

Real-Time Asthma Outreach Reduces Excessive Short-acting β_2 -Agonist Use: A Randomized Study

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What is already known about this topic? Excessive short-acting β_2 -agonist (SABA) use is an administrative asthma impairment marker that identifies patients with uncontrolled asthma; however, efforts to improve care of such patients have been challenging and inadequately studied in managed care organizations.

What does this article add to our knowledge? A novel asthma outreach randomized study that uses innovative information technology in a large managed care organization with an electronic medical record system demonstrated that real-time identification, notification, and facilitated allergy specialist referral for excessive SABA users reduce subsequent SABA canister dispensings and improves markers of asthma care in patients without prior asthma specialist care.

How does this study impact current management guidelines? This novel administrative-based outreach intervention directed at excessive SABA users could be adaptable to other managed care organizations with electronic medical records.

BACKGROUND: Excessive use of short-acting β_2 -agonists (SABA) indicates impaired asthma control.

OBJECTIVE: To determine whether real-time outreach to excessive SABA users reduces SABA canister dispensings.

METHODS: After real-time determination of a seventh SABA canister dispensing in the prior 12 months by using informational pharmacy technology, 12 to 56 year old patients with physician-coded asthma and inhaled corticosteroid

dispensing were block randomized by prior asthma specialist care and medication step-care level into intervention ($n = 1001$) and control groups ($n = 998$). Intervention included real-time letter notification to patients and an electronic message to their physician with management suggestions, including facilitated allergy referral for patients without prior asthma specialist care. The control group received this organization's standard asthma care management without research contact. Frequency of the seventh SABA canister dispensing in the follow-up year was the primary outcome.

RESULTS: Compared with controls, intervention patients reached 7 SABA canister dispensings less frequently (50.7% vs 57.1%; risk ratio 0.89 [95% CI, 0.82-0.97]; $P = .007$) and later (hazard ratio 0.80 [95% CI, 0.71-0.91]; $P < .001$). SABA canister dispensings (mean $\pm$ SD) were less in intervention (7.5 ± 4.9 canisters) than controls (8.6 ± 5.3 canisters) (rate ratio 0.87 [95% CI, 0.82-0.93]; $P < .001$). The intervention reduced the risk of ≥ 7 SABA canister dispensings in patients without specialist care compared with patients with specialist care in the prior 3 years ($P < .001$) ($P = .04$ for interaction by prior specialist care). Visits to allergists were more frequent for intervention patients (30.9%) than for control patients (16.8%) (risk ratio 1.83 [95% CI, 1.54-2.16]; $P < .001$). Asthma exacerbations were unaffected.

CONCLUSIONS: A novel administrative-based asthma outreach program improves markers of asthma impairment in patients without prior asthma specialist care and is adaptable to managed care organizations with electronic medical records. © 2014 American Academy of Allergy, Asthma & Immunology (J Allergy Clin Immunol Pract 2014;2:445-56)

Key words: Administrative data; Allergist; Asthma control; Exacerbations; Impairment; Risk; Inhaled corticosteroids; Oral corticosteroids; Long-acting β_2 -agonists; Managed care organization; Persistent asthma; Short-acting β_2 -agonists

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Abbreviations used

ED- Emergency department
HEDIS- Healthcare Effectiveness Data and Information Set
HR- Hazard ratio
ICS- Inhaled corticosteroid
IQR- Interquartile range
KPSC- Kaiser Permanente Southern California
LABA- Long-acting β_2 -agonist
MCO- Managed care organization
NAEPP- National Asthma Education and Prevention Program
RIDUNA- Reduce Identified Uncontrolled Asthma
RR- Risk ratio
SABA- Short-acting β_2 -agonist

Asthma guidelines focus on defining and improving asthma control. The National Asthma Education and Prevention Program¹ and Global Initiative for Asthma² guidelines define impairment and risk domains of asthma control. The impairment domain examines rescue medication, symptoms, nocturnal awakenings, school and/or work absences, exercise problems, and pulmonary function. The risk domain includes exacerbation frequency and severity, lung function loss, and adverse effects of medications.^{1,2} These guidelines also recommend step-care levels of asthma controller medication based on asthma control.

To improve asthma outcomes, population asthma care management uses electronic surveillance of medical records and pharmacy databases to (1) identify patients with persistent asthma based on Healthcare Effectiveness Data and Information Set (HEDIS) definitions,^{3,4} (2) establish and follow markers of uncontrolled asthma,⁵ (3) determine medication dispensing intensity,⁶ and (4) report asthma quality markers⁷ to the National Committee for Quality Assurance. Administrative markers predictive of poor outcomes include prior year excessive short-acting β_2 -agonist (SABA) canister dispensings,⁸⁻²¹ low controller-to-total asthma medication ratios,^{7,22,23} and asthma exacerbations.²⁴⁻²⁶ Effective programs are needed to reduce the frequency of excessive SABA use and improve suboptimal guideline adoption by physicians.^{22,27-29} Most population-based asthma studies have been retrospective or cross-sectional.³⁰ Some documented improved outcomes by using population management processes, but most were pre-post designed rather than randomized.

SABA canister dispensing of ≥ 7 canisters per year, which equates to ≥ 4 puffs/d per year, is associated with poorer asthma control, quality of life, and increased risk for future asthma exacerbations.⁸ To reduce excessive SABA use, we conducted the Reduce Identified Uncontrolled Asthma (RIDUNA) study, to our knowledge, the first prospective, randomized, controlled, real-world outreach study to determine the effectiveness of (1) real-time identification of excessive SABA users, (2) notification of uncontrolled status to patients and their physicians, and (3) provision of management recommendations to patients and physicians, including facilitated allergy referral for patients without an asthma specialist. We hypothesized that this real-time outreach would reduce subsequent SABA canister dispensings compared with our organization's standard asthma care management.

METHODS**Patients in the RIDUNA study**

Patients ages 12 to 56 years old were eligible if they met the following criteria: (1) physician diagnosed asthma (International

Classification of Disease, Ninth Revision code 493.xx) in the prior 3 years, (2) ≥ 7 SABA canister dispensings and continuous health plan membership and pharmacy benefit in the prior year, and (3) ≥ 1 inhaled corticosteroid (ICS) canister dispensing in the prior 6 months.

RIDUNA study protocol

The RIDUNA study was a prospective and randomized study with a stratified block design of patients with excessive SABA canister dispensing (NCT identifier 01449409) (Figure 1, A). On a weekly basis from February 24, 2011, to October 25, 2011, patients who met the eligibility criteria were identified through a computer algorithm based on administrative pharmacy and health care utilization data collected in the Kaiser Permanente Southern California (KPSC) research data warehouse (Figure 1, B). Exclusion criteria, including other chronic conditions, are detailed in Figure 1, B. The identified patients were randomly selected and randomized to either the intervention (outreach) or the control (standard asthma care provided by the managed care organizations [MCO]) groups in a 1:1 ratio. Randomization was done centrally at the KPSC Research and Evaluation Department by using a computer-generated random schedule in permuted blocks of 2 within the 2 strata of prior asthma specialist visits in the prior 3 years (yes/no) and within the 2 strata of step-care level (levels 2/3 vs levels 4/5).³¹ Intervention included a single real-time notification by letter to the patient and by electronic message within the KPSC electronic medical record system to each patient's primary care provider and asthma specialist (if the patient had previously seen one). The patient letters and physician messages noted excessive SABA dispensing, suggestions for management, and facilitated allergy referral recommendation for those patients without prior asthma specialist care (see Appendix E1 in this article's Online Repository at www.jaci-inpractice.org). Controls received KPSC standard asthma care management without research contact. Standard KPSC asthma care management at KPSC includes an asthma task force, care managers, intermittent alerts to physicians of their patients with excessive SABA dispensings, and an electronic registry that allows physicians to access asthma medications dispensed to and asthma emergency department (ED) visits and/or hospitalizations experienced by their patients with persistent asthma. The KPSC Institutional Review Board approved the study with waiver of written consent.

