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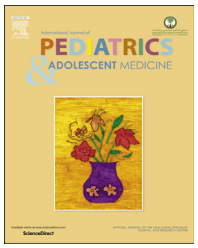

ORIGINAL ARTICLE

Replacing nebulizers by MDI-spacers for bronchodilator and inhaled corticosteroid administration: Impact on the utilization of hospital resources

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Abstract *Background and objectives:* Metered-dose inhalers plus spacers (MDI-spacer) are as effective as, or better than, nebulizers in aerosol delivery. The selection of aerosol delivery system for hospitalized children can have a significant impact on the utilization of healthcare resources.
Design and setting: A quality improvement project to evaluate the impact of conversion to MDI-spacer to administer bronchodilators (BDs) and inhaled corticosteroids (ICSs) to hospitalized children on the utilization of hospital resources. The project was conducted in a tertiary pediatric ward from April to May 2013.
Materials and methods: The project was conducted over a six-week period. In the first two weeks, data were gathered from all hospitalized children receiving BDs and/or ICSs by nebulizers. This data collection was followed by a two-week washout period during which training of healthcare providers and operational changes were implemented to enhance the conversion to MDI-spacer. In the last two weeks, data were gathered from hospitalized children after conversion to MDI-spacer. The primary outcomes included the mean time (in minutes) of medication preparation and delivery. Secondary outcomes included the following: need for respiratory therapy assistance, estimated cost of treatment sessions, and patient/caregiver satisfaction.
Results: Five hundred seventy-five treatment sessions were enrolled (288 on nebulizers, 287 on MDI-spacer). The nebulizer group had more male predominance and were slightly older compared to the MDI-spacer group (male: 59% vs. 53% and mean age: 52 vs. 40 months

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respectively). The duration of treatment preparation and delivery was significantly lower in the MDI-spacer group (2 min reduction in preparation time and 5 min reduction in delivery time; $p < 0.01$). Caregivers mastered MDI-spacer use after an average of two observed sessions, eliminating the need for respiratory therapy assistance during the hospital stay. Medication cost analysis showed savings in favor of MDI-spacer (cost reduction per 100 doses: 50% for albuterol, 30% for ipratropium bromide, and 87% for ICSs). The patient satisfaction survey showed "very good" to "excellent" levels in both groups.
Conclusions: Conversion to MDI-spacer for BDs and ICSs administration in hospitalized children improve hospital resource utilization.

1. Introduction

Inhalational therapy represents the preferred mode of delivery for asthma medications. Nebulizers (for medications in solution) and spacers (for metered-dose inhalers, MDIs) are among the most widely used modalities. Several studies have shown that MDI-spacers are as effective as, or better than, nebulizers in aerosol delivery in children [1—5]. Nebulizers use require a power supply, take more time, are not conveniently portable, are generally more expensive, require maintenance, and need more supervision [6]. In contrast, spacers are easier to use, require less effort and time, do not require dose preparation or electricity for delivery, are portable, and require lower medication doses compared to nebulizers [7].

Nebulizers can also have a significant impact on infection control. Use of nebulizers was associated with a major outbreak of severe acute respiratory syndrome (SARS) in Hong Kong in March 2003 [8].

In some hospitals, the use of nebulizers for hospitalized children requires additional resources in terms of cost and human resources because a respiratory therapist is required to supervise treatment sessions. Despite all of these facts, nebulizers are still widely used as the modality of choice to administer bronchodilators (BDs) and inhaled corticosteroids (ICSs) to hospitalized children. Most asthma guidelines, including the recently published Saudi Initiative for Asthma (SINA) guidelines, recommend the use of spacers for children even younger than 6 yrs old [9,10].

2. Aim of the study

The aim of the study is to investigate the impact of conversion to MDI-spacers to administer BDs and ICSs to hospitalized children on the utilization of hospital resources (treatment preparation and delivery time, need for respiratory therapy assistance, and cost).

3. Materials and methods

This was a quality improvement project conducted to evaluate the impact of inhalational device selection for hospitalized children on the utilization of hospital resources (treatment preparation and delivery time, need for respiratory therapy assistance, and cost). The project was conducted in a tertiary pediatric ward (King Faisal Specialist Hospital & Research Centre) during April—May 2013. The ultimate goal of this study was to come up with an evidence-based practice policy for inhalational therapy that minimizes unnecessary waste of hospital resources without any negative impact on patient care. The study is not intended to compare the pharmacological efficacy of new interventions (both nebulizers and MDI-spacers are licensed for use in children). The study was reviewed and registered as a quality improvement project under the organization quality improvement board. Inclusion Criteria: Hospitalized children requiring BDs and/or ICSs, age <14 years, and presence of caregiver. Exclusion Criteria: Uncooperative patients, sick patients requiring shift to intensive care unit, or unavailable caregiver.

