Results of a Physician and Respiratory Therapist Collaborative Effort to Improve Long-Term Metered-Dose Inhaler Technique in a Pediatric Asthma Clinic

Beena A Minai MBBS MPH, James E Martin RRT, and Robert C Cohn MD

BACKGROUND: Despite advances in therapy, asthma continues to be the chronic condition most responsible for school absenteeism and pediatric hospitalizations. This is especially true for inner-city children. We operate an inner-city Pediatric Asthma Compliance and Technique (PACT) clinic in which physicians and respiratory therapists collaborate to improve metered-dose inhaler (MDI) technique and outcomes among asthmatic children. OBJECTIVE: To determine the efficacy of our strategy for improving MDI technique and asthma outcomes. METHODS: Children referred to the PACT clinic underwent standardized assessment based on the Expert Panel Guidelines of the National Heart, Lung, and Blood Institute (NHLBI). Clinicians demonstrated and reinforced correct MDI technique at each visit. Using a standardized format we prospectively collected, at the patient's first visit (T1) and most recent visit (T2), data on demographics, MDI-technique scores (MDI steps done correctly; scale of 0–8), pulmonary function, and asthma severity (NHLBI classification scale: 1 = mild intermittent to 4 = severe persistent). Statistical analyses were performed using parametric and non-parametric tests. RESULTS: Of the 60 patients who attended the PACT clinic between 1999 and 2002, 15 were excluded from the study because of incomplete data recording. Mean duration from T1 to T2 was 11.8 ± 9.5 months. At T1 and T2, respectively, the mean MDI-technique scores were 53% and 81%, the mean overall asthma severity scores were 2.6 and 2.3, and the mean overall pulmonary function severity scores were 2.4 and 2.1. MDI-technique scores significantly improved between TI and T2 ($p < 0.001$). The black patients had the largest improvement in MDI technique ($p < 0.001$), but their pulmonary function test results, overall asthma severity, and pulmonary function severity did not improve significantly. The white patients significantly improved both their MDI technique ($p = 0.004$) and their overall asthma severity scores ($p = 0.005$). CONCLUSION: In our PACT clinic asthmatic children showed sustained improvement in MDI technique, and some of the patients improved in pulmonary function and overall asthma severity score. *Key words: asthma, metered-dose inhaler, pediatric.* [Respir Care 2004;49(6):600–605. © 2004 Daedalus Enterprises]

Introduction

Approximately 4.4 million American children suffer from asthma.[1–3] According to the National Heart, Lung, and Blood Institute asthma prevalence increased by 160% (among children < 5 years old) from 22.2 per 1,000 in 1980 to 57.8 per 1,000 in 1994, and the death rate nearly doubled in the 5–24-year-old age group.[1,4] Children, especially those in the inner-city, are more likely to develop

Beena A Minai MBBS MPH, James E Martin RRT, and Robert C Cohn MD are affiliated with the Department of Pediatrics, MetroHealth Medical Center, and School of Medicine, Case Western Reserve University, Cleveland, Ohio.

Correspondence: Robert C Cohn MD, Department of Pediatrics, Pediatric Pulmonology, MetroHealth Medical Center, 2500 MetroHealth Drive, Cleveland OH 44109. E-mail: rcohn@metrohealth.org

This study was funded by grants from the Edwin D Northrop II Foundation, Cleveland, Ohio; GlaxoSmithKline, Research Triangle Park, North Carolina; Merck & Co, Whitehouse Station, New Jersey; and AstraZeneca, Wilmington, Delaware.