Outcome measures

The primary outcome was the frequency of ≥ 7 SABA canister dispensing in the follow-up year. Secondary outcomes obtained at 3, 6, and 12 months after randomization were the number of SABA canister and controller medications dispensed; controller-to-total medication ratio⁷; change in National Asthma Education and Prevention Program step-care level, including implementation of at least a 1-step increase³¹; asthma exacerbations that require oral corticosteroids within 2 days of an outpatient visit coded as uncontrolled asthma or an ED visit or hospitalization with a primary asthma diagnosis or secondary asthma diagnosis when there was a primary respiratory diagnosis³²; and any allergist or pulmonologist visit.³³ Other secondary outcomes included times to the seventh SABA canister dispensing and time to the allergist visit. Asthma exacerbations were considered distinct when separated by at least 30 days. The controller-to-total medication

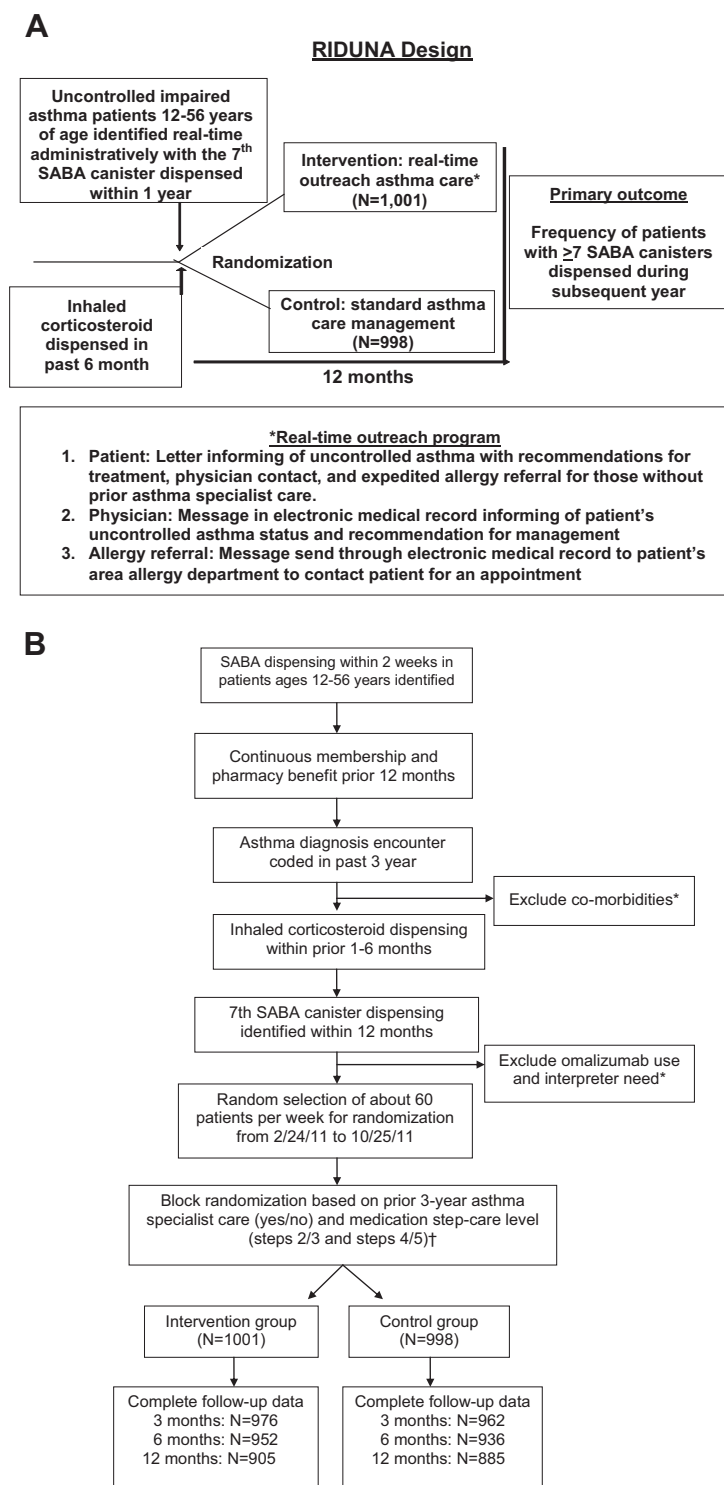


FIGURE 1. Depicts the study design, administrative logistics for patient identification, and number of patients who underwent randomization and completed the study. **(A)** A summary of the study design. **(B)** Administrative algorithm for patient identification weekly from February 24, 2011, to October 25, 2011, and the numbers of patients in the final randomized study cohort and who completed the study during the follow-up year. Loss of membership or pharmacy coverage was responsible for loss to follow-up. *Excluded comorbidities included encounters in the prior year coded for chronic obstructive lung disease, emphysema, cystic fibrosis, chronic bronchitis, bronchiectasis, Churg Strauss syndrome, Wegener granulomatosis, sarcoidosis, pulmonary hypertension, steroid-dependent asthma, or other clinically relevant nonasthma pulmonary disorder (eg, autoimmunity, immune deficiency, cancer, and HIV). Patients also were excluded if they were coded for omalizumab use in the prior 3 months or required an interpreter. †An algorithm and formula based on Expert Panel-3 guidelines calculated medication step-care level as previously reported.³¹

ratio is defined as the number of dispensed asthma controller units (inhaled controller medication canisters or 30-day supplies of oral control medications) divided by the total number of controller units and SABA canisters dispensed, and is an administrative data quality marker predictive of future ED visits and/or hospital care. A ratio ≥ 0.5 is the minimum recommended cut-point.⁷ An algorithm and a formula based on Expert Panel-3 guidelines calculated medication step-care levels, as previously reported.³¹ Patients were required to be at least at step-care level 2. Administratively, we could not accurately determine step-care level 6 (systemic corticosteroid dependency) because physician coding for this diagnosis was incomplete. As such, step-care level 5 also included an indeterminate number of patients at step-care level 6.

Statistical analyses

Patient demographics and clinical features were examined by intervention status. Dichotomous variables were reported as counts and proportions, whereas continuous variables were presented as mean (SD). The χ^2 test was used for hypothesis testing for comparisons of categorical variables, and the Wilcoxon rank sum test was used for continuous variables. Poisson regression models with a robust error variance were applied to calculate the risk ratios and 95% CIs.³⁴ The rate ratios and 95% CIs were estimated by using negative binomial models with a robust error variance. The Cox proportional hazards models were applied to assess the impact of intervention on time-to-event outcomes. To address the issue of enlarged type I errors that will result in a loss of power, we adjusted for the 2 stratification variables (prior asthma specialist variable and step-care level) in all the models mentioned above of unstratified analyses but only adjusted for step-care level in all the models stratified by prior asthma specialist care.³⁵ Kaplan-Meier curves were plotted for time-to-event outcomes for all patients and for patients with and without prior asthma specialist visits. Log-rank testing stratified by prior asthma specialist care and step-care level was performed and reported on the Kaplan-Meier plots. To investigate whether or not the associations between the intervention and the SABA-related outcomes, and the allergist visit-related secondary outcomes were modified by the stratification variables, we added the interaction (cross-product) terms between the intervention and the stratification variables into the models. Results were considered significant if $P < .05$, 2-tailed. All the point estimates and the 95% CIs were generated by using SAS software (version 9.2; SAS Institute, Cary, NC).

The RIDUNA study was originally designed with 80% power and 0.01 type I error to detect a 20% reduction in ≥ 7 SABA canister dispensings in follow-up, which required 1400 patients over a planned 6-month enrollment. However, a decision was made during enrollment, without examining interim data, to extend the enrollment period by 2 months to increase the feasibility of conducting subgroup analyses by enrolling an additional 600 patients.

RESULTS

Characteristics of study groups at randomization

Of 1999 patients identified, 1001 and 998 were randomized to intervention and control groups, respectively, with randomization well balanced based on demographics (Table I); prior asthma burden except for a small increase in asthma exacerbations that required oral corticosteroids in controls ($P = .05$) (Table I); the 16 KPSC medical service areas (see Table E1 in

this article's Online Repository at www.jaci-inpractice.org); comorbidities (see Table E2 in this article's Online Repository at www.jaci-inpractice.org); and these features by asthma specialist care in the prior 3 years (see Tables E3 and E4 in this article's Online Repository at www.jaci-inpractice.org). In the study cohort, 31% of patients had an asthma specialist visit in the prior 3 years, most with an allergist (88%). Intervention and control patients were compared in the subgroups without ($n = 1380$ [69% of all randomized patients]) (Table E3) and with ($n = 619$ [31% of all randomized patients]) (Table E4) asthma specialist care in the prior 3 years and were well balanced for baseline demographics, asthma burden, and step-care level. However, compared with patients without asthma specialty care (Table E3), those with prior asthma specialty care had greater disease burden and/or severity by requiring higher step-care level and experiencing more exacerbations than patients without asthma specialty care (Table E3).

Demographics. The mean (SD) ages of the patients were 36 ± 13.5 years, 53.2% were women, frequently obese (46%), infrequent current smokers (11%), more often from ethnic minorities (54.5%), of moderate estimated family income by geocoding, long-term health plan members (mean [SD] 13.5 ± 9.1 years), and predominately commercial insurance members (81.5%) (Table I).

