

Original article

Achieving and maintaining asthma control in inner-city children

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Background: Despite guidelines-defined care, inner-city children of low socioeconomic status have poor asthma control. **Objective:** This study evaluated time to achieve control, maintenance of control, and factors associated with well controlled asthma for pediatric patients receiving specialty-based asthma care in mobile asthma clinics designed to reduce barriers to delivering effective asthma care (the Breathmobile Program).

Methods: Existing clinical data collected from January 1998 to June 2008 for 7822 pediatric patients with asthma (34,339 visits) enrolled in similarly structured mobile asthma programs across the United States evaluated the effect of asthma control on the reduction of asthma-related morbidity, time to achieve asthma control, maintenance of asthma control, and factors associated with well controlled asthma.

Results: Comparison of pre and post year data for subjects enrolled in the program for at least 1 year revealed reductions in the percentage of patients reporting emergency department visits (mean, 66%), hospitalizations (mean, 84%), and missed school days ≥ 5 /year (mean, 78%). Well controlled asthma was achieved by visit 3 for an estimated 80% of patients. Factors contributing to well controlled asthma include non-African American race, visit interval < 90 days, and adherence to prescribed therapy.

Conclusion: This study demonstrates the ability to achieve and maintain asthma control in high-risk populations in association with intensive, accessible, guidelines-defined care with close follow-up. (*J Allergy Clin Immunol* 2011;■■■:■■■-■■■.)

Key words: Pediatric asthma, inner city, asthma control, asthma morbidity

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Abbreviations used

BMI: Body mass index
ED: Emergency department
MC: Maintenance of asthma control
NAEPP: National Asthma Education and Prevention Program
NHLBI: National Heart, Lung, and Blood Institute
OR: Odds ratio
TC: Time to achieve asthma control
WCA: Well controlled asthma

National guidelines focus on asthma control as a therapeutic goal.^{1,2} Although numerous studies report asthma control can be achieved for a majority of patients receiving appropriate therapy,³⁻⁵ poor asthma control is problematic in the United States.⁶ This is particularly true for children and adults of low socioeconomic status living in inner-city environments.⁷ Much of this disparity results from medical care delivery systems' inadequacies.⁸⁻¹⁰

To address this deficiency, approaches for treating inner-city children with asthma have been developed.^{11,12} Among these is the Breathmobile program, initiated in Los Angeles in 1995.¹³ This school-based disease management program uses fully equipped mobile clinics staffed by specialty trained asthma providers and integrates strategies for case identification, community outreach, continuity of care, structured healthcare encounters, and patient tracking. This model serves to reduce barriers to delivering effective asthma care.^{11,13,14} Similarly structured programs now operate in multiple US cities and collaboratively offer a novel opportunity to analyze the efficacy of regular, guidelines-based comprehensive care^{1,15,16} to achieve and maintain asthma control in a large, heterogeneous, real-world pediatric population.

METHODS

Study population

This study evaluated asthma control for patients enrolled in similarly structured mobile asthma programs previously described^{13,14} for the following sites (program name, launch date): Los Angeles, Calif (Los Angeles County + University of Southern California Pediatric Asthma Disease Management Program, LAC+USC PADMAP, Breathmobile Program, November 16, 1995), Chicago, Ill (Mobile Children's Asthma Research and Education (C.A.R.E.) Foundation, November 9, 1999), Baltimore, Md (University of Maryland Medical School [UMMS] Breathmobile Program, March 6, 2002), Orange County, Calif (Children's Hospital of Orange County Asthma Breathmobile Program, April 5, 2002), Mobile, Ala (University of South Alabama Breathmobile Program, September 26, 2006), and San Bernardino County, Calif (Arrowhead Regional Medical Center Breathmobile Program,

