Effectiveness of Interventions to Teach Metered-Dose and Diskus Inhaler Techniques

A Randomized Trial

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Abstract

Rationale: The most effective approach to teaching respiratory inhaler technique is unknown.

Objectives: To evaluate the relative effects of two different educational strategies (teach-to-goal instruction vs. brief verbal instruction) in adults hospitalized with asthma or chronic obstructive pulmonary disease.

Methods: We conducted a randomized clinical trial at two urban academic hospitals. Participants received teach-to-goal or brief instruction in the hospital and were followed for 90 days after discharge. Inhaler technique was assessed using standardized checklists; misuse was defined as 75% steps or less correct (≤9 of 12 steps). The primary outcome was metered-dose inhaler misuse 30 days postdischarge. Secondary outcomes included Diskus technique; acute care events at 30 and 90 days; and associations with adherence, health literacy, site, and patient risk (near-fatal event).

Measurements and Main Results: Of 120 participants, 73% were female and 90% were African American. Before education, metered-dose inhaler misuse was similarly common in the teach-to-goal and brief intervention groups (92% vs. 84%, respectively; $P = 0.2$). Metered-dose inhaler misuse was not significantly less common in the teach-to-goal group than in the brief instruction group at 30 days (54% vs. 70%, respectively; $P = 0.11$), but it was immediately after education (11% vs. 60%, respectively; $P < 0.001$) and at 90 days (48% vs. 76%, respectively; $P = 0.003$). Similar results were found with the Diskus device. Participants did not differ across education groups with regard to rescue metered-dose inhaler use or Diskus device adherence at 30 or 90 days. Acute care events were less common among teach-to-goal participants than brief intervention participants at 30 days (17% vs. 36%, respectively; $P = 0.02$), but not at 90 days (34% vs. 38%, respectively; $P = 0.6$). Participants with low health literacy receiving teach-to-goal instruction were less likely than brief instruction participants to report acute care events within 30 days (15% vs. 70%, respectively; $P = 0.008$). No differences existed by site or patient risk at 30 or 90 days ($P > 0.05$).

Conclusions: In adults hospitalized with asthma or chronic obstructive pulmonary disease, in-hospital teach-to-goal instruction in inhaler technique did not reduce inhaler misuse at 30 days, but it was associated with fewer acute care events within 30 days after discharge. Inpatient treatment-to-goal education may be an important first step toward improving self-management and health outcomes for hospitalized patients with asthma or chronic obstructive pulmonary disease, especially among patients with lower levels of health literacy.

Clinical trial registered with www.clinicaltrials.gov (NCT01426581).

Keywords: asthma; chronic obstructive pulmonary disease; patient education as topic; self-care

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Asthma and chronic obstructive pulmonary disease (COPD) are the most common lung diseases in the United States, accounting for more than 1 million hospitalizations annually (1). Medications delivered through respiratory inhaler devices are recommended in guidelines for rescue and controller therapy to decrease symptoms, exacerbations, and need for rescue medications and to improve quality of life and lung function (2–6). However, inhaler devices require multiple, sometimes complex steps, making them difficult to use (7–11). Patients often do not know these steps or cannot complete them effectively, resulting in misuse (12, 13).

Studies suggest that 28–68% of outpatients (10, 14) and 62–86% of inpatients (13) misuse inhaler devices, placing them at increased risk for poor health outcomes and future hospitalizations (15, 16). The cost of inhaler misuse accounts for $5 billion to $7 billion of the approximately $25 billion spent annually on inhalers (17).

Current guidelines address this risk for misuse by recommending inhaler technique assessment and instruction during all healthcare encounters, including hospitalizations (2, 3). Hospital-based self-management education may be useful, since experience with acute illness can be harnessed as a "teachable moment" (18). Teach-to-goal (TTG) instruction (12, 13), based on the testing effect and allowing memory to be enhanced through the act of retrieving information while learning (19), is comprised of tailored rounds of assessment and instruction to achieve the goal knowledge or skill (7, 12, 13, 20).

We demonstrated in a prior study that hospital-based TTG has greater efficacy than verbal instructions (brief intervention) immediately after instruction in the hospital (13). However, the longer-term effects of hospital-based TTG instruction on inhaler technique and acute care events after discharge to home are unknown. This knowledge may help inform which methods of education are most effective in improving outcomes after discharge among patients using inhalers.

The objectives of this two-center randomized clinical trial among inpatients with asthma or COPD were to compare the effects of hospital-based TTG with brief instruction on inhaler technique and acute care events at 30 and 90 days after discharge to home. We hypothesized that, among participants with asthma or COPD receiving inpatient education, metered-dose inhaler (MDI) misuse would be significantly lower among TTG participants than among brief intervention participants at 30 days after hospital discharge. Some of the results of these studies have been reported previously in abstract form (21–23).