Asthma burden in the prior year. The percentages of patient visits were 16.4% to an allergist and 3.7% to a pulmonologist (Table I). The mean (SD) number of canister dispensings of SABA was 11.1 ± 4.4 and of controllers was 7.8 ± 5.7 . Approximately 30% of patients had a controller-to-total medication ratio ≥ 0.5 , and the majority (59.4%) were at step-care levels 2 and 3 (Table I). Asthma exacerbations that required oral corticosteroids occurred in 32.1% of the cohort, and 10.8% experienced an asthma ED visit and/or hospitalization (Table I).

Primary outcome and SABA canister dispensing in the follow-up year

Unstratified analysis. In the whole cohort, the percentage of patients with ≥ 7 canister dispensings was lower with intervention (50.7%) compared with controls (57.1%) (risk ratio 0.89 [95% CI, 0.82-0.97]; $P = .007$) (Table II). The time to the seventh SABA canister dispensing was longer in the intervention group (hazard ratio [HR] 0.80 [95% CI, 0.71-0.91]; $P < .001$) (Figure 2, A). Consistent with these findings, the mean (SD) numbers of SABA canister dispensings in the follow-up year also were less in the intervention group (7.5 ± 4.9) versus the control group (8.6 ± 5.3) (rate ratio 0.87 [95% CI, 0.82-0.93]; $P < .001$). Sensitivity analyses showed that at baseline a history of asthma exacerbations in the prior year that required oral corticosteroids did not affect primary outcome results (see the Methods section in this article's Online Repository at www.jaci-inpractice.org).

Stratified analyses. The lower frequency of, longer time to the seventh, and the number of SABA canister dispensing in the intervention compared with control groups occurred only in the subgroup without prior asthma specialist care (Table II and Figure 2, B) ($P < .001$) and not with prior asthma specialist care (Table II and Figure 2, C). The treatment effect on the seventh SABA canister dispensing was further explored by stratification

TABLE I. Demographics at baseline and asthma features in the prior year by study group*

Characteristics	Intervention (n = 1001)	Control (n = 998)	Total (n = 1999)
Demographics			
Age (y), mean ± SD	36.2 ± 13.8	36.1 ± 13.3	36.1 ± 13.5
Female sex, no. (%)	544 (54.3)	519 (52)	1063 (53.2)
Ethnicity, no. (%)			
White	409 (40.9)	420 (42.1)	829 (41.5)
Black	173 (17.3)	189 (18.9)	362 (18.1)
Hispanic	294 (29.4)	269 (27)	563 (28.2)
Native American/Alaskan	3 (0.3)	2 (0.2)	5 (0.3)
Asian/Pacific Islander	60 (6)	59 (5.9)	119 (6.0)
Multiple	6 (0.6)	4 (0.4)	10 (0.5)
Others	12 (1.2)	15 (1.5)	27 (1.4)
Unknown	44 (4.4)	40 (4)	84 (4.2)
Estimated household income by geocoding (\$), mean ± SD	66,336 ± 27,469	65,168 ± 29,457	65,756 ± 28,473
Estimated family education level ≤ grade 12 by geocoding (%), median (IQR)	19.5 (10.2-35.9)	19.2 (10.4-33.6)	19.4 (10.4-35.0)
Body mass index (kg/m ²), mean ± SD	30.6 ± 7.8	30.8 ± 7.9	30.7 ± 7.9
Body mass index, no. (%)			
<30 kg/m ²	488 (48.8)	471 (47.2)	959 (48.0)
≥30 kg/m ² (obesity)	463 (46.3)	457 (45.8)	920 (46.0)
Missing data	50 (5)	70 (7)	120 (6)
Smoking status, no. (%)			
Never	596 (59.5)	557 (55.8)	1153 (57.7)
Passive	48 (4.8)	48 (4.8)	96 (4.8)
Quit	188 (18.8)	211 (21.1)	399 (20.0)
Yes	113 (11.3)	107 (10.7)	220 (11.0)
Missing data	56 (5.6)	75 (7.5)	131 (6.6)
Length of health plan membership (y), mean ± SD	13.7 ± 9.0	13.3 ± 9.2	13.5 ± 9.1
Insurance, no. (%)†			
Commercial	819 (81.8)	812 (81.4)	1631 (81.6)
Medicaid	147 (14.7)	141 (14.1)	288 (14.4)
Medicare	25 (2.5)	22 (2.2)	47 (2.4)
Private pay	52 (5.2)	66 (6.6)	118 (5.9)
Asthma features in prior year			
Allergist visit, no. (%)	170 (17)	157 (15.7)	327 (16.4)
Pulmonologist visit, no. (%)	41 (4.1)	32 (3.2)	73 (3.7)
Any asthma specialist visit, no. (%)	200 (20.0)	182 (18.2)	382 (19.1)
No. of SABA canisters dispensed, mean ± SD	11.1 ± 4.5	11.1 ± 4.3	11.1 ± 4.4
No. of controller canister equivalent dispensed	8.1 ± 5.8	7.6 ± 5.6	7.8 ± 5.7
Controller medication ratio‡	0.40 ± 0.17	0.40 ± 0.17	0.40 ± 0.17
Controller medication ratio ≥0.5, no. (%)‡	315 (31.5)	287 (28.8)	602 (30.1)
Step care level, no. (%)			
2	275 (27.5)	268 (26.9)	543 (27.2)
3	322 (32.2)	321 (32.2)	643 (32.2)
4	247 (24.7)	261 (26.2)	508 (25.4)
5	157 (15.7)	148 (14.8)	305 (15.3)
Any oral steroid course for asthma exacerbation, no. (%)§	301 (30.1)	341 (34.2)	642 (32.1)
≥2 oral steroid courses for asthma exacerbations, no. (%)	91 (9.1)	88 (8.8)	179 (9.0)
Any asthma ED visit or hospitalization, no. (%)	97 (9.7)	119 (11.9)	216 (10.8)

IQR, Interquartile range.

*P values were determined by the χ^2 test for categorical variables and the Wilcoxon rank sum test for continuous variables; $P > .05$ for all comparisons between the study groups except for Any oral steroid course for asthma exacerbation data.

†Patients may have more than 1 insurance plan.

‡Controller medication ratio is the number of asthma controller units (canisters of inhaled medication or 30-day supplies of oral medications) dispensed divided by the total number of controller units and SABA canisters.

§ $P = .050$.

TABLE II. Clinical outcomes 1-year after randomization in the whole cohort and stratified subgroups by asthma specialist care in prior 3 years*

Outcomes	Whole cohort			Subgroup without prior asthma specialist care			Subgroup with prior asthma specialist care		
	Intervention (n = 905)	Control (n = 885)	P value†	Intervention (n = 618)	Control (n = 611)	P value†	Intervention (n = 287)	Control (n = 274)	P value†
Primary outcome									
≥7 SABA canisters dispensed, no. (%)	459 (50.7)	505 (57.1)	.007	310 (50.2)	366 (59.9)	<.001	149 (51.9)	139 (50.7)	.77
Secondary outcomes									
No. SABA canisters dispensed, mean ± SD	7.5 ± 4.9	8.6 ± 5.3	<.001	7.4 ± 4.8	8.8 ± 5.2	<.001	7.8 ± 5.1	8.3 ± 5.5	.21
Allergist visit, no. (%)	280 (30.9)	149 (16.8)	<.001	163 (26.4)	46 (7.5)	<.001	117 (40.8)	103 (37.6)	.45
Time to allergist visit among patients with allergist visit (d), median (IQR)	42 (28-98)	127 (57-221)	<.001	36 (28-50)	189 (127-259)	<.001	78 (29-177)	99 (35-192)	.19
Any ICS or ICS-LABA canisters dispensed, no. (%)	793 (87.6)	766 (86.6)	.51	538 (87.1)	517 (84.6)	.24	255 (88.9)	249 (90.9)	.47
Any ICS-LABA canisters dispensed, no. (%)	451 (49.8)	409 (46.2)	.07	275 (44.5)	237 (38.8)	.03	176 (61.3)	172 (62.8)	.93
Controller medication ratio (≥0.5), no. (%)‡	413 (45.6)	331 (37.4)	<.001	267 (43.2)	200 (32.7)	<.001	146 (50.9)	131 (47.8)	.42
At least 1 step-care level increase, no. (%)§	187 (20.7)	151 (17.1)	.05	129 (20.9)	106 (17.3)	.10	58 (20.2)	45 (16.4)	.29
Any oral steroid course for asthma exacerbation, no. (%)	223 (24.6)	211 (23.8)	.71	133 (21.5)	134 (21.9)	.83	90 (31.4)	77 (28.1)	.38
≥2 Oral steroid courses for asthma exacerbation, no. (%)	62 (6.9)	67 (7.6)	.55	36 (5.8)	41 (6.7)	.50	26 (9.1)	26 (9.5)	.89
Any asthma ED visit and/or hospitalization, no. (%)	59 (6.5)	58 (6.6)	.96	34 (5.5)	30 (4.9)	.66	25 (8.7)	28 (10.2)	.55

IQR, Interquartile range.