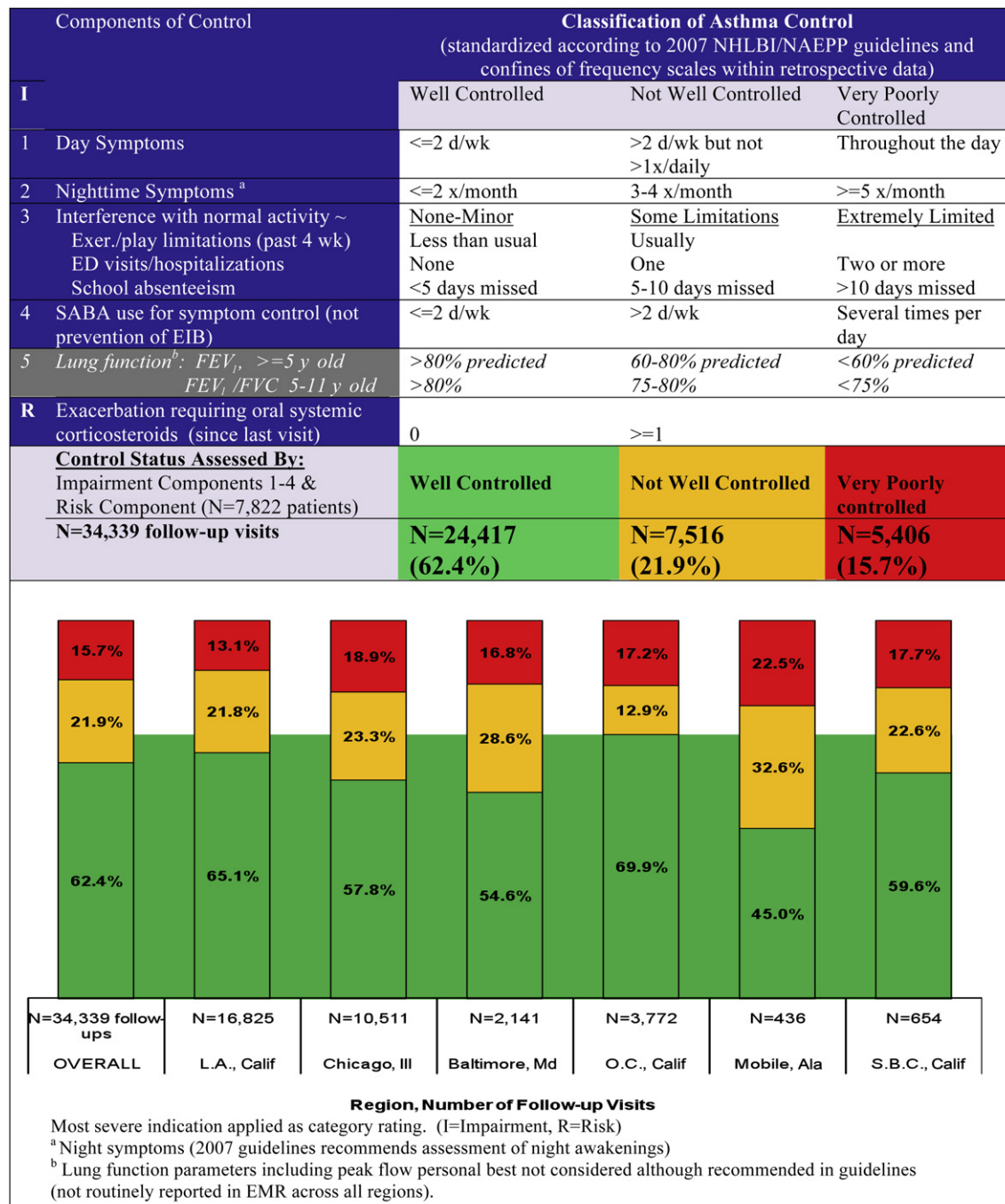


FIG 1. Classification of asthma control and distribution across 34,339 follow-up visits. *EMR*, Electronic medical record; *Exer.*, exercise; *FVC*, forced vital capacity; *L.A.*, Los Angeles; *O.C.*, Orange County; *SABA*, short-acting β -agonist; *S.B.C.*, San Bernadino.

June 18, 2007). Hereafter, sites are referred to by geographic region. Data for all sites were collected at each visit (scheduled 4-8 weeks) and stored in an electronic medical record, EMR (Asmatrax, created by Loran Clement, Los Angeles, Calif). The study was approved by the institutional review boards of participating academic centers. Patient selection criteria included (1) program enrollment between January 1998 and June 2008, (2) age 3 to 18 years, (3) an initial visit with asthma diagnosis and guideline-based baseline severity recorded,^{1,15,16} (4) follow-up visits 7 to 365 days after program entry, and (5) follow-up visit asthma control status determinable by National Heart, Lung, and Blood Institute (NHLBI)/National Asthma Education and Prevention

Program (NAEPP) 2007 guidelines using a minimum of 3 impairment components (defined as daytime symptoms, nighttime symptoms, interference with normal activities, and short-acting β_2 -agonist use) and a risk component (defined as interval steroid burst; Fig 1).

A total of 7822 subjects met inclusion criteria. Of these, 5790 subjects had persistent baseline disease and were included in the time to achieve well controlled asthma analysis (time to achieve asthma control, TC). A total of 5442 subjects met inclusion criteria and were included in the maintenance of control analysis (MC). These subjects had intermittent or persistent baseline severities and returned for follow-up care after

TABLE I. Characteristics of pediatric patients with asthma who met study criteria

