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Inhalation technique practical skills and knowledge among physicians and nurses in two pediatric emergency settings

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Abstract

Introduction: Correct technique with a pressurized metered-dose inhaler (pMDI) equipped with a valved holding chamber (VHC) or spacer provides an important advantage for adequate control of asthma and virus-induced wheezing in young children. The aim of this study was to assess the

ability and knowledge of physicians and nurses to use a pMDI with a masked VHC in two pediatric emergency units.

Methods: Study design: two-center observational study. Inhaler use technique was assessed in 50 physicians and 50 nurses using a child mannequin and a validated videotaped nine-step scoring method. The participants' knowledge was evaluated by a questionnaire.

Results: The inhalation technique was perfectly mastered by 49% of the study participants and almost perfectly mastered by another 34% (mean score 8.3 ± 0.7 ; range 5–9). Nurses were more likely than doctors to demonstrate the technique perfectly (66% vs. 32%, $p < .05$). The two most common errors were forgetting to shake the pMDI between two consecutive puffs (38% of the participants) and putting the patient in an incorrect position (11%). About half of the participants reported that they checked each patient's inhalation technique at every opportunity and knew how to clean the VHC. A large majority did not employ a reliable method to determine the amount of medication remaining in pMDIs without a counter.

Conclusion: Healthcare professionals' practical skills and knowledge on inhalation therapy were not completely mastered and could be improved with a mandatory training program.

Introduction

Asthma and virus-induced wheezing are common childhood illnesses. Approximately 10% of the pediatric population in Switzerland suffers from asthma [1]. Effective asthma treatment requires an appropriate inhalation technique. The preferred delivery system for asthma-alleviating medication in young children is a pressurized metered-dose inhaler (pMDI) with a valved holding chamber (VHC) or spacer (with or without a facemask) [2, 3]. However, inhalers are often used errantly [4-7]. Such errors can hinder deposition of the active compound into the

lungs, thus diminishing treatment efficiency, which can lead to inadequate control of the disease [8].

To overcome this problem, the Global Initiative for Asthma report [3] recommend that patients be asked to demonstrate their inhaler device technique at every visit to enable improper use to be corrected and ongoing use technique to be monitored. Unfortunately, many healthcare professionals who are charged with providing instruction and monitoring aimed at optimizing inhaler use are not well versed with the use of these devices themselves [4, 9]. For example, only 25 of 71 pediatricians in a cross-sectional survey involving two university-affiliated hospitals in Kuwait demonstrated good inhalation technique [10].

Identifying gaps in knowledge regarding proper inhaler technique for patient education is important to propose initial or continued education to improve patient outcomes. As recently reviewed by Plaza et al. [9], few studies have been conducted with healthcare professionals in pediatric settings, and even less in emergency units. We hypothesized that inhaler techniques were not perfectly mastered by them in these settings. The aim of this study was to assess the ability and knowledge of physicians and nurses to use a pMDI with a masked VHC in the pediatric emergency units of two university hospitals.

Methods

Healthcare professionals' enrollment

A two-center observational study was conducted in two pediatric emergency units at the Children's Hospitals in Lausanne and Geneva, Switzerland, within a 6-month period in 2013. The aim of the study was presented to all physicians and nurses at a monthly meeting by the investigator (third year postgraduate pharmacist). All physicians and nurses working in the two

units were eligible for participation. They were approached during their shift and were invited to voluntarily participate in the study until the number of participants was reached (50 physicians and 50 nurses, half from each center). The number was chosen to represent more than 75% of the staff. Characteristics of the participants are presented in Table 1. The healthcare professionals' inhalation demonstrations were video-recorded. Informed consent was obtained from all involved healthcare professionals, and the study was approved by the Human Research Ethics Committees of both hospitals.

Correct inhalation technique checklist

The inhaler technique was checked using a mannequin lying on a table at the beginning of the trial. Our inhalation technique checklist was based on previously published criteria [2-5, 7, 9, 11]. It included nine operational steps, as detailed in Table 2. Because we used a mannequin, a 10th step (ensure that the child is breathing quietly) was excluded from our study assessments. If step 1–9 was performed correctly, it was given a score of 1, whereas a score of 0 indicated a missed or incorrectly performed step.