The project was conducted over a period of 6 weeks. In the first 2 weeks, data were gathered from all hospitalized children receiving BDs and/or ICSs by nebulizers. This was followed by a 2-week washout period during which training of healthcare providers and operational changes were implemented to enhance the conversion to MDI-spacer. In the last 2 weeks, data were gathered from hospitalized children after conversion to MDI-spacer. Primary outcomes included the mean time (in minutes) of medication preparation and delivery. Secondary outcomes included need for respiratory therapy assistance, estimated cost of treatment sessions, and patient/caregiver satisfaction. Device instruction was provided for caregivers involved in patient care.

The following data were collected during every treatment session: preparation time, delivery time, medication name, dosage, mode of delivery and oxygen flow rate during nebulization therapy. An assessment sheet was used to determine the minimum number of sessions supervised by respiratory therapist required to ensure caregiver competency in the use of MDI-spacer.

A patient/caregiver satisfaction survey was performed as part of the quality assurance measurement that is routinely collected by respiratory therapists in our hospital. Medication and device cost were estimated based on the information provided by hospital pharmacy and respiratory therapy department, respectively. The medications that were observed include bronchodilators (albuterol and ipratropium bromide), inhaled corticosteroids (fluticasone and budesonide) or a combination of long-acting bronchodilator and ICS (fluticasone/salmeterol). MDI-equivalent dosages of BDs and ICSs solutions were developed (see Table 1). Our target was to collect data from more than 100 treatment sessions in each part of the two project phases (nebulizer phase and MDI-spacer phase) for a minimum of

200 observational events. In addition to descriptive data analysis, the Student *t*-test was used to compare the means of preparation and delivery time between the two groups. Statistical significance was set at $p < 0.05$.

4. Results

Five hundred seventy-five treatment sessions were enrolled (288 on nebulizers, 287 on spacers). Table 2 shows the demographic characteristics of both groups. The nebulizer group had more male predominance (59%) compared to the spacer group (53%). The average age of the children was 66 months. Children in the nebulizer group were slightly older (mean age 52 months; range: 2–165 months) compared to the spacer group (mean age 40 months; range: 9–168 months). The prescribed medications were the following: albuterol (45%), ICS (20%), combinations (31%), ipratropium bromide (4%), and others (4%).

In the nebulizer group, the mean time for treatment preparation was 2.05 min (95th% CI: 1.45–2.15 min), and the mean time for treatment delivery was 9.39 min (95th% CI: 9.06–10.12). In the MDI-spacer group, the mean time for treatment preparation was 0.3 min (95th% CI: 0.03–0.5 min), and the mean time for treatment delivery was 4.38 min (95th% CI: 4.2–4.56 min) (see Table 3). These results indicate that replacing nebulizers by MDI-spacers shortens the time for medication preparation time by 98% and delivery time by 48% (2 min difference for preparation time and 5 min for delivery time; $p < 0.01$).

Caregivers mastered MDI-spacer use after an average of 2 supervised sessions. As a result, conversion to MDI-spacer will lead to more independent treatment administration by patients/caregivers. This can have a significant impact on resource utilization in organizations that mandate that all nebulizer sessions be supervised by a respiratory therapist. Patient satisfaction survey showed stable "very good" to "excellent" levels in both phases of the study. Medication cost reduction analysis showed that cost reduction per 100 doses as the following: 50% for albuterol, 30% for ipratropium bromide, and 87% for ICSs in favor of MDI-spacer (taking into account cost of medication, spacer, and nebulization kit).

Table 1 MDI equivalent dosage of BDs and ICSs solutions.

Medication	Solution (nebulizer) dosage	MDI equivalent dosage
Albuterol	2.5 mg	3–5 puffs[a]
Albuterol	5.0 mg	5–10 puffs[a]
Ipratropium bromide	0.25 mg	2 puffs
Ipratropium bromide	0.5 mg	4 puffs
Budesonide	0.25 mg	Fluticasone (125 mcg) 2 puffs
Budesonide	0.5 mg	Fluticasone (250 mcg) 2 puffs

[a] The range provided for MDI doses need to be adjusted based on (response: side-effect) assessment.

Table 2 Demographic data of participants.

	Nebulizer group	MDI-spacer group
Sex		
Male	170 (59%)	153 (53%)
Female	118 (41%)	134 (47%)
Age (months)		
Range	46–58	35–44
Mean	52	40
Total	288	287

5. Discussion

This study demonstrates the important role of quality improvement projects that implement evidence-based practice to optimize the utilization of hospital resources. The study results indicate the need for hospital policy modification to enhance conversion to MDI-spacer as the delivery method of choice for BDs and ICSs whenever applicable for hospitalized children. We believe that this will lead to better utilization of hospital resources without negatively affecting the pharmacological effect of medications. In fact, this simple practice change will lead to wiser utilization of respiratory therapists' time and efforts, which can be utilized for other important aspects of patient care. This is of extreme importance, especially with the significant shortage in respiratory therapists across hospitals globally. Cost savings is also expected as a result of the lower cost of medications, elimination of the need for nebulizer machines and disposable nebulizer kits, prevention of unnecessary use of oxygen treatment, and, more importantly, reducing the need for the cost of respiratory therapist overtime shifts. Although these savings are theoretically plausible, there is a lack of solid evidence to confirm those assumptions. We note that conversion to MDI-spacer might raise the concern of increasing costs due to spacer expenses, but this might not be a valid concern because these devices can be provided for patients for long-term use.