Methods

Study Design and Randomization

We conducted a two-site, block-stratified randomized clinical trial comparing TTG and brief education interventions. Participants were assigned to interventions stratified by site (hospitals 1 and 2) and health literacy level (adequate health literacy, low health literacy, or insufficient vision to complete the health literacy assessment) (24). Study personnel were masked to intervention assignments. Participants received compensation for their time. The institutional review boards at University of Chicago Medicine and Mercy Hospital and Medical Center, Chicago, approved the study.

Study Participants and Procedures

Patients were eligible if they were aged 18 years or older, hospitalized with a physician's diagnosis of asthma or COPD, and discharged using a pressurized MDI per the assenting primary clinical team. Patients were excluded if the treating physician did not provide assent or if the patient did not provide written informed consent.

One trained research assistant collected information on participant demographics, health literacy level (Short Test of Functional Health Literacy in Adults [10, 24, 25]), and vision assessment (Snellen chart) (10, 24). The research assistant assessed inhaler technique using previously validated standardized checklists for both MDI use with an AeroChamber device (Geo. S. Trudell Co., London, ON, Canada) (Cohen's $\kappa = 0.94$) (12) and the breath-actuated Diskus device (Glaxo Group Limited, Brentford, UK) (only among participants being discharged to home with a Diskus device in addition to their MDI) (12, 13). Participants were asked about their rescue inhaler use at their 30- and 90-day follow-up visits, as well as about missed doses of their Diskus devices, when prescribed. Participants were considered at high risk if they reported a lifetime near-fatal event (i.e., intensive care unit hospitalization and/or intubation).

Intervention

Participants were randomized to TTG or brief intervention and were provided instructions on 12-step MDI with spacer (all patients) and 10-step Diskus (only those prescribed) instructions, as per our previously published approach (Figure 1). Detailed descriptions of the intervention and its rationale are available as an online supplement and in our prior publication (13). The interventions were delivered by trained research educators who were masked to the other strategy to prevent

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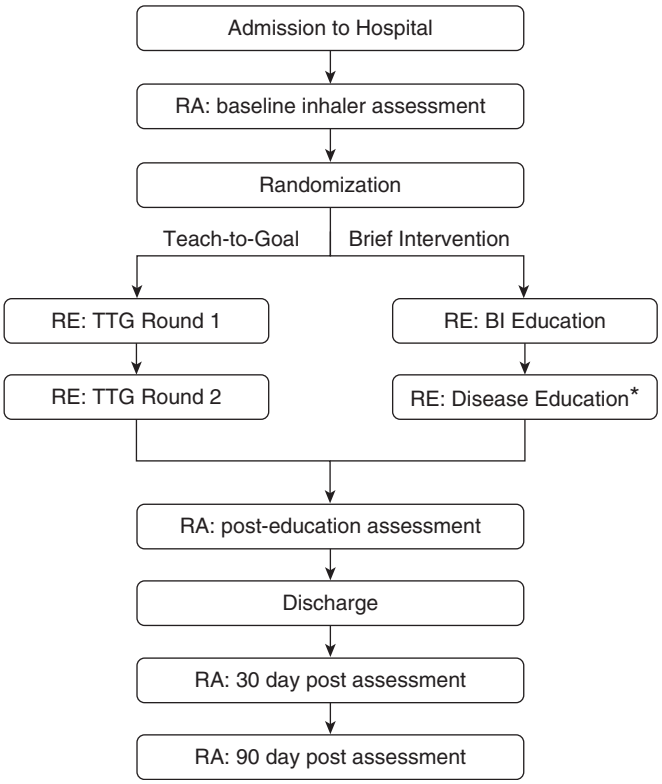

Figure 1. Intervention. *Disease education served as an attention control. BI = brief intervention; RA = research assessor; RE = research educator; TTG = teach-to-goal.

contamination, and the interventions were consistent across sites. Participants returned for in-person study visits at 30 (±7) and 90 (±14) days.

Outcomes

The primary outcome was MDI misuse at 30 days postdischarge. Secondary outcomes included MDI misuse immediately after education and at 90 days, Diskus misuse immediately after education and at 30 and 90 days, rescue inhaler use and adherence to inhaled controller medications, and postdischarge acute care events (self-reported all-cause emergency department visits or hospitalizations) at 30 or 90 days.

Statistical Analyses

Participant characteristics were described using proportions, mean (SD), or median (interquartile range). We used two-sample *t* tests and Mann–Whitney *U* tests to compare baseline characteristics between groups, as appropriate. We used two-sample *t* tests of proportions to compare MDI misuse in each group over time and χ^2 tests to evaluate MDI technique at each time point postdischarge. Technique was dichotomized using our prior definition of MDI misuse (≤75% [≤9 of 12] steps correct) (12, 13).

The study was powered at 80% for an effect size of greater than or equal to 20% improvement of the TTG group compared with the brief intervention group. To ascertain whether baseline misuse and/or other patient characteristics factored into group differences at the 30- and 90-day time points, in secondary analyses we examined MDI misuse as a repeated measures variable, adjusting for baseline MDI misuse, Diskus use, health literacy, sex, and race using a generalized estimating equation model (26).