Dr Cohn is on the speakers' bureau and has received research grants from GlaxoSmithKline, Merck & Co, and AstraZeneca.

asthma than adults.[5] Blacks are hospitalized for asthma 3–4 times more often and are 4–6 times more likely than whites to die from asthma.[3,6,7] Asthma is the number 1 chronic condition causing children to be absent from school.[8] It is the most common cause of emergency room visits for children 0–14 years old and the highest-ranked cause of pediatric hospitalizations in the United States among children 5–14 years old.[1]

Many parents and patients do not use prescribed asthma-control medications consistently or with proper technique.[1,9,10] The inhalation route (usually via metered-dose inhaler [MDI] or dry-powder inhaler) is preferred over the oral route for asthma drug delivery because delivering drug directly to the airway receptors allows for a lower dose,[11] faster onset of action, and fewer medication-related adverse effects.[12,13] Improper inhaler technique results in inadequate drug delivery and may contribute to mortality. Although only a relatively simple set of instructions need to be followed to ensure proper drug delivery, some patients find the instructions confusing and don't use their inhalers correctly.[12,13] Because of incorrect MDI technique, less than 50% of children receiving inhaler therapy benefit from it. [14] Among both parents and children, lack of familiarity with correct MDI technique results in misuse, overdose, and diminished response to the drug, which can cause unnecessary hospitalization.[10] Improper MDI use can also result in severe respiratory failure and life-threatening events.[10]

The Pediatric Asthma Compliance and Technique (PACT) clinic was created by a collaborative effort among physicians and respiratory therapists (RTs) to improve asthma outcome in our population of inner-city asthmatic children. The philosophy supporting the genesis of the clinic was that pediatric asthma outcome is greatly influenced by the patient's therapy behaviors. Inner-city children have high rates of hospitalization and mortality from asthma. To successfully treat asthma RTs, clinicians, children, and parents and/or caregivers must work together to develop individual treatment plans based on the National Heart, Lung, and Blood Institute's Expert Panel Guidelines for the Diagnosis and Management of Asthma,[15] and the treatment plan must be tailored to the specific needs and circumstances of the child and family. The PACT clinic targets high-risk and difficult-to-manage patients who are $>$ 4 years old and who have an established asthma diagnosis. We stress achievable, sustainable interventions and focus on prevention appropriate for the patient's and family's lifestyle and education to improve adherence to a medical regimen.

At our PACT clinic we have previously shown short-term improvement in MDI administration technique with improved patient/family coaching.[9] The present study examined whether that MDI-technique improvement is sustainable and if it improves pulmonary function and asthma outcomes in one cohort of children.

Methods

The PACT clinic was established in 1999 to improve childhood asthma outcomes at MetroHealth Medical Center, a 428-bed hospital in the inner-city of Cleveland, Ohio. The clinic personnel included a pediatric pulmonologist, an RT, resident physicians, and medical students. Patient visits lasted approximately an hour. Children $>$ 4 years of age were referred to the PACT clinic if they had excessive emergency-department visits or were perceived as difficult to treat by their primary care providers and had been prescribed an MDI before the visit. Children underwent a standardized assessment of pulmonary function and MDI technique, based on the National Institute of Health's Expert Panel Report 2 Guidelines for the Diagnosis and Management of Asthma.[15] RTs demonstrated and reinforced correct MDI technique at each visit. The frequency of follow-up is determined by asthma severity. Pulmonary function testing (PFT) was performed with each patient before and after bronchodilator (albuterol) therapy via MDI. During each visit each patient was asked to demonstrate correct MDI technique, which consists of 8 steps:

1. Remove cap and hold inhaler upright
2. Shake inhaler
3. Breathe out slowly and fully
4. Place inhaler 1–2 inches away from mouth or in mouth
5. Start to breathe in slowly and press down inhaler
6. Breathe in slowly over 3–5 seconds
7. Hold breath at full inhalation for 10 seconds
8. Exhale. Repeat puff as directed, waiting 1 min between puffs.

For each step the RT marked on the scoring sheet whether the patient correctly completed the step or if, instead, prompting or teaching was necessary. Because there are 8 steps, each step accounted for 12.5% of the total test score, and a score of 100% meant that all 8 steps were performed correctly. The patient's MDI score was the percentage of steps performed correctly.