*Outcome data are presented as frequency, no. (%), mean (SD), or median (IQR) for patients with continual membership and pharmacy benefit at 1-year follow-up by the whole cohort and stratified subgroups except time to outcomes in which censored data used for the entire cohort.

†P values were determined by Poisson regression with a robust error variance for categorical variables and a negative binomial model for count variables when controlling for prior asthma specialist care and step-level care for whole cohort and step-level care only for subgroups stratified by asthma specialist care.

‡Controller medication ratio is the number of asthma controller units (canisters of inhaled controller medications or 30-day supplies of oral controller medications) dispensed divided by the total number of controller units and SABA canisters.

§At least 1 step-care level increase vs no step-level increase from 12 mo before baseline.

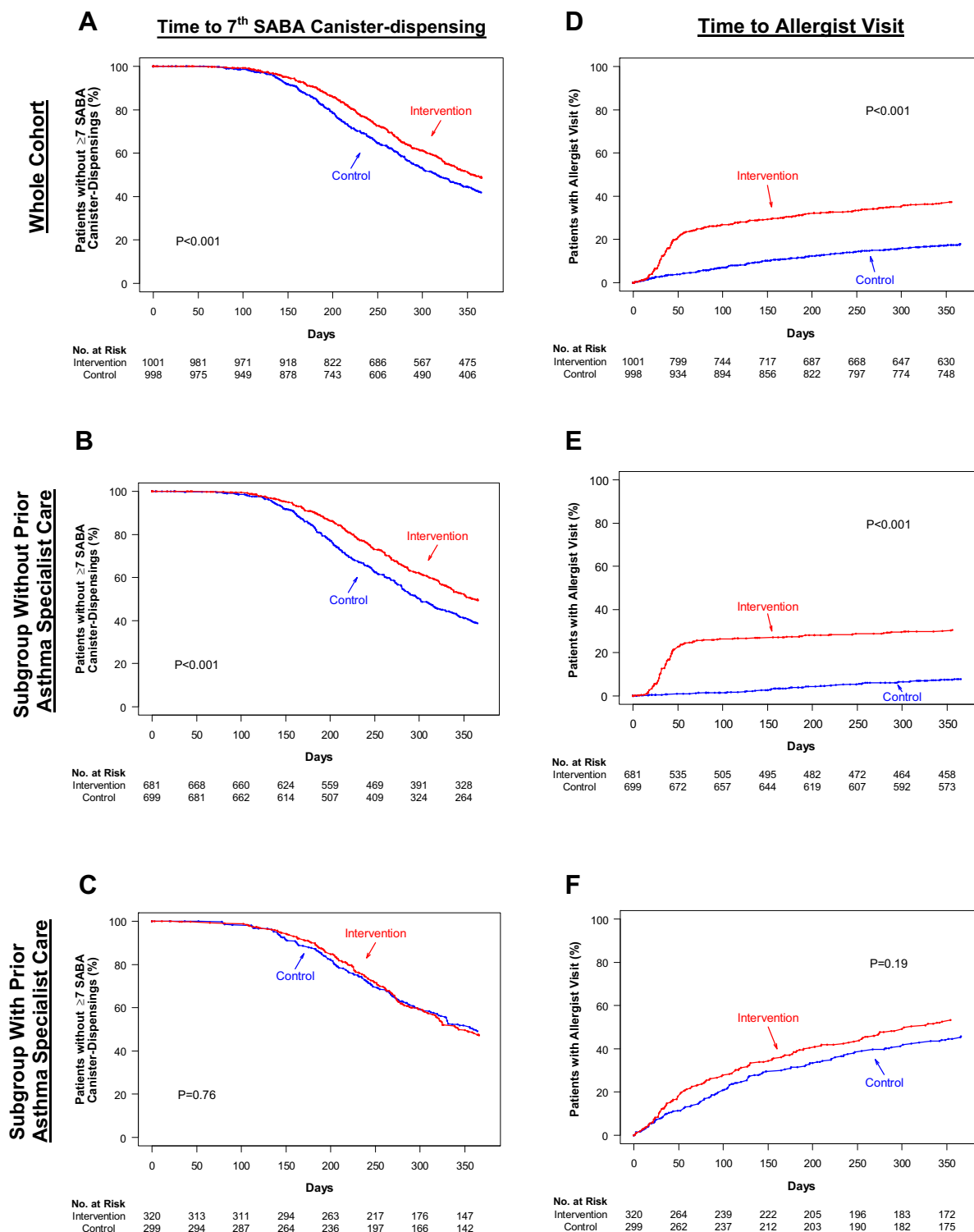


FIGURE 2. Kaplan-Meier analysis for time to seventh SABA canister dispensing (**A**, whole cohort; **B**, subgroup without prior asthma specialist care; and **C**, subgroup with prior asthma specialist care) and time to allergy department visit (**D**, whole cohort; **E**, subgroup without prior asthma specialist care; and **F**, subgroup with prior asthma specialist care). P values for the survival curves are based on the log-rank test stratified by prior asthma specialist care, and step-care level for whole cohort and step-care level for stratified subgroups.

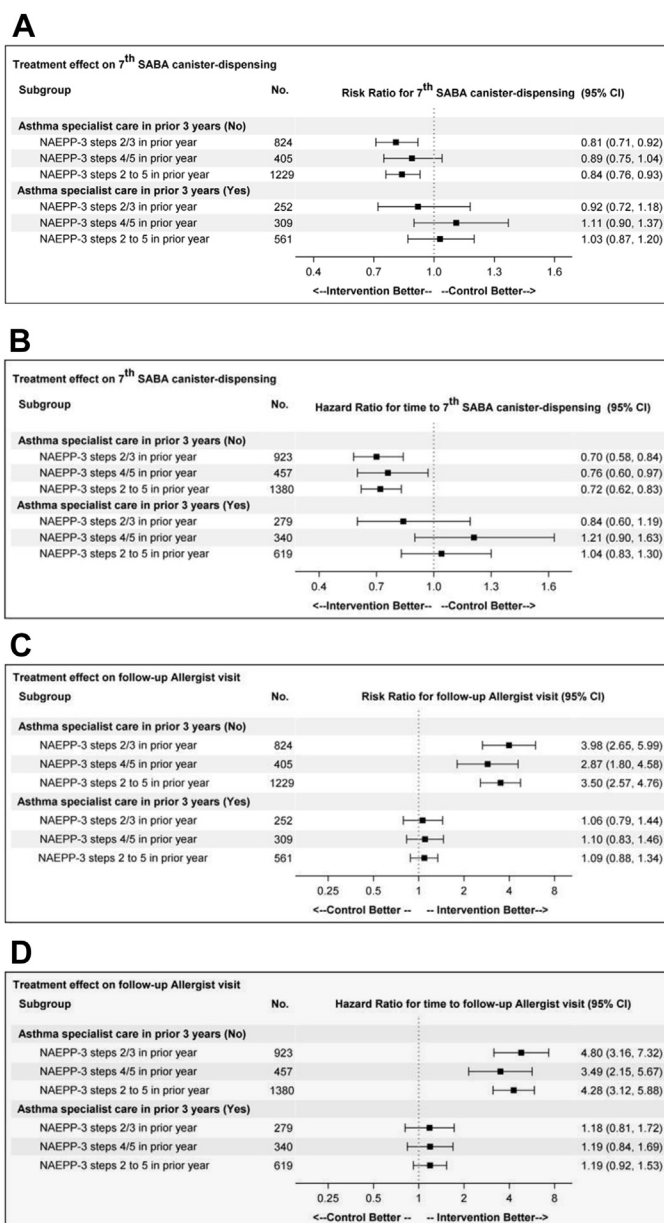


FIGURE 3. Risk Ratio (RR) for frequency of ≥ 7 SABA canister dispensings (**A**), HR for time to seventh SABA canister dispensing (**B**), RR for allergist visit frequency (**C**), and HR for time to allergist visit (**D**) by asthma specialist care in the prior 3 years and the National Asthma Education and Prevention Program (NAEPP-3) step-care level in the prior year. The P value for interaction by prior asthma specialist care observed for frequency of patients with ($P = .04$) and time to ($P < .001$) seventh SABA canister dispensing and for frequency of patients with and time to allergist visit ($P < .001$ for both outcomes).

by both prior asthma specialist care and National Asthma Education and Prevention Program 3 step-care levels (Figure 3). The lower risk ratio for frequency of patients (risk ratio 0.84 [95% CI, 0.76-0.93]) (Figure 3, A) and HR for time to seventh SABA canister dispensing (HR 0.72 [95% CI, 0.62-0.83]) (Figure 3, B) was observed in the intervention subgroup without prior specialist care regardless of step-care level. P values for interactions between intervention and prior specialist visit were $P = .04$ for frequency of and $P < .001$ for time to seventh SABA canister dispensing. The risk for frequency of and time to a seventh SABA canister dispensing was not reduced in the

subgroup with prior asthma specialist care (risk ratio 1.03 [95% CI, 0.87-1.20] and HR 1.03 [95% CI, 0.83-1.30], Figure 3, A and B, respectively).