A *post hoc* sensitivity analysis was performed to evaluate MDI technique using two additional misuse cutoffs: (*1*) χ^2 tests were used to dichotomize misuse if participants missed only "mission critical" steps as advised by pulmonary specialists that would, if missed, result in no medication reaching the lungs (removing cap, activating inhaler); and (*2*) linear regression was used to evaluate misuse based on the delta score at 30 days versus immediately after education. Fisher's exact tests were used to test for differences in acute care events between groups.

All analyses were performed using intention-to-treat analyses. In tests of significance, we used a two-sided *P* value less than 0.05. STATA version 12 software (StataCorp LP, College Station, TX) was used in the analyses.

Results

A total of 872 patients were screened to participate in the study, 120 of whom were eligible. Participants were randomized into TTG intervention (n = 62) and brief intervention (n = 58) groups between September 2011 and February 2013 (Figure 2). Of the 120 participants, 100 were enrolled at hospital 1 and 20 were enrolled at hospital 2. Among enrolled participants, the median age was 48.5 years (interquartile range, 35–58 yr), and the sample included a preponderance of females and African Americans.

Most participants returned for their 30-day (overall, n = 107 [89%]; TTG, n = 54 [87%]; brief intervention, n = 53 [91%]) and 90-day (overall, n = 103 [86%]; TTG, n = 52 [84%]; brief intervention, n = 51 [88%]) follow-up visits. Only 32% of participants were prescribed a Diskus device for use postdischarge. Eighty-three percent of participants reported having a healthcare provider for their asthma or COPD. Two-thirds were hospitalized at least once in the last year, and nearly one-half had had a near-fatal event in their lifetime (Table 1). Baseline characteristics and inhaler techniques (MDI and Diskus) were similar in the TTG and brief intervention groups (Figure 3A). The average time needed for TTG education was 6 minutes, and for the brief intervention group it was 2 minutes.

All 120 participants completed the pre- and posteducation evaluations in the hospital. At 30 days after hospital discharge, there were no significant differences in participant characteristics between those who completed the assessments and those who were lost to follow-up (Table 2). However, participants with a prior near-fatal event (53% vs. 24%; $P = 0.03$) were more likely to return for the 90-day follow-up visit.

MDI technique improved immediately after education, with decreased proportions of misuse for both the TTG group (from 92% to 11%; $P < 0.001$) and the brief intervention group (from 84% to 60%; $P < 0.001$). However, the reduction in misuse was greater in the TTG group than in the