Each patient visit included prospective PFT and determination of the patient's asthma symptom severity. The Appendix shows the assessment form. Assessment methods were in place and unchanged throughout the study period. Results were documented by the clinician seeing the patient. PACT clinic patient charts were retrospectively reviewed for demographic data, symptom severity, and PFT results. Data were collected at 2 time points: time 1 (T1) was the initial patient visit; time 2 (T2) was the last recorded visit. Overall asthma severity was graded from 1 to 4 (1 = mild intermittent, 2 = mild persistent, 3 = moderate persistent, 4 = severe persistent). PFT severity was also graded in the same manner, on a scale of 1–4. Overall asthma severity was defined as the most severe category reflected in the patient's symptom history or PFT

results. The term "PFT severity" refers to the assessment based only on the PFT results.

The study was approved by MetroHealth Medical Center's institutional review board. The patients included in the study obtained care according to the national guidelines. The data were routinely collected from the patients as part of their asthma care. Patient information was kept confidential. Data collection sheets did not include patient names.

Statistical analyses were performed with commercially available software (SPSS version 11.0 for Windows, SPSS Inc, Chicago, Illinois). Both parametric and nonparametric tests were performed. Descriptive statistics were done to obtain means, standard deviations, cross tabulations, and frequencies of the variables. We used Student's paired *t* test to compare differences in the pulmonary variables between T1 and T2. We used 1-way analysis of variance and linear regression analysis to assess the relationship between improvement in MDI technique and other pulmonary measures. The nonparametric test included the chi-square test for significant differences between expected and observed frequencies in one or more categories of all the test variables. Differences were considered statistically significant when $p < 0.005$.

Results

Of the 60 patients who attended the PACT clinic between 1999 and 2002, 15 were excluded from the study because of incomplete data recording. Of the 45 patients included in the analysis 31 were male, 14 were female, 17 were white, 20 were black, and 8 were Hispanic. Mean age was 11.6 ± 2.8 years. Seventy percent of the patients were 10–14 years old. Mean duration between T1 and T2 was 11.8 ± 9.5 months.

Table 1 shows the MDI, PFT severity, and overall asthma severity data.

Table 1. MDI Scores, PFT Severity Scores, Overall Asthma Severity Scores, and PFT Data

	T1	T2
Mean MDI score (%)	53	81
Mean PFT severity score	2.4	2.1
Mean overall asthma severity score	2.6	2.3
Mean FEV_1 (% of predicted)	87	87
Mean FVC (% of predicted)	92	95
Mean $FEF_{25–75}$ (% of predicted)	70	69

MDI = metered-dose inhaler
PFT = pulmonary function test
T1 = initial visit
T2 = last recorded visit
FEV_1 = forced expiratory volume in the first second
FVC = forced vital capacity
$FEF_{25–75}$ = forced expiratory flow during the middle half of the forced vital capacity

Table 2 shows the numbers and percentages of patients who improved, deteriorated, and were unchanged in MDI scores and PFT variables between T1 and T2. At T2 MDI scores had improved in 71% of the patients, PFT severity had improved in 38%, overall asthma severity had improved in 47%, FEV_1 values had improved in 47%, FVC values had improved in 53%, and $FEF_{25–75}$ values had improved in 44%.

Table 3 shows the changes in overall severity and PFT severity between T1 and T2. Student's *t* test indicated a statistically significant improvement in MDI scores ($p < 0.001$) but there was no statistically significant relationship between improved MDI score and pulmonary outcomes. MDI technique improvement was significant among both boys ($p < 0.001$) and girls ($p < 0.01$). The most statistically significant improvement in MDI technique was among blacks ($p < 0.001$) and whites ($p = 0.004$). The Hispanic children's MDI scores did not significantly improve ($p = 0.061$).

The PFT results did not show a statistically significant improvement. Blacks had the worst outcomes: 40% (8/20) of the black patients showed improvement and 60% (12/20) stayed the same or worsened. Among the white patients 53% (9/17) showed improvement. Among the Hispanic patients 50% (4/8) improved.

With regard to overall asthma severity, 40% of the black patients worsened, 30% remained the same, and 30% improved. The difference between T1 and T2 was not significant ($p = 0.560$). Overall asthma severity improved significantly among the white patients: 65% improved, 23% remained the same, and 11% worsened. The mean score at T1 was 2.8 and at T2 it was 2.0 ($p = 0.005$).