Secondary outcomes

Allergist visits. Facilitated referral to allergists in the subgroup without prior asthma specialist care was a component of the intervention outreach (Table II). In the whole cohort, a higher frequency of intervention than control patients visited an allergist in the outcome year (30.9% vs 16.8%; risk ratio 1.83 [95% CI, 1.54-2.16]; $P < .001$), with the first visit in those

patients with an allergist visit that occurring significantly earlier in the intervention group (Table II) (42 vs 127 days) (HR 2.12 [95% CI, 1.74-2.57]; $P < .001$) (Figure 2, D). Similar to the outcomes above, the frequency and time to allergist visit in the follow-up year was observed only in the subgroup without prior asthma specialist care (Table II, Figure 2, E) ($P < .001$) and not the subgroup with prior asthma specialist care (Table II, Figure 2, F) prior asthma specialist care. Significant interactions were revealed for the treatment effect on frequency of (Figure 3, C) and time to (Figure 3, D) allergist visit follow-up stratified by prior asthma specialist care ($P < .001$ for both outcomes) but not step-care level.

Other outcomes. Intervention patients compared with controls at 1-year follow-up had a higher frequency of controller-to-total medication ratio, of ≥ 0.5 (45.6% vs 37.4%; $P < .001$), any ICS–long-acting β_2 -agonist (LABA) canister dispensing (49.8% vs 46.2%; $P = .07$), and at least 1 step-care level increase from baseline (20.7% vs 17.1%; $P = .05$) (Table II). These outcomes occurred with a higher effect size and significantly only in the subgroup without prior asthma specialist care (Table II). Moreover, the effect of the intervention on the number of SABA canister dispensings, allergist visits, and the other outcomes above occurred as early as 3 months after randomization (Table III). There was no effect of the intervention on asthma exacerbations or ED visits and/or hospitalizations (Tables II and III).

DISCUSSION

Population care management is an important activity of MCOs to identify patients at high risk and to implement effective therapy. With the advent of highly efficient electronic medical records and robust computer-generated pharmacy and encounter databases, opportunities exist to use these systems to promote novel interventions. We designed and tested such an innovative real-time intervention in the randomized RIDUNA study. We identified, in real-time, asthma patients when they reached an excessive level of SABA canister dispensings previously shown to be associated with subsequent poor asthma outcomes (7 canisters in a year).⁸ We enrolled this cohort of patients with uncontrolled asthma by applying inclusion and exclusion criteria in real time. The intervention included notification of patients by letter and their physicians by electronic medical record messaging of the uncontrolled status with management recommendations, including referral to an allergist for those without prior asthma specialist care. This novel approach led to significant improvements in markers of appropriate asthma care, including (1) reductions in the frequency of patients with and time to ≥ 7 SABA canister dispensings, (2) more frequent and earlier visits to allergists in the subgroup without prior asthma specialist care, (3) small increases in the frequency of ICS-LABA canister dispensings, (4) attaining the HEDIS defined asthma quality care measure of controller-to-total medication ratio ≥ 0.5 , and (5) demonstrating step-up care level implementation. These benefits were experienced in the stratified subgroup without prior asthma specialist care and not the subgroup with prior asthma specialist care (Tables II and III; Figure 2, B and E; Figure 3). Perhaps the greater asthma burden (Table E4) and existing asthma specialist access in patients with prior asthma specialist care may be responsible for the lack of effect in this subgroup. These improvements occurred as early as

3 months after randomization (Table III) but did not translate into reductions in asthma exacerbations (Tables II and III).

As noted earlier, most population-based intervention studies that used health information technology have not been randomized. Published nonrandomized systematic interventions to reduce excessive SABA use and increase asthma controller use include (1) reducing the number of physicians who prescribe SABAs for individual patients,³⁶ (2) notifying providers of their patients with excessive SABA use,³⁷ and (3) instituting asthma care managers and management programs.^{38,39} A recent randomized administrative trial in patients with asthma in a large MCO by using health information technology and interactive voice technology speech recognition software to promote ICS adherence reported modest, but significant, improvements in ICS dispensing but not SABA use or health care utilization.⁴⁰ The present study, however, directed at patients with excessive SABA use found significant reductions in SABA dispensing but did not demonstrate any effect on asthma exacerbations.

To what can the effectiveness of the study intervention in reducing SABA dispensing be attributed? First, facilitated referral to allergist care of patients' naive to asthma specialist care improves asthma outcomes.^{33,41} We noted significant increased frequencies of allergist visits in the intervention group compared with the control group (Table II and Figure 2), which reached almost 4-fold in the whole cohort and 10-fold in the subgroup without prior asthma specialist care by 3 months after randomization (Table III). This difference decreased in magnitude but remained significantly different by 12 months' follow-up (Tables II and III). Only a minority (approximately 30% of the intervention patients) took advantage of this facilitated referral to allergy care. Historically, these patients with excessive SABA use at KPSC are a major challenge to incorporate into asthma care management programs or asthma specialist care because they may perceive their asthma as controlled or prefer primary care services. Second, LABA addition to ICS in uncontrolled asthma reduces future SABA use.¹⁰ The intervention was associated with marginally more combination ICS-LABA canister dispensings in the whole cohort and particularly in the subgroup without prior asthma specialist care (Tables II and III). These factors may explain the significant increased frequency of step-up care level and the significantly greater attainment of a controller-to-total medication ratio ≥ 0.5 (less SABA dispensing was principally responsible) in the intervention group as early as 3 months (Table III); although the effect size of the difference was small between the study groups. The present randomized study confirms our previous cross-sectional, administrative, retrospective study that reported that step-up care in an uncontrolled asthma cohort was associated with a 16% reduction in SABA dispensings in a subsequent 12-month period but had no effect on health care utilization.³¹

The RIDUNA study is limited by its intervention being implemented only one time. More frequent patient-physician notifications could potentially increase the magnitude of the benefits, which will need further study. Because of the administrative nature of the study, we were unable to determine whether or how much of the medication dispensed was actually used. Reducing asthma risk as manifested by an asthma exacerbation probably requires more intensive intervention than the single patient intervention implemented in the RIDUNA study. Clinical trials that report effective reductions in asthma exacerbations with a pharmaceutical intervention monitor adherence to

TABLE III. Clinical outcomes 3 and 6 months after randomization in the whole cohort and stratified subgroups by asthma specialist care in prior 3 years*

Outcomes	Whole cohort			Subgroup without prior asthma specialist care			Subgroup with prior asthma specialist care		
	Intervention	Control	P value†	Intervention	Control	P value†	Intervention	Control	P value†
No. of patients									
3 mo	976	962		662	671		314	291	
6 mo	952	936		646	651		306	285	
No. of SABA canisters dispensed, mean ± SD									
3 mo	1.7 ± 1.6	1.9 ± 1.7	.002	1.6 ± 1.5	1.9 ± 1.7	<.001	1.8 ± 1.7	1.8 ± 1.7	.92
6 mo	3.7 ± 2.6	4.2 ± 2.8	<.001	3.6 ± 2.6	4.4 ± 2.8	<.001	3.8 ± 2.7	4.0 ± 2.9	.47
Allergist visit, no. (%)									
3 mo	225 (23.1)	61 (6.3)	<.001	153 (23.1)	10 (1.5)	<.001	72 (22.9)	51 (17.5)	.11
6 mo	254 (26.7)	103 (11.0)	<.001	157 (24.3)	25 (3.8)	<.001	97 (31.7)	78 (27.4)	.24
Any ICS or ICS-LABA canisters dispensed, no. (%)									
3 mo	543 (55.6)	510 (53.0)	.24	358 (54.1)	335 (49.9)	.12	185 (58.9)	175 (60.1)	.79
6 mo	718 (75.4)	702 (75.0)	.82	487 (75.4)	467 (71.7)	.14	231 (75.5)	235 (82.5)	.05
Any ICS-LABA canisters dispensed, no. (%)									
3 mo	321 (32.9)	281 (29.2)	.04	197 (29.8)	160 (23.8)	.004	124 (39.5)	121 (41.6)	.73
6 mo	414 (43.5)	371 (39.6)	.03	258 (39.9)	210 (32.3)	<.001	156 (51.0)	161 (56.5)	.27
Controller medication ratio ≥0.5), no. (%)‡									
3 mo	442 (45.3)	375 (39.0)	.01	281 (42.4)	239 (35.6)	.01	161 (51.3)	136 (46.7)	.25
6 mo	450 (47.3)	386 (41.2)	.01	293 (45.4)	232 (35.6)	<.001	157 (51.3)	154 (54.0)	.55
At least 1 step-care level increase, no. (%)§									
3 mo	216 (22.1)	167 (17.4)	.01	150 (22.7)	106 (15.8)	.002	66 (21.0)	61 (21.0)	.95
6 mo	151 (15.9)	114 (12.2)	.02	110 (17.0)	83 (12.7)	.03	41 (13.4)	31 (10.9)	.46
Any oral steroid course for asthma exacerbation, no (%)									
3 mo	84 (8.6)	80 (8.3)	.84	52 (7.9)	47 (7.0)	.55	32 (10.2)	33 (11.3)	.66
6 mo	137 (14.4)	141 (15.1)	.66	81 (12.5)	87 (13.4)	.65	56 (18.3)	54 (18.9)	.87
≥2 Oral steroid courses for asthma exacerbation, no. (%)									
3 mo	8 (0.8)	6 (0.6)	.64	2 (0.3)	3 (0.4)	.67	6 (1.9)	3 (1.0)	.38
6 mo	25 (2.6)	27 (2.9)	.71	15 (2.3)	14 (2.2)	.84	10 (3.3)	13 (4.6)	.42
Any asthma ED visit or hospitalization									
3 mo	23 (2.4)	20 (2.1)	.71	13 (2.0)	11 (1.6)	.66	10 (3.2)	9 (3.1)	.96
6 mo	37 (3.9)	33 (3.5)	.71	20 (3.1)	16 (2.5)	.49	17 (5.6)	17 (6.0)	.84