Minimizing the use of nebulizers might have health benefits related to decreasing the airborne spread of infectious agents, which have significant effects in inpatient care in pediatric hospitals [8]. This might have significant "infection control" impact. However, to our knowledge this has not been investigated in a pediatric population.

Table 3 Summary of preparation and delivery times for nebulizer and MDI-spacer groups.

	Nebulizer group	MDI-spacer group	Time difference
Preparation time	2.05 min (95th% CI: 1.45–2.15)	0.3 min (95th% CI: 0.03–0.5)	2 min ($p < 0.01$)
Delivery time	9.39 min (95th% CI: 9.06–10.12)	4.38 min (95th% CI: 4.2–4.56)	5 min ($p < 0.01$)

Studies have shown that in asthmatic children, use of MDI-spacers and nebulizers for bronchodilator administration in the emergency department have resulted in similar clinical responses, with shorter duration of stay, lower incidence of tachycardia, and even lower rate of admissions. In one study, 168 infants (aged 2—24 months) were randomized in a double blind trial comparing MDI-spacer- to nebulizer-administered albuterol for wheezing episodes in the emergency department [11]. Patients in the spacer group had a significantly lower admission rate (5% versus 20% in the nebulizer group), received fewer treatments, had a lower mean increase in heart rate and were less likely to receive steroids. Lower admission rates in the spacer group were found primarily in children with more severe asthma exacerbation [11]. Another randomized, double-blind, placebo-controlled trial in an emergency department at a children's hospital included children 1—4 years of age with moderate to severe acute asthma. The spacer was as effective as the nebulizer in terms of clinical score, respiratory rate, and oxygen saturation but produced a greater reduction in wheezing ($P = 0.03$). Heart rate increased to a greater degree in the nebulizer group (11.0/min vs. 0.17/min for spacer, $p < 0.01$). Fewer children in the spacer group required admission (33% vs. 60% in the nebulizer group, $P = 0.04$, adjusted for sex). No differences were observed in rates of tremor or hyperactivity [12]. Interestingly, this study showed cost savings in spacer group. Such cost benefits have been reported in studies of American adults, documenting a 30%—50% annual cost savings for asthma therapy with substitution of spacers for nebulizers [13—16]. A meta-analysis and systematic review showed that patients who received beta-agonists by MDI-spacer showed a significant decrease in admission rate compared with those by nebulizer (OR, 0.42; 95% CI, 0.24—0.72; $P = 0.002$); this decrease was even more significant among children with moderate to severe exacerbations (OR, 0.27; 95% CI, 0.13—0.54; $P = 0.0003$). Additionally, measures of severity (eg, clinical score) significantly improved in the group that received beta-agonists by MDI-spacer in comparison to those who received nebulizer treatment (standardized mean difference, −0.44; 95% CI, −0.68 to −0.20; $P = 0.0003$) [17].

Conversion to MDI-spacer might encounter difficulties such as lack of awareness of healthcare practitioners, patient and/or caregiver disbelief that nebulizers are more effective, shortage of the proper size and type of spacers, and need for effective patient education to ensure proper device use. In a Canadian study, a national survey on barriers to MDI-spacer use in pediatric emergency departments revealed that MDI-spacer are infrequently used to treat patients with acute asthma in Canadian pediatric emergency departments despite the fact that most emergency staff believe that they are effective. The largest perceived barriers to MDI-spacer implementation include concerns regarding safety and costs, feasibility of providing and sterilizing spacers, and parental expectations for use of nebulizers. Other barriers included staff beliefs regarding the effectiveness of MDI-spacer, changes in nursing workload, and lack of a physician champion for change [18]. A report on US children's hospital's strategy to implement conversion to MDI-spacer showed increase spacer use from 25% to 77% among all non-intensive-care patients receiving albuterol and from 10% to 79% among patients with asthma ($p < 0.001$) [19]. The strategy includes the following 4 distinct interventions to plan and implement this conversion program: literature review, product selection, policy and operational changes, and staff training.

Our study showed no change in patient and/or caregiver satisfaction after conversion to MDI-spacer. In an Australian study, the majority of parents (84%) found it 'easy' or 'very easy' to use the spacer, and 85% reported that they intended to use the spacer at home. The majority of children (82%) said that they preferred using spacers because it was quicker (29%) or easier to use (53%) [20]. In another study of young patients, 86% of children and 85% of parents preferred the spacer [12].

6. Conclusions

Conversion to MDI-spacer for the administration of bronchodilators and inhaled corticosteroids to hospitalized children led to a reduction in treatment preparation and delivery time and enabled early independent administration by patient/caregiver in addition to a potential reduction in medication cost. This quality improvement project indicates that the selection of inhalational device can have a major impact on resource utilization in hospitals. Further studies are required to investigate the impact of such strategies on hospital length of stay and in different settings, eg, the emergency department.

Conflict of interest

The authors have no conflict of interest related to this project to disclose.

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