Discussion

Numerous publications, including the National Heart, Lung, and Blood Institute's Guidelines for Asthma Management, have stressed the importance of repeatedly educating patients on MDI technique.[1,2,10,15–17] Despite those efforts the rate of patient success with MDI use remains low.[1,16,17] Patients demonstrate better MDI technique when given both verbal instructions and demonstration with a placebo inhaler than when given only an MDI-technique instruction leaflet.[18] Many studies have documented improper MDI use by patients.[19–21] Even after formal MDI training many asthmatic patients continue to use their MDIs incorrectly.[22] In 1980 Shim and Williams[23] reported their startling finding that only 50% of patients were using correct MDI technique 1–30 days after having been instructed in and having demonstrated the correct MDI technique. Resnick et al[11] reported that even among physicians only 26% (10 of 38) demonstrated MDI technique perfectly. More importantly, they also found that even after an instruction session only 26% of those physicians demon-

Table 2. Change in Scores and PFT Variables Between T1 and T2

	MDI score *n* (%)	Overall Asthma Severity Score *n* (%)	PFT Asthma Severity Score *n* (%)	FEV_1 *n* (%)	FVC *n* (%)	$FEF_{25–75}$ *n* (%)
Improved	32 (71)	21 (47)	17 (38)	21 (47)	24 (53)	20 (44)
Unchanged	7 (16)	13 (29)	20 (44)	0 (0)	4 (9)	4 (9)
Deteriorated	6 (13)	11 (24)	8 (18)	24 (53)	17 (38)	21 (47)
p†	< 0.001	0.10	0.10	0.96	0.15	0.87

T1 = initial visit
T2 = last recorded visit
MDI = metered-dose inhaler
PFT = pulmonary function test
FEV_1 = forced expiratory volume in the first second
FVC = forced vital capacity
$FEF_{25–75}$ = forced expiratory flow during the middle half of the forced vital capacity
†p value of difference between T1 and T2

strated the MDI technique perfectly. It is interesting to note that physicians, despite a wealth of health care knowledge and awareness, did not improve their MDI technique with one session alone; this demonstrates the importance of repeated evaluation, assessment, and instruction in MDI technique to optimize MDI drug delivery.[24]

Scarfone et al studied patients' MDI technique in an emergency department setting.[17] All the patients were between 2 and 18 years old, were receiving emergency-department treatment for asthma, and had previously used MDI. The patients were asked to perform the 8 steps of the MDI technique. Only 24.7% performed all the steps correctly. Unlike our study, Scarfone et al did not follow their patients' MDI technique over time. The Scarfone et al study was cross-sectional and the patients were not taught correct MDI technique. They found that younger patients and parents were more likely to perform poorly on several steps.[17]

Teaching patients how to use their medication properly and reinforcing proper use at every visit are key components of practice at the PACT clinic, so we place special emphasis on proper MDI technique. We hypothesized that better MDI technique would improve drug delivery and asthma control, as measured by overall asthma severity and PFT results. We found that PACT patients improved their MDI technique, even over a prolonged period, but there was no statistically significant relationship between improved MDI technique and FEV_1, FVC, or $FEF_{25–75}$. Improved pulmonary function and asthma severity score is, however, related to adherence to asthma-control medications. Perhaps in some of our patients improved MDI technique gave them greater immediate symptom relief and consequently made them less adherent to their asthma-control medications.

Table 3. Change in Overall Severity and PFT Severity Between T1 and T2*

	Overall Asthma Severity Score		PFT Asthma Severity Score	
	T1 *n* (%)	T2 *n* (%)	T1 *n* (%)	T2 *n* (%)
Mild intermittent	6 (13)	18 (40)	13 (30)	21 (47)
Mild persistent	15 (33)	3 (7)	10 (22)	2 (4)
Moderate persistent	16 (36)	17 (38)	13 (30)	17 (38)
Severe persistent	8 (18)	7 (16)	9 (20)	5 (11)

T1 = initial visit
T2 = last recorded visit
PFT = pulmonary function test
FEV_1 = forced expiratory volume in the first second
FVC = forced vital capacity
$FEF_{25–75}$ = forced expiratory flow during the middle half of the forced vital capacity