*Outcome data are presented as frequency, no. (%), or mean (SD), and reported for patients with continual membership and pharmacy benefit at 3- and 6-mo follow-up by whole cohort and stratified subgroups.

†P values were determined by Poisson regression with a robust error variance for categorical variables and a negative binomial model for count variables by controlling for prior asthma specialist care and step-level care for whole cohort and step-level care only for subgroups stratified by asthma specialist care.

‡Controller medication ratio is the number of asthma controller units (canisters of inhaled controller medications or 30-day supplies of oral controller medications) dispensed divided by the total number of controller units and SABA canisters.

§At least 1 step-care level increase vs no step-level increase from 3 and 6 mo before baseline, respectively.

assure that the vast majority of the intervention group adhere to the treatment regimen. In the RIDUNA population management single contact study, such a high level of oversight does not occur. Specifically, only a minority of intervention patients recommended for facilitated allergy referral took advantage of the opportunity, which probably reduced the chance to affect asthma exacerbations. Experience at KPSC has shown that patients with a history of excessive SABA use are particularly resistant to seeking asthma specialty care. Obesity could be another explanation for the lack of effect of the study intervention on reducing the risk of asthma exacerbations. A high proportion of the study patients were obese (>45%); although their distribution between the study groups was well balanced. Adult patients with asthma who also are obese are reported to be more severe,⁴² more poorly controlled,⁴³ at an increased risk for asthma exacerbations,⁴⁴ exhibit glucocorticoid insensitivity,⁴⁵ and frequently need oral corticosteroids to manage asthma exacerbations.⁴⁶ As such, the relatively high proportion of obesity in patients in the RIDUNA study may produce a cohort more recalcitrant to the study intervention. Capturing objective measures, for example, spirometry, in our databases requires natural language techniques or improved electronic collection, which we are in the process of operationalizing. Nonetheless, "physician diagnosed asthma," persistent asthma defined by HEDIS criteria, and multiple asthma medication dispensings are considered appropriate administrative criteria to identify patients with asthma in administrative data-based studies in our MCO,³ by HEDIS,³ and elsewhere.⁴⁷

In summary, the RIDUNA study provides proof of concept of the effectiveness of an intervention that incorporates information pharmacy technology for the real-time identification, notification, and facilitated allergy referral of patients with excessive SABA dispensing, which can be adapted to other MCOs with electronic patient medical records. The present intervention is most clearly applicable to and efficiently implemented in a health care system such as an integrated staff model health care organization as Kaiser Permanente that has the capacity to electronically monitor pharmacy data, notify physicians through electronic messaging, and promote facilitated referral to allergy departments for patients without prior asthma specialty. In addition, the present intervention would be applicable to independent practice associations, integrated medical groups, accountable care organizations, and similar medical organizations that most likely will have access to pharmacy claims data from the health plan or through their integrated system, rather than from a local or regional pharmacy. However, it also is possible for other health care systems without these resources to use innovative practices that work with local and/or regional pharmacies to send real-time alerts to providers at the time their patients are dispensed the seventh SABA canister in a prior 12-month period. In addition, contact with such a patient by telephone, e-mail, or letter could advise more appropriate asthma controller use to reduce SABA use and, if warranted, a referral to an asthma specialist. However, this type of approach is limited by the lack of electronic automation as used for the intervention in the RIDUNA study.

The impact of our novel, yet simple, single-time outreach intervention was modest in significantly reducing SABA canister dispensing, increasing ICS-LABA dispensing, and facilitating allergist access. However, these benefits occurred in an organization with ongoing asthma care management strategies,

including asthma task forces, asthma physician champions, dedicated asthma care managers, and provider access to electronic medical records and disease registries, which suggests that the impact is conservative and might be greater in organizations without such programs. Moreover, the benefits appeared to be primarily due to facilitated allergy referral and were experienced by those without and not by those with prior specialist care, possibly due to the latter subgroup already receiving asthma specialist care and exhibiting markers of more burdensome and/or severe asthma (Tables E3 and E4). Given the partial benefits inherent in improving asthma care through single-population care management interventions as reported in the present study and other randomized studies,^{40,48,49} optimal population care management requires adoption of multiple interventions to enhance their overall effectiveness. Such an approach could certainly combine other promising administrative interventions with the present study's intervention, including (1) more frequent notifications to patients and physicians of a patient's uncontrolled status, (2) interactive voice reminders to refill controller medication,⁴⁰ (3) active efforts to prevent multiple physician prescribing of SABA to individual patients,³⁶ (4) more-intensive monitoring of SABA canister dispensing, and (5) Internet-based asthma management linked to a health plan Web site.⁴⁸⁻⁵¹

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Online Repository

METHODS

Sample size estimation used a previously reported administrative-derived cohort (2005-2007)^{E1} when applying the present study eligibility criteria. Of the 3814 patients identified with at least 7 SABA canisters dispensed in 1 year, 51.1% had at least 7 SABA canisters dispensed in the next year.

RESULTS

For comorbidities (Table E2), the following comorbidities were identified by International Classification of Disease, Ninth Revision coding in the year before randomization at a rate higher than 10% in decreasing order of frequency: allergic rhinitis (27.3%), any sinusitis (17.1%), acute respiratory tract infection (16.5%), and gastroesophageal reflux (11.9%), and were balanced between the study groups.

Sensitivity analyses when adjusting for prior asthma exacerbations that required oral corticosteroids

Patients in the control group experienced a marginally greater frequency of asthma exacerbations that require oral corticosteroids in the year before randomization ($P = .05$) (Table I [main text]). When prior asthma exacerbations that require oral corticosteroids were used in the primary outcome model without interaction (≥ 7 SABA canisters dispensed, yes/no) for the whole cohort, the treatment effect that favored intervention was $P = .008$ similar to the $P = .007$ in the model without the addition of baseline asthma exacerbations. Similarly, the risk ratio and CIs remained unchanged when prior asthma exacerbations were used in the primary outcome model with interaction for the whole cohort.

Appendix E1

Patient letters

Patient letter 1. Patient letter to adults without asthma specialist care in the prior 3 years. A modified letter was sent to parents of adolescents.

Patient letter 2. Patient letter to adults with asthma specialist care in the prior 3 years. A modified letter was sent to parents of adolescents.

Electronic messages to physicians

Physician electronic message 1. Electronic message to primary care physician for patient without asthma specialist care in the prior 3 years.

Asthma specialist electronic message 2. Electronic message to asthma specialist for patient with asthma specialist care in the prior 3 years.

Patient letter 1. Patient letter to adults without asthma specialist care in the prior 3 years.

Dear Patient Name:

We at Kaiser Permanente are looking for better ways to improve the health of our members with asthma. We are studying a new outreach program to improve asthma care. You do not have to take part in it, but participation involves only following national asthma guidelines recommended to improve asthma.

You are receiving this letter since our records show that you have asthma and have been dispensed seven or more canisters of an asthma rescue inhaler (such as ProAir inhaler [TEVA Pharmaceutical, North Wales, PA], also called albuterol inhaler) in the past year. Too much use of ProAir (or similar rescue inhalers) may indicate that your asthma control (condition) could be better.

