 puffs of placebo via MDI-spacer, followed by 0.15 mg/kg salbutamol respiratory solutions via jet nebulizer. The second group received 2 puffs (100 microg/puff) of salbutamol via MDI-spacer, followed by placebo via jet nebulizer.	Forty-seven wheezing children were studied (24 received salbutamol via MDI-spacer, and 23 received it via jet nebulizer). There was no statistical difference between the two groups regarding clinical scores and Clinical scores and tidal breathing pulmonary function test were evaluated before and after treatment. Pulmonary function parameters included those derived from flow volume loops (volume to peak tidal expiratory flow over total expiratory volume, V(PTEF)/V(E); time to peak tidal expiratory flow over total expiratory time, T(PTEF)/T(E); and ratio of tidal expiratory flow at 25% remaining expiration to peak expiratory flow, 25/PF), compliance (Crs), and resistance (Rrs) of the respiratory system. Using analysis of covariance compared the efficacy of both methods. heart rate was significantly increased after treatment in the nebulizer group when compared to those in the MDI-spacer group (P = 0.004).	· The efficacy of salbutamol aerosol therapy via MDI-spacer compared to jet nebulizer in young wheezing children was not different in terms of clinical score and post bronchodilator pulmonary function parameters. · Salbutamol aerosol therapy via jet nebulizer significantly increased the heart rate when compared to the MDI-spacer.
6. Cates CJ, Welsh EJ, & Rowe BH. (2013). Holding chambers (spacers) versus nebulisers for beta-agonist treatment of acute asthma.	We searched the Cochrane Airways Group Trial Register and reference lists of articles. We contacted the authors of studies to identify additional trials. Date of last search: February 2013.	N=2626 Randomized trials in adults and children (from two years of age) with asthma, where spacer beta$_2$-agonist delivery was compared with wet nebulization.	Two review authors independently applied study inclusion criteria (one review author for the first version of the review), extracted the data and assessed risks of bias. Missing data were obtained from the authors or estimated. Results are reported with 95% confidence intervals (CIs). This review includes a total of 1897 children and 729 adults in 39 trials. Thirty-three trials were conducted in the emergency room and equivalent community settings, and six trials were on in patients with acute asthma (207 children and 28 adults). The method of delivery of beta$_2$-agonist did not show a significant difference in hospital admission rates. In adults, the risk ratio (RR) of admission for spacer versus nebulizer was 0.94 (95% CI 0.61 to 1.43). The risk ratio for children was 0.71 (95% CI 0.47 to 1.08, moderate quality evidence). In children, length of stay in the emergency department was significantly shorter when the spacer was used. The mean duration in the emergency department for children given nebulized treatment was 103 minutes, and for children given treatment via spacers 33 minutes less (95% CI -43 to -24 minutes, moderate quality evidence). Length of stay in the emergency department for adults was similar for the two delivery methods. Peak flow and forced expiratory volume were also similar for the two delivery methods. Pulse rate was lower for spacer in children, mean difference -5% baseline (95% CI -8% to -2%, moderate quality evidence), as was the risk of developing tremor (RR 0.64; 95% CI 0.44 to 0.95, moderate quality evidence).	· Metered-dose inhalers with a spacer can perform at least as well as wet nebulization in delivering beta$_2$-agonists in children with acute asthma

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7. Leversha, Campanella, Aickin, & Asher (2000). Costs and effectiveness of spacer versus nebulizer in young children with moderate and severe acute asthma.	To compare the costs and effectiveness of albuterol by metered dose inhaler (MDI) and spacer versus nebulizer in young children with moderate and severe acute asthma.	N=30 Randomized, double-blind, placebo-controlled trial in an emergency department at a children's hospital. The participants were children 1 to 4 years of age with moderate to severe acute asthma. Patients assigned to the spacer group received albuterol (600 microg) by MDI by spacer (AeroChamber) followed by placebo by nebulizer (n = 30). The nebulizer group received placebo MDI by spacer followed by 2.5 mg albuterol by nebulizer (n = 30). Treatments were repeated at 20-minute intervals until the patient was judged to need no further doses of bronchodilator, or a total of 6 treatments.	Clinical score, heart rate, respiratory rate, auscultatory findings, and oxygen saturation were recorded at baseline, after each treatment, and 60 minutes after the last treatment. Baseline characteristics and asthma severity were similar for the treatment groups. The spacer was as effective as the nebulizer for clinical score, respiratory rate, and oxygen saturation but produced a greater reduction in wheezing (P =.03). Heart rate increased to a greater degree in the nebulizer group (11.0/min vs. 0.17/min for spacer, P <.01). Fewer children in the spacer group required admission (33% vs. 60% in the nebulizer group, P =.04, adjusted for sex). No differences were seen in rates of tremor or hyperactivity. The mean cost of each emergency department presentation was NZ$825 for the spacer group and NZ$1282 for the nebulizer group (P =.03); 86% of children and 85% of parents preferred the spacer.	· MDI and spacer combination was a cost-effective alternative to a nebulizer in the delivery of albuterol to young children with moderate and severe acute asthma.