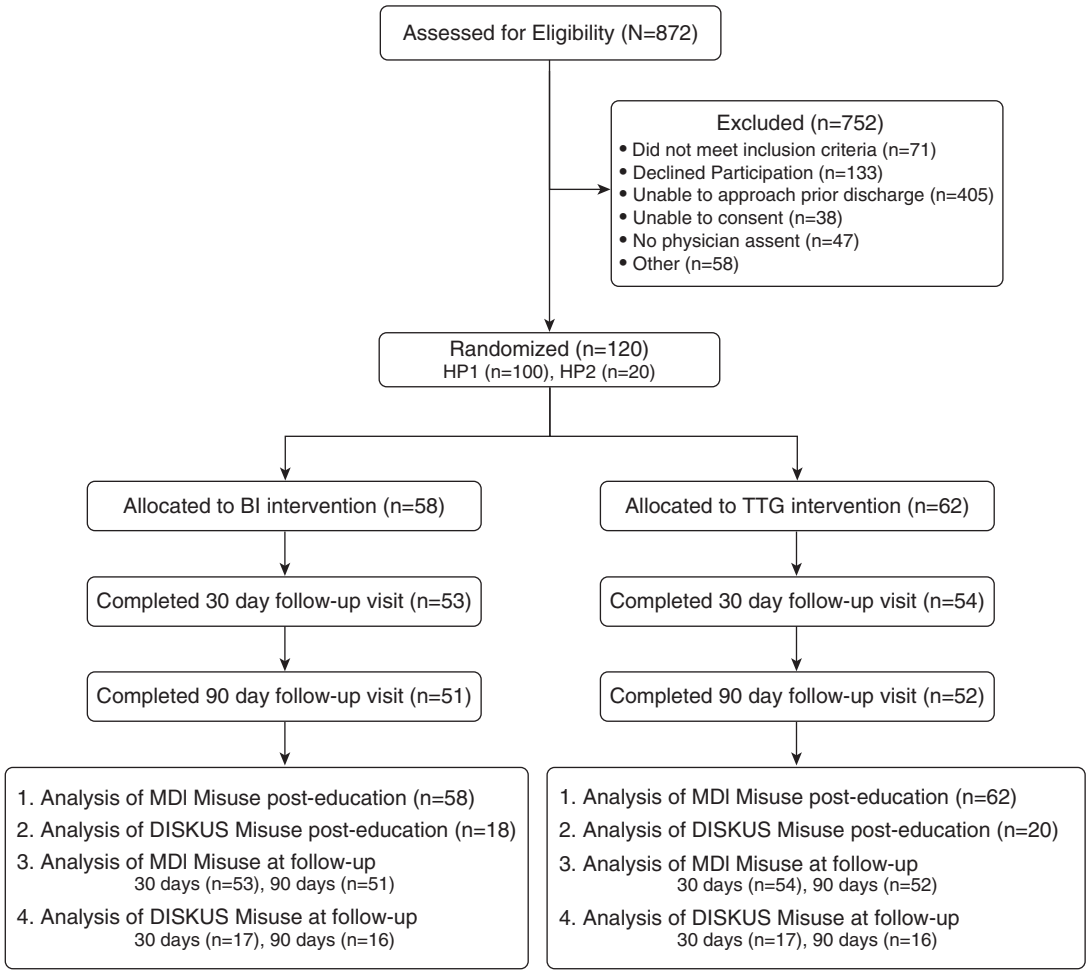

Figure 2. Participant flow from initial assessment through primary outcome analysis. BI = brief intervention; HP1 = hospital 1; HP2 = hospital 2; MDI = metered-dose inhaler; TTG = teach-to-goal.

brief intervention group (81% in TTG group vs. 24% in brief intervention group; $P < 0.001$) (Figure 3A).

Postdischarge Metered-Dose Inhaler Technique

The proportion of participants who misused MDIs during the first 30 days after hospital discharge in the TTG group (54%) versus the brief intervention group (70%) was not significantly different ($P = 0.1$). Among participants who received TTG education, the proportion of MDI misuse immediately after hospital education versus 30 days after hospital discharge increased from 11% to 54% ($P < 0.001$) (Figure 3A). The proportion of misuse in the brief intervention group did not change significantly at 30 days versus immediately after hospital discharge (70% vs. 60%; $P = 0.1$). At 90 days, the proportion of participants with MDI misuse was significantly lower in the TTG group than in the brief intervention group (48% vs. 76%; $P = 0.004$).

In multivariable analyses that accounted for baseline MDI misuse, use of Diskus device, health literacy, sex, and race, the odds of MDI misuse in the brief intervention group at 30 days was 4.0 (95% confidence interval [CI], 1.0–14.0; $P = 0.01$) times that of the TTG group. At 90 days, the results of multivariable analyses also suggested a higher OR of MDI misuse with the brief intervention compared with TTG (OR, 7.0; 95% CI, 2.0–21.0; $P = 0.001$).

In our sensitivity analysis using the outcome of any MDI critical step missed, we found that the OR of MDI misuse was higher in the TTG group than in the brief intervention group posteducation (OR, 4; 95% CI, 0.48–32; $P = 0.004$). Using an outcome of number of MDI steps correct was significantly different in the TTG and brief intervention groups posteducation ($P < 0.001$) and at 90-day follow-up ($P = 0.01$), with an average of 4.4 more steps correct posteducation and 2.4 more steps correct at 90-day follow-up in the TTG group versus the brief intervention group. These data suggest that participants educated with the TTG intervention retained knowledge of critical steps in the use of MDI better than those educated using the brief intervention.

When we examined potential differences between subgroups, we found no significant differences between sites for MDI technique at each time point analyzed. There were also no differences in MDI misuse between the TTG group and the brief intervention group by health literacy group at 30 days; those with adequate health literacy had a lower OR of MDI misuse at

Table 1. Participant characteristics

Characteristic	All Participants (*n* = 120)	Brief Intervention (*n* = 58)	Teach-to-Goal Intervention (*n* = 62)
Sociodemographic			
Age, years, median (IQR)	48.5 (35–58)	49 (39–57)	48 (35–59)
Asthma vs. COPD	82 (68%)	36 (62%)	46 (76%)
Female sex	88 (73%)	41 (71%)	47 (76%)
African American*	108 (90%)	52 (90%)	56 (90%)
Hispanic or Latino	10 (8%)	5 (9%)	5 (8%)
Ever-smoker†	83 (69%)	41 (71%)	42 (68%)
Insufficient vision‡	18 (15%)	8 (14%)	10 (16%)
Less than adequate health literacy§	23 (23%)	10 (20%)	13 (25%)
Postdischarge inhaler prescribed			
MDI	120 (100%)	58 (100%)	62 (100%)
Diskus	38 (32%)	18 (31%)	20 (32%)
Study site			
Hospital 1	100 (83%)	49 (84%)	51 (82%)
Hospital 2	20 (17%)	9 (16%)	11 (18%)
Healthcare services			
Healthcare provider for asthma/COPD care‖	99 (83%)	51 (88%)	48 (77%)
Hospitalized in the last 12 mo, ⩾1 time, excluding study period	79 (66%)	34 (59%)	45 (73%)
Near-fatal respiratory event, ⩾1 ICU admission or intubation for asthma or COPD	59 (49%)	26 (45%)	33 (53%)

Definition of abbreviations: COPD = chronic obstructive pulmonary disease; ICU = intensive care unit; IQR = interquartile range; MDI = metered-dose inhaler. All data are presented as number (%) unless otherwise indicated.
*Other races: white (12%), American Indian or Alaska native (1%), and native Hawaiian or other Pacific Islander (1%).
†Ever-smoker was defined as more than 100 lifetime cigarettes versus never-smoker.
‡Insufficient vision was defined as worse than 20/50 vision in both eyes using the Snellen chart.
§Health literacy was assessed in 102 participants with brief intervention (n = 50) or treat-to-goal intervention (n = 52). The remaining subjects had insufficient vision to complete assessments (n = 18). Less than adequate health literacy was defined as a score less than 23 of 36 on the Short Test of Functional Health Literacy (24).
‖Identified either a general physician, specialist physician (pulmonologist or allergist), or nurse practitioner as providing care for participants' asthma or COPD.