To validate the method of assessment of inhalation technique with pMDIs and a masked VHC, three experts in aerosol therapy (a pulmonologist, a clinical nurse, and a clinical pharmacist) and the investigator used the checklist to score 40 video-recorded inhalation demonstrations in children ≤ 5 years old (pre-study). To enable intra-observer reliability assessment, each expert observer scored the demonstrations twice, with a 1-month inter-score interval. Subsequently, the trained investigator did the study with the 100 participants, checking each video twice. In case of doubt, the opinion of a second expert was requested.

Healthcare professionals' knowledge

In the second part of the study, healthcare professionals' knowledge was evaluated with a semi-structured oral questionnaire. The questions were chosen based on the literature (6, 9, 11, 15) and prior experience (common errors). First, the physicians and nurses were asked about their training in inhalation technique and if they knew how local patients were instructed about pMDI-VHC use. Then, we asked each participant to answer ten questions detailed in Table 3.

Statistical analysis

Mean scores are reported with standard errors. Checklist and knowledge data were compared using descriptive statistics (unpaired Student's t-test, Fisher's exact test or non-parametric Mann-Whitney test). For assessment of inhalation technique videos, inter- and intra-observer reliability were determined with a weighted Kappa coefficient, κ . Perfect agreement is indicated by $\kappa = 1$, whereas $\kappa = 0$ indicates no agreement.

Results

Study healthcare professionals

From a total of 127 healthcare professionals, 103 physicians and nurses were contacted from the pediatric emergency units in Lausanne and Geneva. Three nurses, but no physicians refused to enter in the study. The demographic and practice characteristics of the 100 healthcare professionals are detailed in Table 1. The proportion of intern/resident physicians was nearly the same in both sites and reflected their own organization. Of the 50 nurses in the two units, 11 additionally had a diploma of emergency or intensive care. The nurses' ages were comparable to those of the attending/senior physicians ($p > .99$, Student's t test), but higher than those of the intern/resident physicians ($p < .001$).

Validation of the method for assessing videotaped inhalation technique

Inter- and intra-observer reliability κ scores for checklist items ranged from 0.66 to 1.00. The checklist was sufficiently precise to enable the investigator to evaluate the videotaped evaluations independently ($\kappa = 0.93$ and 0.97 for inter- and intra-observer reliability, respectively).

Physicians' and nurses' inhalation technique

The inhalation technique performance of all observed healthcare professionals from both emergency centers is presented in Figure 1 (score distribution) and Table 2 (performance by step). The mean score overall was 8.3 ± 0.9 (median 8, range 5–9). Just under half of the healthcare professionals (49%) performed all nine steps of the inhalation technique perfectly, with about a third (34%) performing eight steps correctly, and slightly less than a fifth (17%) performing five, six, or seven steps correctly (combined).

Performance levels of the nurse and physician groups for each inhalation technique step are reported in Table 2. Significantly better technique was observed for professionals at the Lausanne center (mean score, 8.6 ± 0.7 ; range, 7–9) than at the Geneva center (mean score, 8.0 ± 0.9 ; range, 5–9; $p = .0001$, Mann-Whitney), as well as for nurses (mean score, 8.6 ± 0.6 ; range, 7–9) relative to physicians (mean score 8.0 ± 1.0 ; range, 5–9; $p = .0004$). Surprisingly, better results were obtained by registered nurses compared to registered nurses with a diploma of emergency or intensive care (8.7 ± 0.5 vs 8.1 ± 0.8 , $p = .0094$). Mean inhalation technique scores were similar for intern/resident doctors (8.2 ± 0.8) and attending/senior doctors (8.0 ± 1.0 ; $p = 0.51$). Perfect inhalation technique was observed in 66% ($N = 33$) of nurses, but only 32% ($N =$

16) of physicians ($p = .0013$, Fisher's exact test). The most frequent errors were forgetting to shake the pMDI before the second dose and incorrect patient or VHC positioning.