A study by Chen et al[10] evaluated the impact of long-term education regarding asthma practices and inhalation technique on improving asthma control in children. That study found a significant relationship between inhalation technique and children's knowledge of asthma. None of the children in that study correctly completed all the MDI steps. Family members who had either participated in educational programs or had previously received instruction had a better understanding of asthma and better inhaler technique. Although there are cross-sectional studies of MDI technique among children, each of those highlights the need for regular evaluation of patients' MDI technique. Those studies also found that reliance on patient education pamphlets alone is not sufficient in clinical practice and that clinician-patient interaction and reinforcement are extremely important.[10] It is true that busy clinicians do not have the time to incorporate regular patient asthma education and MDI technique evaluation, but doing so would result in long-term asthma improvement among children. Our study, which was the result of a collaborative effort between RTs and physicians, demonstrated sustained MDI-technique improvement among high-risk children, despite

the fact that most of them were socioeconomically disadvantaged. However, improved MDI technique alone did not improve pulmonary function or clinical outcome in all the patients.

One limitation of our study was that we had no control group. Another limitation was that the statistical power was low, because there were only 45 patients. We did not examine any confounding factors leading to better or worse prognosis, such as asthma-related quality of life, including but not limited to symptoms, emotions, asthma limitations on activities, and tolerance of environmental factors such as cigarette smoke. However, despite those limitations we believe that an asthma compliance and MDI technique clinic can improve and sustain MDI skills among high-risk asthmatic children. We also want to point out that all the children were taught techniques for using an MDI with and without a spacer. We founded our data collection on MDI technique without a spacer, since children often need to be able to administer medication without one.

Conclusion

In our PACT clinic asthmatic children improved their MDI technique over a mean duration of 11.8 months. This is an example of a successful collaborative partnership between RTs and physicians for managing an important disease. However, only some of the patients had improved pulmonary function and overall asthma severity score.