90 days in the TTG group than those in the brief intervention group ($P = 0.03$) (Figure 3B).

We did not observe effect modification by health literacy on the association between MDI misuse and TTG versus the brief intervention group immediately after education or at 30- or 90-day follow-up. Additionally, using multivariate analysis after adjusting for sex, race, and health literacy level, we found that the OR of MDI misuse remained significantly lower in the TTG group than in the brief intervention group immediately after education ($P < 0.001$) and at 90-day follow-up ($P = 0.005$), but not at 30-day follow-up ($P = 0.06$). This analysis suggests that TTG was broadly applicable and superior to brief intervention for MDI in the different subgroups and literacy levels in our patient population.

Postdischarge Diskus Technique

Among patients who were prescribed a Diskus device, TTG education was superior to the brief intervention, with a significantly lower proportion of misuse immediately following education (5% vs. 61%; $P = 0.001$). In the TTG group, Diskus misuse increased from 5% immediately after education to 53% at 30 days postdischarge ($P = 0.001$). There was no significant change in Diskus misuse in the brief intervention group during the same time period (61% vs. 59%; $P = 0.9$). We did not observe a significant change in Diskus misuse at 90 days compared with 30 days postdischarge in either the TTG group (38% at 90 days vs. 53% at 30 days; $P = 0.3$) or the brief intervention group (62% at 90 days vs. 59% at 30 days; $P = 0.5$). In addition, at 90 days, Diskus misuse was common and not significantly different between the TTG and brief intervention groups (38% vs. 63%; $P = 0.2$).

Multiinhaler (Metered-Dose Inhaler + Diskus) Technique

For patients using both MDI and Diskus (n = 38), 39% misused at least one device (15 of 38) and 18.4% (7 of 38) misused both devices posteducation ($P = 0.005$). We observed higher risk of misuse among those using multiple devices at baseline ($P = 0.02$), but not after teaching began ($P > 0.05$). Among the 34 participants using both devices at 30 days postdischarge, we observed a significant association between MDI and Diskus misuse ($P = 0.04$). For instance, of the participants who misused at least one device (24 [71%] of 34), more than half misused both devices (14 [58%] of 24). Among the 32 participants using both devices at 90 days postdischarge, the association between MDI and Diskus misuse remained ($P = 0.01$). Of the 21 participants misusing at least one device (66%), 13 individuals misused both devices (62%). In our analysis of confounding by multiple device use, we found no significant differences in misuse between the TTG and brief intervention groups at any time point (posteducation, $P = 0.06$; 30 days postdischarge, $P = 0.19$; 90 days postdischarge, $P = 0.06$).

Acute Care Events Postdischarge

Overall, 23% (28 of 120) of participants reported an acute care event at 30 days after hospital discharge (Figure 4). Fewer events (9 [17%] of 54) occurred in the TTG group