Healthcare professionals' knowledge

Only 9/50 physicians (18%) and 32/50 nurses (64%) reported having had specific training on inhalation technique (41% overall). Those who reported that they had not had specific training indicated that their inhaler-use knowledge was self-taught or obtained by observing colleagues. Notably, 19/50 physicians and 45/50 nurses knew the local patient instructions (64% overall). Gaps in inhalation technique knowledge in the analyzed professionals are presented in Table 3. As the results obtained for the intern/resident doctors and the attending/senior doctors did not reach statistical significance ($p=.1704-1.000$), they were pooled together. Only slightly more than half of the healthcare professionals reported that they check the patient's inhalation technique at every visit, and that it was important to prime the pMDI before its first use. Concerning the method used to determine if a pMDI is empty, 59 of 100 participants recommended the flotation technique, 34 relied on listening to noises produced by shaking the inhaler or the presence of spray coming out of the pMDI, 2 said the doses administered should be counted (as recommended by manufacturer), 1 observed the effect of a bronchodilator. Of the 100 participants, 4 indicated that they did not know how to check whether a pMDI was empty. We found that 16% of the healthcare professionals were unable to cite at least one advantage of a VHC, and 89% thought that a mouthpiece should not be used in children less than 5 years old. Only 39 of the 100 healthcare professionals surveyed knew the recommended frequency of cleaning, while 54 indicated that they knew how to clean the VHC.

Discussion

This study, conducted in two pediatric emergency centers, showed that inhalation technique was perfectly mastered (9/9 steps) by 49% of physicians and nurses and almost perfectly mastered (8/9 steps) by an additional 34%. Notwithstanding, a notable portion of the healthcare professionals lacked practical knowledge about pMDI and VHC use. We evaluated the inhalation techniques by filming them on a child mannequin in a calm environment. This allowed us to show the healthcare professionals the steps to improve with the help of the video and to complete their training.

The role of healthcare professionals in correct inhaler use is critical with each type of drug delivery system requiring a certain level of practical skill [2, 3]. In recent years, the importance of repeating instructions and checking asthmatic patients for the optimal inhaler use has been emphasized [3]. In our study, less than one-fifth of physicians and two-thirds of nurses reported having had specific training on inhalation techniques. This lack of structured training for professionals has been highlighted in several studies and led to calls to “train the trainer” [2, 9, 11, 12]. Despite this lack of systematic training, more than 80% of the participants in this study were able to achieve perfect or near-perfect demonstrations based on some combination of on-the-job experience and/or training, use of illustrative booklets, and adherence to local care procedures. Our findings showing better mastery of inhalation technique by nurses than doctors may be explained, at least in part, by the specific training of the participants given that intern and resident doctors had less training than nurses. In practice, mainly nurses in both units teach the inhalation technique to patients. The fact of having of an additional diploma of emergency or intensive care did not seem to have an advantage in this context. Slightly better results were

obtained in the Lausanne center, likely because of the use of a local patient booklet describing the correct use of pMDI-VHC.

Our study is consistent with a study comparing the ability of physicians and nurses. Hanania et al. [13] obtained mastery-level pMDI-VHC demonstration scores for 78% of nurses and 57% of doctors examined in Toronto, Canada ($p < .0001$). Our results are better than those of Iheagwara et al. [14] where only 3% of pediatric physicians and nurses demonstrated all steps correctly with a pMDI and AeroChamber[®] Plus.

The most frequent errors observed in this study were to forgetting to shake the pMDI before the second dose and incorrect patient positioning. Because most patients and caregivers do not know whether an inhaled drug is in solution or suspension, it has become standard practice to shake all pMDIs before use [15-18]. A pMDI should be shaken between successive deliveries of medicine; multiple actuations into the VHC before inhalation can alter the amount of drug inhaled [3, 15, 16]. Additionally, it is important that there be minimal delay between activating the pMDI and inhalation through the VHC [15, 16]. If the child is not able to inhale with a slow and deep breath, tidal breathing is a preferred alternative maneuver, especially in emergencies [16, 17]. If tidal breathing is employed, the pMDI should be activated at the beginning of a tidal inhalation [16]. Two or three tidal breaths are enough to empty a small-volume VHC [16], though five or more breaths are considered safe for all children [3].