Summary Points

a) MDI-spacers are at least as effective if not better than nebulizers in the delivery of bronchodilators used to treat children under the age of 5 years with exacerbations of wheezing or asthma

b) MDI-spacers decreased hospitalization and improved clinical scores

c) Lower admission rates were identified in MDI-spacers group compared to a nebulizer group

d) Length of stay in the emergency department was found to be significantly shorter when an MDI-spacer was used compared to a nebulizer

e) Bronchodilator therapy via nebulizer increased the heart rate and risk of developing tremor when compared to the MDI-spacer

f) MDI-spacer significantly reduced wheezing when compared to the nebulizers

g) MDI-spacer were found to be a more cost-effective alternative to a nebulizer in the delivery of inhaled medication

h) 40% of the preschool children who participated in one of the studies had an actual diagnosis of asthma while 66% of the preschool were taking some type of asthma medication

i) 86% of the preschool children and 85% of parents who participated in one of the studies preferred the MDI-spacer over the nebulizer

j) Parents may not recognize the seriousness of their child's diagnosis of asthma

Barriers

Frequent emergency department visits for pediatric asthma care is associated with lack of education regarding diagnosis and medication use [25,26] found children frequently used MDIs-spacers incorrectly and recommended that repeated education would result in better medication therapy. A study [27] found that caregivers of urban, minority children with persistent asthma lacked proper techniques for effective use of MDIs with spacers which suggests the potential value of educational interventions. Recommended interventions for successful adherence promotion include providing reinforcement for caregivers, providing feedback on progress, tailoring education to individual needs and circumstances, standardizing therapy, and continuity of care and education [28].

Conclusion

The MDI-spacer is an efficient, more convenient and cost-effective way to delivering first line bronchodilators to children under the age of 5 years with exacerbations of wheezing or asthma. Despite evidence and guidelines, nebulizers continue to be the device of choice. It is well documented that children under the age of 5 years have the highest rate of potentially preventable hospital stays for asthma. While asthma can be a manageable disease, children under the age of 5 years, particularly those who are minorities and/or whose family's incomes fall below poverty lines, are not, as a population, receiving evidence based, patient and family centered asthma care [29,30]. Therefore, it is imperative to identify, implement, and disseminate evidenced based approaches to ensure improvement and high standards of asthma care among all children, especially those under the age of 5 years with exacerbations of wheezing or asthma. This review of

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the most current evidence supports recommended guidelines and provides further evidence of the efficacy of using an MDI-spacer compared to nebulizers for children under the age of 5 years with exacerbations of wheezing or asthma. The identification and implementation of evidence-based practice, a systematic approach to clinical decision making that aims to provide the most current, consistent and best possible care to patients, can improve outcomes for young children with asthma [31]. Although the use of MDI-spacers is an efficient, more convenient and cost-effective way to administer inhaled medications to children under the age of 5 years with wheeze or asthma exacerbations, it is not widely used. There is a need for well-designed pediatric asthma studies that assess outcomes of implementing evidence based approaches and costs for improving asthma care. Patient satisfaction also needs to be considered as it is an important aspect of patient and family centered care and has been found to significantly correlate with better outcomes [32-38]. Efforts need to be targeted to improve pediatric management in urban communities, decrease risks of exacerbations, standardize and improve therapy, and reduce costs by reducing overuse of healthcare resources.

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