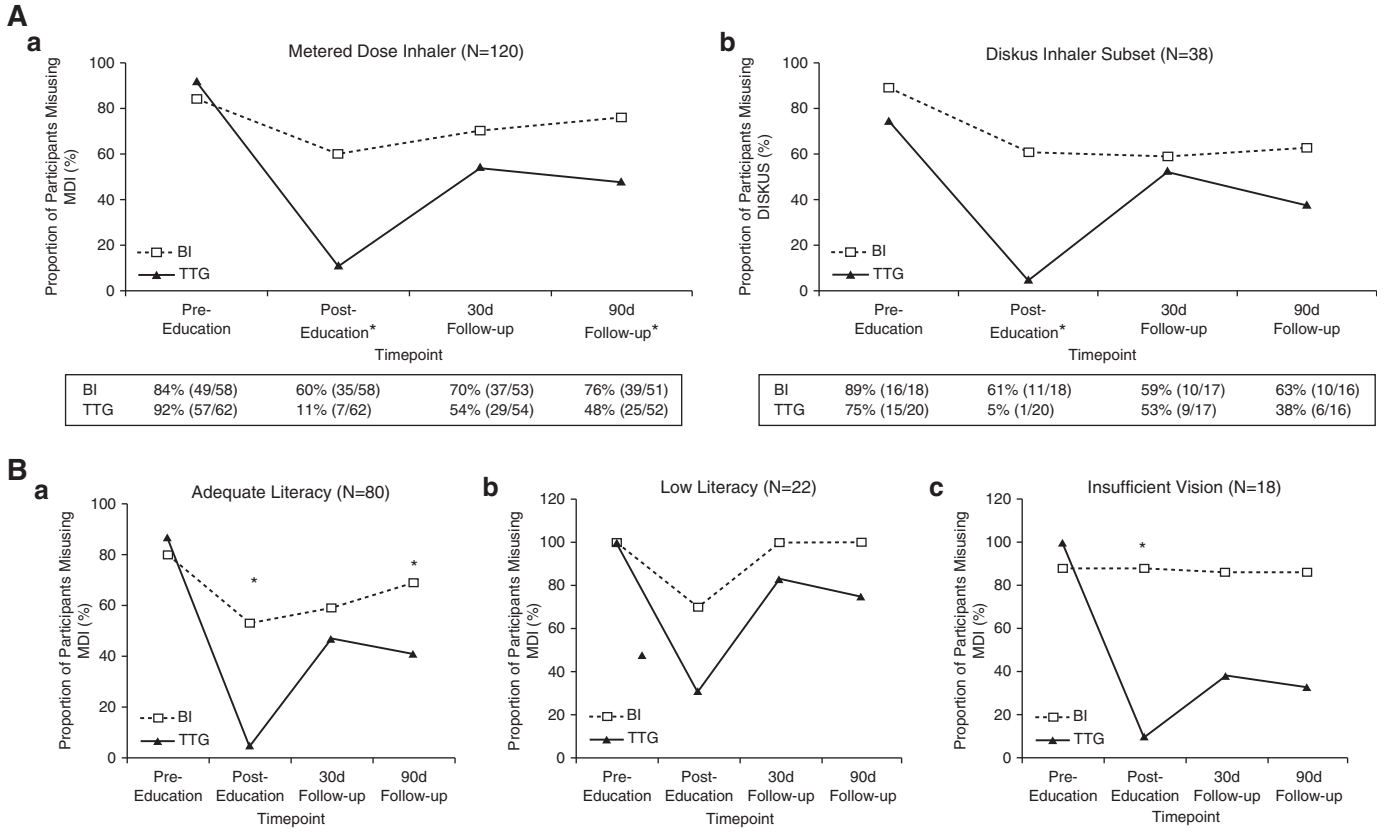

Figure 3. (*A*) Proportion of participants misusing either (*a*) metered-dose inhaler or (*b*) Diskus inhaler. (*B*) Proportion of participants who misused metered-dose inhaler with (*a*) adequate literacy, (*b*) low literacy, and (*c*) insufficient vision. BI = brief intervention; MDI = metered-dose inhaler; TTG = teach-to-goal. *Significant association at the $P < 0.05$ level.

than in the brief intervention group (19 [36%] of 53) ($P = 0.03$). At 90 days postdischarge, 36% (43 of 120) of participants reported an acute care event due to any cause (43 [36%] of 120 reported an emergency department visit; 26 [22%] of 120 reported a hospitalization). There were no longer any differences in the proportion with acute care events in the TTG group compared with the brief intervention group (34% vs. 38%; $P = 0.6$).

Participants with low health literacy (n = 23) were more likely than participants with adequate health literacy (n = 79) to have an acute care event within 30 days after discharge (39% vs. 18%; $P = 0.03$). However, among participants with low health literacy, those receiving TTG education were less likely than those receiving the brief education intervention to report an acute care visit within 30 days after discharge (15% vs. 70%; $P = 0.008$). We did not find that TTG mitigated acute care visits among participants with adequate health literacy at 30 days ($P = 0.08$). No differences by level of health literacy, within or across participant groups, were found for acute care events at 90 days. There were no differences by site or patient risk (high risk defined by at least one lifetime near-fatal event) at 30 or 90 days after hospital discharge ($P > 0.05$).

Rescue Use and Controller Adherence Postdischarge

Participants did not differ across the TTG and brief intervention groups with respect to their use of rescue MDIs postdischarge. Participants reported at the 30-day follow-up visit (overall, n = 107; TTG, n = 54; brief intervention, n = 53) that they had, on average, used their rescue MDIs on 2.5 of the last 7 days (2.4 d in TTG group vs. 2.5 d in brief intervention group; $P = 0.8$) and on 7.7 of the last 30 days (7.9 d in TTG group vs. 7.6 d brief intervention group; $P = 0.8$). Similarly, at the 90-day follow-up visit (overall, n = 103; TTG, n = 52; brief intervention, n = 51), participants reported, on average, that they had used their rescue MDIs on 2.5 of the last 7 days (2.3 d in TTG group vs. 2.8 d in brief intervention group; $P = 0.3$) and on 9.2 of the last 30 days (8.1 d in TTG group vs. 10.3 d in brief intervention group; $P = 0.2$).

Participants also did not differ with respect to adherence to their Diskus device. Among the 34 participants returning at the 30-day follow-up visit (TTG, n = 17; brief intervention, n = 17), exactly the same number of participants in each group (TTG, n = 4; brief intervention, n = 4) reported missing more than one dose of their controller medication ($P > 0.999$). Among the 32 participants returning at the 90-day follow-up visit who used the Diskus device, almost equal numbers of participants (TTG, n = 3; brief intervention, n = 2) reported missing more than one dose in the last 30 days ($P = 0.6$).