Clinical risk for children who continue to use an empty inhaler is evident [18]. Generally, pMDIs containing albuterol/salbutamol are not equipped with a dose counter outside of the USA [19]. There are several techniques for estimating the number of remaining doses in a pMDI; however, shaking, spraying, and flotation are not reliable. Although the manufacturer's instructions tell the user to count every dose, only 2 out of 100 participants answered correctly that doses should be

counted in our questionnaire. The practicality of this expectation is highly questionable for a drug that is not administered regularly [19]. Although the flotation method was considered to be appropriate at the time of the study, we now recommended in our hospitals that the number of doses remaining in albuterol/salbutamol pMDIs be checked by weighing the pMDIs on a digital scale [19]. Furthermore, we advise our staff that patients should be told to keep a spare inhaler available at all times [18].

VHCs with a facemask rather than a mouthpiece may be preferable for very young children (e.g. ≤ 3 years of age) and for all children incapable of making a slow, measured inspiratory effort while holding a mouthpiece between the teeth [3, 16]. Most of the healthcare professionals in this study thought that a mouthpiece should not be used until children are 5 years old, or even later in some cases. Regardless, when a facemask is used, it is important to check its size according to the patient's age.

Some VHCs are equipped with a whistle that sounds if the patient inhales too quickly. In such cases, it is important to explain to the patient that the whistle is not intended to sound [16]. Because VHCs are at risk of bacterial contamination, all devices, including newly purchased and previously used devices, should be washed with low-concentration dishwashing liquid and then be allowed to air dry [2]. Electrostatic charge in non-antistatic VHCs or spacers can also be reduced by washing with soapy water [16]. Conversely, new antistatic devices should be rinsed with soap-free water after cleaning to reduce patient exposure to cleaning agents. Product information is inconsistent across different VHCs with respect to how often it should be cleaned, ranging from weekly to monthly [2]. Plastic pMDI containers should also be cleaned at the same time that the inhaler device is cleaned [12].

This study has several limitations. Participants were recruited during their work time. Thus, it is possible that their inhalation technique and survey responses were influenced by stress. On the other hand, the participants may have exhibited better performance because they knew that the study was underway and that they were being observed (Hawthorne effect). The assessment of other health professionals (respiratory therapists, pharmacists), other patient age groups, and other inhalation devices (nebulizers, dry-powder inhaler) was outside the scope of this study though it would be of interest to examine. Finally, with a mannequin, we cannot ensure that the child is breathing quietly.

A recent review of 39 studies showed that educational interventions on inhaler technique in asthma and chronic obstructive pulmonary disease patients are effective, at least on the short term [20]. These skills and knowledge could be improved with a mandatory training program, including e-learning programs and video tutorials, which can be inexpensive educational resources for improving healthcare practices [9, 11, 21]. The use of brief, repeated training programs has been shown to improve clinical outcomes among patients [22]. The same method with simulation training and video recording could be employed with healthcare professionals.

In conclusion, healthcare professionals' practical skills and knowledge related to inhalation therapy were not completely mastered. In light of these results, we provided information to participating healthcare professionals to help them observe good practices and provide suitable inhalation technique support.

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Table 1. Demographic and practice characteristics of the participants.

Step	Lausanne (N = 50)	Geneva (N = 50)	Total (N = 100)
Gender (male/female)	9 / 41	6 / 44	15 / 85
Age (years, mean $\pm$ SD)	33.5 $\pm$ 9.3	37.5 $\pm$ 9.7	35.5 $\pm$ 9.7
Intern/resident physicians			
N	17	20	37
Age (years, mean $\pm$ SD)	26.9 $\pm$ 1.8	30.6 $\pm$ 3.6	28.9 $\pm$ 3.4
Years of experience (mean $\pm$ SD)	1.8 $\pm$ 1.7	3.8 $\pm$ 3.1	2.9 $\pm$ 2.7
Attending/senior physicians			
N	8	5	13
Age (years, mean $\pm$ SD)	39.4 $\pm$ 6.4	39.4 $\pm$ 8.9	39.4 $\pm$ 7.1
Years of experience (mean $\pm$ SD)	12.5 $\pm$ 5.5	12.4 $\pm$ 8.0	12.5 $\pm$ 6.3
Registered nurses			
N	25	25	50
Age (years, mean $\pm$ SD)	36.1 $\pm$ 10.7	42.7 $\pm$ 10.1	39.4 $\pm$ 10.8
Years of experience (mean $\pm$ SD)	11.5 $\pm$ 11.5	17.8 $\pm$ 8.6	14.6 $\pm$ 10.5