Our records also show that, in the past 6 months you have been prescribed an inhaled anti-inflammatory medication such as QVAR (TEVA Pharmaceuticals, North Wales, PA) or ADVAIR (GlaxoSmithKline, Research Triangle Park, NC). Every day use of QVAR or ADVAIR (or similar inhaled anti-inflammatory medication) reduces the need for rescue drugs like ProAir (or similar rescue inhalers).

If you are not taking your QVAR or ADVAIR (or similar inhaled anti-inflammatory medication), or if you are only taking it now and then, you should begin taking it now, and take it every day as prescribed for at least 6 months. Call for refills before you run out since it is important to take QVAR or ADVAIR (or similar inhaled anti-inflammatory medication) every day without lapses. Every day use of your QVAR or ADVAIR (or similar inhaled anti-inflammatory medication) as prescribed should improve your asthma control.

Kaiser Permanente and other groups have shown that care by allergists helps improve asthma control. Therefore, a referral has been made for you to the Allergy Department to help improve your care. The Allergy Department will contact you within 7 days for an appointment.

Your primary care provider Dr [name of PCP] has also been notified that your asthma could be better controlled. If you decide against an Allergy Department appointment, please contact your primary care provider Dr [name of PCP] at [phone number] for follow-up care.

We hope this information will improve your asthma and how you feel.

Chiefs of Allergy, Kaiser Permanente Southern California Region
Robert Zeiger, MD, PhD, Director of Allergy Research, Kaiser Permanente San Diego

Patient letter 2. Patient letter to adults with asthma specialist care in the prior 3 years.

Dear Patient Name:

We at Kaiser Permanente are looking for better ways to improve the health of our members with asthma. We are studying a new outreach program to improve asthma care. You do not have to take part in it, but participation involves only following national asthma guidelines recommended to improve asthma.

You are receiving this letter since our records show that you have asthma and have been dispensed seven or more canisters of an asthma rescue inhaler (such as ProAir inhaler, also called albuterol inhaler) in the past year. Too much use of ProAir (or similar rescue inhalers) may indicate that your asthma control (condition) could be better.

Our records also show that, in the past 6 months, you have been prescribed an inhaled anti-inflammatory medication such as QVAR or ADVAIR. Every day use of QVAR or ADVAIR (or similar inhaled anti-inflammatory medication) reduces the need for rescue drugs like ProAir (or similar rescue inhalers).

If you are not taking your QVAR or ADVAIR (or similar inhaled anti-inflammatory medication), or if you are only taking it now and then, you should begin taking it now, and take it every day as prescribed for at least 6 months. Call for refills before you run out since it is important to take QVAR or ADVAIR (or similar inhaled anti-inflammatory medication) every day without lapses. Every day use of your QVAR or ADVAIR (or similar inhaled anti-inflammatory medication) as prescribed should improve your asthma control.

Kaiser Permanente and other groups have shown that care by asthma specialists helps improve asthma control. Our records

show that you have had a visit to asthma specialist Dr. [name of Asthma Specialist] in the past 3 years. Therefore, we have notified your asthma specialist that your asthma could be better controlled. We recommend that you contact your asthma specialist Dr. [name of Asthma Specialist] at [phone number] to help improve your asthma control.

We hope this information will improve your asthma and how you feel.

Chiefs of Allergy, Kaiser Permanente Southern California Region
Robert Zeiger, MD, PhD, Director of Allergy Research, Kaiser Permanente San Diego

Physician electronic message 1. Electronic message to **Primary Care** physician for patient without asthma specialist care in the prior 3 years.

Southern California Permanente Medical Group is determining whether a novel real-time identification of uncontrolled asthma and real-time notification of this uncontrolled status to providers will improve asthma care by lowering the rate of uncontrolled asthma and asthma utilization in a follow-up year.

Your patient (Name, MR #) was recently identified with uncontrolled asthma based on being dispensed a seventh canister of albuterol within the past year. Kaiser Permanente and other groups have documented that this amount of use of albuterol is a sign of uncontrolled asthma and is associated with an increased rate of future asthma ED visit and/or hospitalizations.

Your patient was sent a letter with specific recommendations to improve asthma control by restarting or taking regularly your prior prescribed inhaled corticosteroid regimen.

A referral to the Allergy Department was made to assist in your patient's asthma care. If your patient declines the allergy

referral, your patient was encouraged to contact you for future asthma care.

Thank you for your pivotal input to improve asthma care in the region.

Chiefs of Allergy, Kaiser Permanente Southern California Region
Robert Zeiger, MD, PhD, Director of Allergy Research, Kaiser Permanente San Diego

Physician electronic message 2. Electronic message to asthma specialist for patient with asthma specialist care in the prior 3 years.

Your patient NAME MR# has been identified recently with uncontrolled asthma based on being dispensed a seventh canister of albuterol within the past year. Kaiser Permanente and other groups have documented that this amount of use of albuterol is a sign of uncontrolled asthma and is associated with an increased rate of future asthma ED visit and/or hospitalizations.

Your patient was sent a letter with specific recommendations to improve asthma control, including restarting or taking regularly prior prescribed asthma controllers and contacting your office for advice to potentially increase their step-care level, if appropriate.

Thank you for your pivotal input to improve asthma care in the region.

Chiefs of Allergy, Kaiser Permanente Southern California Region
Robert Zeiger, MD, PhD, Director of Allergy Research, Kaiser Permanente San Diego

REFERENCE

- E1. Zeiger RS, Schatz M, Li Q, Zhang F, Purdum A, Chen W. Step-up care improves impairment in uncontrolled asthma: administrative data study. *Am J Manag Care* 2010;16:897-906.

TABLE E1. Distribution of study groups by Kaiser Permanente Southern California service areas*

Kaiser Permanente Southern California Care service area	Intervention, no. (%) (n = 1001)	Control, no. (%) (n = 998)	Total, no. (%) (n = 1999)
1	72 (7.2)	50 (5)	122 (6.1)
2	45 (4.5)	43 (4.3)	88 (4.4)
3	39 (3.9)	45 (4.5)	84 (4.2)
4	89 (8.9)	71 (7.1)	160 (8)
5	5 (0.5)	11 (1.1)	16 (0.8)
6	124 (12.4)	147 (14.7)	271 (13.6)
7	28 (2.8)	33 (3.3)	61 (3.1)
8	13 (1.3)	18 (1.8)	31 (1.6)
9	93 (9.3)	107 (10.7)	200 (10)
10	44 (4.4)	62 (6.2)	106 (5.3)
11	90 (9)	87 (8.7)	177 (8.9)
12	190 (19)	172 (17.2)	362 (18.1)
13	63 (6.3)	51 (5.1)	114 (5.7)
14	8 (0.8)	10 (1)	18 (0.9)
15	61 (6.1)	56 (5.6)	117 (5.9)
16	37 (3.7)	35 (3.5)	72 (3.6)

*Data are presented as frequency, no. (%); $P > .05$ for comparison of facilities between the study groups.

TABLE E2. Clinically relevant comorbidities by study group*

Comorbidity	Intervention (n = 1001)	Control (n = 998)	Total (n = 1999)
Rhinitis, no. (%)			
Allergic	266 (26.6)	280 (28.1)	546 (27.3)
Chronic	71 (7.1)	84 (8.4)	155 (7.8)
Any	314 (31.4)	334 (33.5)	648 (32.4)
Sinusitis, no. (%)			
Acute	78 (7.8)	72 (7.2)	150 (7.5)
Chronic	113 (11.3)	125 (12.5)	238 (11.9)
Any	166 (16.6)	175 (17.5)	341 (17.1)
Acute upper respiratory infection, no. (%)	165 (16.5)	164 (16.4)	329 (16.5)
Gastroesophageal reflux, no. (%)	115 (11.5)	123 (12.3)	238 (11.9)
Pharyngitis, no. (%)†	111 (11.1)	83 (8.3)	194 (9.7)
Pneumonia, no. (%)	48 (4.8)	59 (5.9)	107 (5.4)
Any otitis media, no. (%)	41 (4.1)	52 (5.2)	93 (4.7)
Eczema, no. (%)	45 (4.5)	37 (3.7)	82 (4.1)
Tonsillitis, no. (%)	37 (3.7)	39 (3.9)	76 (3.8)
Nasal polyps, no. (%)	16 (1.6)	14 (1.4)	30 (1.5)
Charlson comorbidity score, mean $\pm$ SD	1.0 $\pm$ 0.62	1.0 $\pm$ 0.57	1.0 $\pm$ 0.60

* $P > .05$ for all comparisons between the study groups except pharyngitis.

† $P = .04$.