REFERENCES

1. Brottman G. Asthma in children: a report on the Minnesota Asthma Coalition. Minn Med 2002;85(6):41–44.
2. Benson V, Marano MA. Current estimates from the National Health Interview Survey, 1992. Vital Health Stat 10 1994 Jan;(189):1–269.
3. Facts about controlling your asthma. National Institute of Health. National Heart, Lung and Blood Institute. Available at http://www.nhlbi.nih.gov/health/public/lung/asthma/asth_fs.htm. Accessed April 5, 2004.
4. Lara M, Rosenbaum S, Rachelefsky G, Nicholas W, Morton SC, Emont S, et al. Improving childhood asthma outcomes in the United States: a blueprint for policy action. Pediatrics 2002;109(5):919–930.
5. Christiansen SC, Martin SB, Schleicher NC, Koziol JA, Mathews KP, Zuraw BL. Current prevalence of asthma-related symptoms in San Diego's predominantly Hispanic inner-city children. J Asthma 1996;33(1):17–26.
6. Homa DM, Mannino DM, Lara M. Asthma mortality in U.S. Hispanics of Mexican, Puerto Rican, and Cuban heritage, 1990–1995. Am J Respir Crit Care Med 2000;161(2 Pt 1):504–509.
7. Joseph CLM, Ownby DR, Peterson EL, Johnson CC. Racial differences in physiologic parameters related to asthma among middle-class children. Chest 2000;117(1):1336–1344.
8. Pediatric Asthma: Promoting best practice. Guide for managing asthma in children. Milwaukee: American Academy of Allergy, Asthma, and Immunology, the American Academy of Pediatrics; 1999.
9. Foland AP, Stern T, Ramacciotti T, Martin J, Gilbert I, Cohn RC. Improvement of metered-dose inhaler administration technique: the effect of training sessions at a specialized pediatric asthma compliance and technique clinic. Curr Ther Res Clin Exp 2002;63:142–147.
10. Chen SH, Yin TJ, Huang JL. An exploration of the skills needed for inhalation therapy in school children with asthma in Taiwan. Ann Allergy Asthma Immunol 2002;89(3):311–315,.
11. Resnick DJ, Gold RL, Lee-Wong M, Feldman BR, Ramakrishnan R, Davis WJ. Physicians' metered dose inhaler technique after a single teaching session. Ann Allergy Asthma Immunol 1996;76():145–148.
12. Newman SP. Aerosol deposition considerations in inhalation therapy. Chest 1985;88(2 Suppl):152s–160s.
13. Newman SP, Clarke SW. Therapeutic aerosols 1—physical and practical considerations. Thorax 1983;38(12):881–886.
14. Buckley D. Assessment of inhaler technique in general practice. Ir J Med Sci 1989;158(12):297–299.
15. Expert Panel Report 2: Guidelines for the diagnosis and management of asthma. National Asthma Education and Prevention Program Bethesda, MD: National Heart, Lung, and Blood Institute; 1997.
16. Numata Y, Bourbeau J, Ernst P, Duquette G, Schwartzman K. Teaching time for metered–dose inhalers in the emergency setting. Chest 2002;122(2):498–504.
17. Scarfone RJ, Capraro GA, Zorc JJ, Zhao H. Demonstrated use of metered-dose inhalers and peak flow meters by children and adolescents with acute asthma exacerbations. Arch Pediatr Adolesc Med 2002;156(4):378–383.
18. Roberts RJ, Robinson JD, Doering PL, Dallman JJ, Steeves RA. A comparison of various types of patient instruction in the proper administration of metered inhalers. Drug Intell Clin Pharm 1982;16:53–55,59.
19. Kemp JP, Meltzer EO. β_2 adrenergic agonists: oral or aerosol for the treatment of asthma? Asthma 1990;27(3):149–157.
20. Hilton S. An audit of inhaler technique among asthma patients of 34 general practitioners. Br J Gen Pract 1990;40(341):505–506.
21. Crompton GK. The adult patient's difficulties with inhalers. Lung 1990;168 Suppl:658–662.
22. Thompson J, Irvine T, Gratwohl K, Roth B. Misuse of metered-dose inhalers in the hospitalized patients. Chest 1994;105(3):715–717.
23. Shim C, Williams MH Jr. The adequacy of inhalation of aerosol from canister nebulizers. Am J Med 1980;69(6):891–894.
24. Pedersen S, Frost L, Arnfred T. Errors in inhalation technique and efficiency in inhaler use in asthmatic children. Allergy 1986;41(2):118–124.

Appendix

Asthma Assessment Form

SYMPTOM CLASS: CURRENT CLINICAL FEATURES

☐	Mild Intermittent	Intermittent symptoms (wheeze/cough/dyspnea) ≤ 2 times a week Brief exacerbations (from a few hours to a few days) Nighttime asthma symptoms ≤ 2 times a month Asymptomatic between exacerbations
☐	Mild Persistent	Symptoms > 2 times a week but < 1 time per day Exacerbations may affect activity and sleep Nighttime asthma symptoms > 2 times a month, but < 1 time per week
☐	Moderate Persistent	Symptoms daily Exacerbations ≥ 2 times a week; may last days and affect activity Nighttime asthma symptoms > 1 time a week
☐	Severe Persistent	Continuous symptoms Frequent exacerbations Frequent nighttime asthma symptoms Physical activities limited by asthma symptoms

PULMONARY FUNCTION CLASS: FEV_1 AND PEF

☐ MILD INTERMITTENT ≥ 80% FEV_1 and PEF pre bronchodilator and < 12 and 20% change respectively post bronchodilator)

☐ MILD PERSISTENT (≥ 80% FEV_1 and PEF pre bronchodilator and > 12 and 20% change respectively post bronchodilator)

☐ MODERATE PERSISTENT (60–80% FEV_1 or PEF pre bronchodilator)

☐ SEVERE PERSISTENT (< 60% FEV_1 or PEF pre bronchodilator)

PRE: FEV_1 _____L _____% PEF _____L/m _____%

POST: FEV_1 _____L _____% PEF _____L/m _____%

FEV_1 % CHANGE _____% PEF % CHANGE _____%