Table 2. Comparison of success percentage for each step between professional groups.

Step	Inhalation technique	Percent correct answers (N)		
		Total (N = 100)	Physicians (N = 50)	Nurses (N = 50)
1.	Remove the cap	99%	100% (50)	98% (49)
2.	Shake the inhaler	93%	88% (44)	98% (49)
3.	Assemble pMDI and VHC correctly	96%	94% (47)	98% (49)
4.	Position the patient and device correctly such that he or she is seated upright with his or her chin up), the pMDI device upright, and the VHC horizontal	89%	86% (43)	92% (46)
5.	Ensure that the mask/mouthpiece fits well on child's face/mouth	100%	100% (50)	100% (50)
6.	Activate the inhaler once after the mask/mouthpiece is in place	92%	90% (45)	94% (47)
7.	Instruct the child take five breaths	100%	100% (50)	100% (50)
8.	Shake the inhaler before a second dose	62%	46% (23)*	78% (39)*
9.	Activate the inhaler once to administer the second dose	99%	98% (49)	100% (50)

*p = .0018, p > .05 for the other steps (Fischer's exact test)

Table 3. Comparison of responses to inhaler use knowledge between professional groups.

No.	Questions	Percent correct answers (N)			Correct answers
		Total (N = 100)	Physicians (N = 50)	Nurses (N = 50)	
1	Do you check your patient's inhalation technique at every visit?	54%	34% (17)*	74% (37)*	Healthcare professionals should be assessing each pediatric asthmatic patient's inhaler technique at every clinical visit [2, 3]
2	Do you think it is important to prime the pMDI before the first use?	55%	64% (32)	46% (23)	pMDIs should be primed at their first use and following non-use for a week or more [2, 12]
3	How do you determine if a pMDI (without a counter) is empty?	2%	2% (1)	2% (1)	The manufacturer's instructions tell the user to count every dose
4	What are the advantages of a VHC (at least 1 answer)?	84%	88% (44)	80% (40)	Reduces impact of hand-breath (activation-inhalation) coordination problems Reduces oropharyngeal deposition Can be used with tidal breathing [12, 16]
5	From what age do you expect patients to use a mouthpiece?	11%	10% (5)	12% (6)	From ≥ 3 years of age [3, 16]
6	Do you know the function of the whistle on some VHCs?	39%	34% (17)	44% (22)	A whistle sounds if the patient inhales too quickly [16]
7	How often do you clean the VHC?	39%	30% (15)	48% (24)	Once a week to once a month [2]
8	How do you clean the VHC?	54%	38% (19)**	70% (35)**	It depends on the VHC (see Discussion)
9	Which inhaler do you use first, a bronchodilator or a corticosteroid?	70%	78% (39)	62% (31)	A bronchodilator should be used before a corticosteroid [2]
10	Do you think it is important to rinse a patient's mouth after inhalation of corticosteroid?	91%	94% (47)	88% (44)	Mouth should be rinsed after inhalation of corticosteroids for the prevention of local adverse effects such as hoarseness and oropharyngeal candidiasis [18]

*p = .0001, **p = .0024, p > .05 for the other questions (Fischer's exact test)

Figure 1. Distribution of inhalation technique score with a pMDI and VHC for 50 physicians and 50 nurses in two pediatric emergency settings. The number of steps performed correctly is equivalent to the assesment score because 1 point was awarded for each correctly performed step.