TABLE E3. Demographics at baseline and asthma features in the prior year in the subgroup without asthma specialty care in the prior 3 years by intervention and control group status*

Characteristics	Intervention (n = 681)	Control (n = 699)	Total (n = 1380)
Demographics			
Age (y), mean $\pm$ SD	36.4 $\pm$ 13.5	36.3 $\pm$ 13.3	36.3 $\pm$ 13.4
Female sex, no. (%)	342 (50.2)	340 (48.6)	682 (49.4)
Ethnicity, no. (%)			
White	282 (41.4)	288 (41.2)	570 (41.3)
Black	113 (16.6)	134 (19.2)	247 (17.9)
Hispanic	194 (28.5)	195 (27.9)	389 (28.2)
Native American/Alaskan	3 (0.4)	1 (0.1)	4 (0.3)
Asian/Pacific Islander	39 (5.7)	34 (4.9)	73 (5.3)
Multiple	5 (0.7)	2 (0.3)	7 (0.5)
Others	8 (1.2)	10 (1.4)	18 (1.3)
Unknown	37 (5.4)	35 (5)	72 (5.2)
Estimated household median income by geocoding (\$), mean $\pm$ SD	65,026 $\pm$ 26,482	65,282 $\pm$ 28,286	65,155 $\pm$ 27,395
Estimated family education level up to grade 12 by geocoding (%), median (IQR)	20.0 (10.4-36.7)	19.9 (11.1-34.6)	19.9 (10.8-35.6)
Body mass index (kg/m ²), mean $\pm$ SD	30.6 $\pm$ 7.9	30.7 $\pm$ 8.0	30.7 $\pm$ 7.9
Body mass index, no. (%)			
<30 kg/m ²	335 (49.2)	333 (47.6)	668 (48.4)
$\geq$ 30 kg/m ² (obesity)	307 (45.1)	305 (43.6)	612 (44.3)
Missing	39 (5.7)	61 (8.7)	100 (7.2)
Smoking status, no. (%)			
Never	380 (55.8)	361 (51.6)	741 (53.7)
Passive	33 (4.8)	38 (5.4)	71 (5.1)
Quit	135 (19.8)	144 (20.6)	279 (20.2)
Yes	89 (13.1)	89 (12.7)	178 (12.9)
Missing	44 (6.5)	67 (9.6)	100 (7.2)
Length of health plan membership (y), mean $\pm$ SD	13.0 $\pm$ 8.8	13.1 $\pm$ 9.0	13.1 $\pm$ 8.9
Insurance, no. (%)†			
Commercial	557 (81.8)	575 (82.3)	1132 (82.0)
Medicaid	102 (15.0)	99 (14.2)	201 (14.6)
Medicare	13 (1.9)	13 (1.9)	26 (1.9)
Private pay	39 (5.6)	37 (5.4)	76 (5.5)
Asthma features in prior year			
No. SABA canisters dispensed, mean $\pm$ SD	10.9 $\pm$ 4.0	11.0 $\pm$ 4.0	10.9 $\pm$ 4.1
No. controller canister equivalent dispensed, mean $\pm$ SD	7.4 $\pm$ 5.3	7.1 $\pm$ 5.4	7.2 $\pm$ 5.3
Controller ratio, mean $\pm$ SD‡	0.4 $\pm$ 0.17	0.4 $\pm$ 0.17	0.4 $\pm$ 0.17
Controller ratio $\geq$ 0.5, no. (%)‡	197 (28.9)	179 (25.6)	376 (27.2)
Step care level, no. (%)			
2	228 (33.5)	219 (31.3)	447 (32.4)
3	224 (32.9)	241 (34.5)	465 (33.7)
4	149 (21.9)	163 (23.3)	312 (22.6)
5	80 (11.7)	76 (10.9)	156 (11.3)
Any oral steroid course for an asthma exacerbation, no. (%)	183 (26.9)	212 (30.3)	395 (28.6)
$\geq$ 2 Oral steroid courses for asthma exacerbations, no. (%)	54 (7.9)	47 (6.7)	101 (7.3)
Any asthma emergency department or hospitalization, no. (%)	56 (8.2)	70 (10.0)	126 (9.1)

IQR, Interquartile range.

*Data are presented as frequency, no. (%), mean (SD), or median (IQR), and $P > .05$ for all comparisons between the study groups.

†Patients may have more than 1 insurance plan.

‡Controller medication ratio is the number of asthma controller units (canisters of inhaled medication or 30-day supplies of oral medications) dispensed divided by the total number of controller units and SABA canisters.

TABLE E4. Demographics at baseline and asthma features in the prior year in the subgroup with asthma specialty care in the prior 3 years by intervention and control status*

Characteristics	Intervention (n = 320)	Control (n = 299)	Total (n = 619)
Demographics			
Age (y), mean $\pm$ SD	35.7 $\pm$ 14.4	35.6 $\pm$ 13.2	35.6 $\pm$ 13.8
Female sex, no. (%)	179 (59.9)	202 (63.1)	381 (61.6)
Ethnicity, no. (%)			
White	127 (39.7)	132 (44.1)	259 (41.8)
Black	60 (18.8)	55 (18.4)	115 (18.6)
Hispanic	100 (31.3)	74 (24.7)	174 (28.1)
Native American/Alaskan	0 (0)	1 (0.3)	1 (0.2)
Asian/Pacific Islanders	21 (6.6)	25 (8.4)	46 (7.4)
Multiple	1 (0.3)	2 (0.7)	3 (0.5)
Others	4 (1.3)	5 (1.7)	9 (1.5)
Unknown	7 (2.2)	5 (1.7)	12 (1.9)
Estimated household median income by geocoding (\$), mean $\pm$ SD	69,090 $\pm$ 29,288	64,909 $\pm$ 32,019†	67,071 $\pm$ 30,683
Estimated family education level up to grade 12 by geocoding (%), median (IQR)	18.8 (9.8-32.8)	18.3 (9.4-32.3)	19.6 (9.7-32.4)
Body mass index (kg/m ²), mean $\pm$ SD	30.6 $\pm$ 7.7	30.9 $\pm$ 7.6	30.8 $\pm$ 7.7
Body mass index, no. (%)			
<30 kg/m ²	153 (47.8)	138 (46.2)	291 (47.0)
$\geq$ 30 kg/m ² (obesity)	156 (48.8)	152 (50.8)	308 (49.8)
Missing data	11 (3.4)	9 (3.0)	20 (3.2)
Smoking status, no. (%)			
Never	216 (67.5)	196 (65.6)	412 (66.6)
Passive	15 (4.7)	10 (3.3)	25 (4.0)
Quit	53 (16.6)	67 (22.4)	120 (19.4)
Yes	24 (7.5)	18 (6.0)	42 (6.8)
Missing data	12 (3.8)	8 (2.7)	20 (3.2)
Length of health plan membership (y), mean $\pm$ SD	15.2 $\pm$ 9.3	13.6 $\pm$ 9.6†	14.4 $\pm$ 9.5
Insurance, no. (%)‡			
Commercial	262 (81.9)	237 (79.3)	499 (80.6)
Medicaid	45 (14.1)	42 (14.0)	87 (14.1)
Medicare	12 (3.8)	9 (3.0)	21 (3.4)
Private pay	15 (4.7)	27 (9.0)†	42 (6.8)
Asthma features in prior year			
No. of SABA canisters dispensed, mean $\pm$ SD	11.5 $\pm$ 5.3	11.3 $\pm$ 4.7	11.4 $\pm$ 5.0
No. of controller canister equivalent dispensed, mean $\pm$ SD	9.6 $\pm$ 6.6	8.8 $\pm$ 5.9	9.2 $\pm$ 6.3
Controller ratio, mean $\pm$ SD§	0.4 $\pm$ 0.17	0.4 $\pm$ 0.17	0.4 $\pm$ 0.17
Controller ratio $\geq$ 0.5, no. (%)§	118 (36.9)	108 (36.1)	226 (36.5)
Step care level, no (%)			
2	47 (14.7)	49 (16.4)	96 (15.5)
3	98 (30.6)	80 (26.8)	178 (28.8)
4	98 (30.6)	98 (32.8)	196 (31.7)
5-6	77 (24.1)	72 (24.1)	149 (24.1)
Any oral steroid course for an asthma exacerbation, no. (%)	118 (36.9)	129 (43.1)	247 (39.9)
$\geq$ 2 Oral steroid courses for asthma exacerbations, no. (%)	37 (11.6)	41 (13.7)	78 (12.6)
Any asthma ED visit or hospitalization, no. (%)	41 (12.8)	49 (16.4)	90 (14.5)

IQR, Interquartile range.

*Data are presented as frequency, no. (%), mean (SD), or median (IQR); $P > .05$ for comparisons between study groups except

† $P < .05$.

‡Patients may have more than 1 insurance plan.

§Controller medication ratio is the number of asthma controller units (canisters of inhaled medication or 30-day supplies of oral medications) dispensed divided by the total number of controller units and SABA canisters.