Discussion

To our knowledge, this is the first study of hospitalized patients with asthma or COPD

Table 2. Comparison of participants completing the study with those lost to follow-up

Characteristic	Completed 30 d of Follow-Up			Completed 90 d of Follow-Up		
	Yes (*n* = 107)	No (*n* = 13)	*P* Value	Yes (*n* = 103)	No (*n* = 17)	*P* Value
Age, yr, median	48	50.6	0.4	48	51	0.4
Female sex	79 (74%)	9 (69%)	0.7	75 (73%	13 (77%)	>0.99
African American	97 (91%)	85	0.6	95 (92%)	13 (76%)	0.07
Ever-smoker*	73 (68%)	10 (77%)	0.8	69 (67%)	14 (82%)	0.4
Insufficient vision†	15 (14%)	3 (23%)	0.4	13 (13%)	5 (29%)	0.1
Inadequate health literacy‡	21 (23%)	2 (20%)	>0.99	21 (23%)	2 (17%)	>0.99
Hospitalized in the last 12 mo, ⩾1 time, excluding study period	71 (66%)	8 (62%)	0.8	69 (67%)	10 (59%)	0.6
No provider§	17 (16%)	4 (31%)	0.2	18 (17%)	3 (18%)	>0.99
Near-fatal respiratory event, ⩾1 ICU admission or intubation for asthma or COPD	54 (50%)	5 (38%)	0.6	55 (53%)	4 (24%)	0.03
Site, hospital 1 vs. hospital 2	91 (85%)	9 (69%)	0.2	86 (83%)	14 (82%)	>0.99
Asthma vs. COPD	76 (71%)	6 (46%)	0.1	73 (71%)	9 (53%)	0.3

Definition of abbreviations: COPD = chronic obstructive pulmonary disease; ICU = intensive care unit.
All data are presented as number (%) unless otherwise indicated. Baseline completers, n = 120; 30-day completers, n = 107 (lost to follow-up, n = 13); 90-day completers, n = 103 (lost to follow-up, n = 17).
*Ever-smoker was defined as more than 100 lifetime cigarettes versus never-smoker.
†Insufficient vision was defined as worse than 20/50 vision in both eyes using the Snellen chart.
‡Health literacy was assessed in 102 participants with brief intervention (n = 50) or treat-to-goal intervention (n = 52). The remaining subjects had insufficient vision to complete the assessment (n = 18). Less than adequate health literacy was defined as a score of less than 23 of 36 on the Short Test of Functional Health Literacy (24).
§Did not identify a general physician, specialist physician (pulmonologist or allergist), or nurse practitioner as providing care for participants' asthma or COPD.

involving a direct comparison of hospital-based education strategies regarding their durability and lasting effects for inhaler technique and acute care events after discharge to home. Two principal findings emerged. First, TTG is superior to a brief education intervention for reducing initial inhaler misuse. However, the overall benefit of TTG wanes, such that the difference in MDI misuse between the two groups is not significant by 30 days. Second, the group that received TTG education was significantly less likely to have acute care events at 30 days (but not at 90 d) after hospital discharge. Further, TTG appeared to be particularly protective for patients with low health literacy.

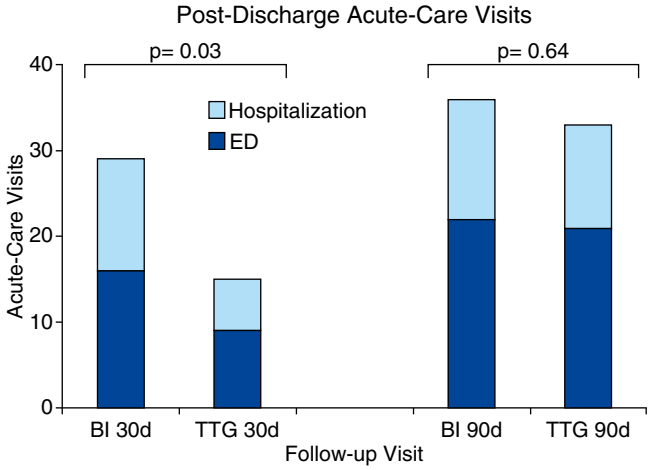

Figure 4. Postdischarge acute care visits. A total of 107 participants (89%) returned at 30 days postdischarge (TTG, 54 of 62; brief intervention, 53 of 58), and a total of 103 (86%) returned at 90 days (TTG, n = 52 of 62; brief intervention, n = 51 of 58). There were fewer acute care visits (emergency department visits and/or hospitalizations) among teach-to-goal participants than among brief intervention participants (9 [17%] of 54 vs. 19 [36%] of 53, respectively; $P = 0.03$) at 30 days, but not at 90 days (21 [40%] of 52 vs. 22 [43%] of 51, respectively; $P = 0.64$) after hospital discharge. BI = brief intervention; ED = emergency department; TTG = teach-to-goal.

Importantly, together, these findings suggest that TTG may be a superior initial strategy for inhaler instruction and that improved clinical outcomes may be gained by providing TTG inpatient inhaler education, especially for patients with lower health literacy levels, but that reinforcement of inhaler technique is required after discharge to achieve long-lasting skill retention and improved health outcomes.

TTG's superior effect compared with a brief education intervention on reducing inhaler misuse among inpatients, initially reported in earlier work (13), was redemonstrated in this study. However, a new finding in this study is that these observed differences in MDI misuse between TTG and brief intervention groups at later time points were smaller, and, although the differences favored the TTG group at both 30 and 90 days, the differences were not consistently significantly different. Despite their decaying skills, however, TTG participants returned less often for acute care events within 1 month; this was true even for participants with low health literacy and did not differ with respect to medication adherence postdischarge. Of note, within 3 months, differences in acute care use did not differ by group, despite differences in MDI misuse. In future work, researchers should explore the relationship with

longer-term skill retention and the impact on clinical outcomes.

The implications of these two findings are that TTG provides initial improvement in inhaler technique and that these enhanced skills may persist long enough to provide initial postdischarge benefit. However, due to patients' declining skills and the lack of persistent differences in clinical outcomes by 3 months, additional education sessions or "doses" may be needed for ongoing effective technique and longer-term beneficial health outcomes.

Participants' decaying inhaler technique skills were not surprising, because, based on the cognitive psychology literature, skill decay is expected with complex tasks (27). Decay of MDI skills is based on many factors, including the nature of the task and time between uses (28).

TTG may have an advantage over brief intervention through its repeated cycles, as TTG provides an opportunity for "overlearning" (28) and uses the cognitive psychology phenomenon of the "testing effect" that can mitigate skill decay (19, 28). This may be observed when looking within groups between the 30-day postdischarge proportion with MDI misuse compared with baseline misuse. MDI misuse at 30 days postdischarge among TTG participants was half what it was before TTG education, while brief intervention participants' MDI misuse was down by only about 10% from baseline. However, even the TTG use of "overlearning" and the testing effect phenomenon would not be expected to be sufficient to completely overcome skill decay. Therefore, repeated dosing of skill education is supported both by clinical guidelines that suggest assessing and teaching self-management skills at all health encounters and by psychology literature which says that regular repetition is required to avoid skill decay (28). In the present study, since the misuse largely plateaued by 30 days, most of the skill decay had already likely occurred. Therefore, the ideal time for the repeated education would be before 1 month postdischarge.

Strengths and Limitations

Our study has multiple strengths, including random allocation to two different educational strategies, masking of research personnel to avoid contamination of educational interventions between study groups or biased collection of outcomes, and high postdischarge follow-up rates.

The study also has potential limitations. The findings derived from our largely high-risk population, nearly half of which had a prior near-fatal respiratory exacerbation, and with its preponderance of African American subjects, may not be applicable to other patient populations. The interventions in our study were delivered by trained research staff. Whether such interventions are effective when delivered by trained clinical staff needs study. We assessed acute care events after hospital discharge, as well as inhaler use and adherence, on the basis of patient self-report. Problems with recall and lack of objective verification may result in less accurate data. However, the follow-up rates at 30 days were similarly high in both groups (nearly 90%), and it is unlikely that patients in the two groups would have differential recall. In future work, investigators can employ objective adherence monitoring for MDI use.

Our sample size for participants using Diskus was only one-third of the enrolled population; therefore, the findings regarding Diskus, including multiple inhaler use results, require further study. Participants with both asthma and COPD were included in this study, and important differences by subpopulation may exist, whether due to disease type, age, or other potential mediators. In future work, researchers can delineate if and how the effects of TTG versus brief intervention differ between the two groups. Further, our patient population had a high rate of lifetime near-fatal events, indicating a patient population that may learn differently from a healthier population. Effects of TTG on outpatients' ability to learn and retain MDI technique skills is warranted.

Finally, while TTG is a relatively inexpensive strategy compared with expenses associated with exacerbations, the need for in-person educators may be cost and/or time prohibitive in some settings. Therefore, in future work, investigators can explore the development of alternative strategies that allow for harnessing the strengths of TTG without resource burden of personnel.

Conclusions

The findings of the present study emphasize the need for self-management training in inhaler technique at all healthcare encounters. The results of our study provide justification for developing and implementing hospital-based strategies, such as TTG, to educate patients about use of their respiratory inhalers. In addition, they suggest the need for postdischarge education, such as when patients present for care in the ambulatory setting, or even at home. Strategies including novel technology-based educational platforms that can be provided initially in the hospital and then extended postdischarge may add value to chronic disease self-management education.

Our data emphasize the critical need for postdischarge educational reinforcement of hospital-based education. The ideal timing, method, and location of this additional education, as well as more robust evaluation of inhaler technique skill, with regard to adherence and health outcomes are important considerations for future work. ■

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