Valid %	Overall N = 7822	Los Angeles, Calif n = 3258	Chicago, Ill* n = 2384	Baltimore, Md n = 618	Orange County, Calif n = 1083	Mobile, Ala n = 186	San Bernardino, Calif n = 293
Age (y), mean (SD)	8.6 (3.4)	8.9 (3.4)	8.8 (3.4)	7.4 (2.9)	8.0 (3.5)	9.9 (3.5)	8.3 (2.8)
3-4 y (%)	10.3	7.6	8.9	18.8	18.6	3.8	8.2
5-11 y (%)	69.5	70.0	70.0	73.1	63.5	64.0	79.2
12-18 y (%)	20.1	22.4	21.1	8.1	17.9	32.3	12.6
Female (%)	41.8	40.0	46.7	39.5	30.4	40.3	52.4
Hispanic (%)	67.1	81.9	56.9	1.6	83.2	2.7	70.3
African American (%)	22.5	7.9	40.4	89.3	0.6	55.9	17.1
Caucasian (%)	4.9	3.1	1.6	7.3	6.3	40.9	6.5
Other ethnicity (%)	5.6	7.1	1.1	1.8	9.9	0.5	6.1
BMI percentile							
<85% (normal) (%)	49.6	51.8	45.6	52.1	47.9	50.3	52.9
85% to 94% (at risk) (%)	17.5	16.6	17.5	18.2	21.3	14.9	16.7
≥95% (overweight) (%)	32.9	31.6	36.9	29.7	30.8	34.8	30.4
Asthma severity (baseline)							
Intermittent (%)	26.0	27.7	18.0	33.0	26.6	23.1	56.7
Mild persistent (%)	31.2	21.7	48.5	30.4	28.9	21.0	13.0
Moderate persistent (%)	29.5	30.8	29.3	32.0	27.3	29.6	20.5
Severe persistent (%)	13.2	19.8	4.2	4.5	17.2	26.3	9.9
Insurance status							
None (%)	23.3	37.1	8.4	4.4	16.2	5.4	18.4
Medicaid/public program (%)	57.2	49.5	64.4	57.1	73.4	59.7	47.1
Private/other (%)†	19.5	13.4	27.1	38.5	10.4	34.9	34.5
Poverty status (zip code)‡							
≥50% poor or near poor (%)	44.7	60.5	43.8	28.3	19.2	38.5	14.0

*Chicago ethnicity and insurance status distributions based primarily on patients entering 2005 forward (routine tracking of these parameters).

†Private insurance, 17.6%; other, 0.4%; and unknown, 1.4% (overall).

‡Percent of patients residing in zip code area where family income for the majority (≥50%) of residences adjusted for family size and inflation poor or near poor by criteria defined in Healthy People 2010 (US Bureau of the Census): poor (below federal poverty level) or near poor (100% to 199% of the federal poverty level). Regional differences significant across characteristics (χ^2 tests, $P < .05$).

achieving well controlled asthma during a maximum 2-year observation period.

Of the 12,418 individuals 3 to 18 years of age diagnosed with asthma during the study, 4596 were excluded because of (1) lack of follow-up ($n = 3555$), (2) first return visit ≤ 1 week or > 1 year after baseline visit ($n = 234$), (3) relevant control measures missing at follow-up ($n = 722$), or (4) both 2 and 3 ($n = 85$). Patients excluded because of these criteria were more likely to be non-Hispanic (44% vs 33%), to be 3 to 4 years of age (12% vs 10%), to have less severe baseline disease (intermittent, 31% vs 26%), and to have entered the program during the last year of the study period (January to June 2008, 13% vs 6%; $P < .05$).

Measures and data collection

Asthma control was assigned to 1 of 3 NHLBI/NAEP¹-defined categories (well controlled asthma [WCA], not well controlled asthma, and poorly controlled asthma). The most severe indicator across components defined asthma control (Fig 1). Additional data recorded include height, weight, sex, race, residential zip code, and insurance status.

Poverty status for each patient was estimated by using 2000 US Census bureau data for patient residential zip code at enrollment.¹⁷ Poverty level was defined by percent of households within a zip code region whose median household income (adjusted for family income, family size, and inflation) was poor (below the federal poverty level) or near poor (100% to 199% of the federal poverty level).

Analytic and statistical methods

Regional differences in distributions of each factor were assessed by χ^2 tests. Factors investigated in TC and MC analyses included the following:

1. Patient characteristics: sex, age (3-4, 5-11, 12-18 years), ethnicity/race (Hispanic vs non-Hispanic: African American, Caucasian, other), and body mass index (BMI) percentile¹⁸ (<85%, normal; 85% to 94%, at risk; ≥95%, overweight)
2. Socioeconomic characteristics: health insurance status and poverty status (zip code region ≥50% households poor or near poor, yes or no)¹⁷
3. Time factors: season of entry (TC analysis), month of visit (MC analysis), and visit interval defined as elapsed days since last visit (≤ 60 , 61-90, ≥90 days)
4. Treatment factors (patients with persistent baseline disease): provider assessment of (patient-reported) adherence with controller medications (adherent, nonadherent/off therapy), and time to achieve WCA (≤ 3 visits, > 3 visits) assessed in MC analysis.

Cox regression analyses were conducted to assess the influence of these factors on the cumulative probability that a patient would achieve WCA with each subsequent visit to the program (TC analysis). Because of the potential interaction of baseline asthma severity with factors investigated and indication that the proportional hazards assumption might be violated, stratification by baseline severity was applied. A stepwise procedure was applied in the multivariable analysis to determine which factors significantly affected time to achieve WCA. The TIES=EXACT approach was specified in the model statement for the PHREG procedure in SAS (SAS Institute, Inc, Cary, NC) to account for the occurrence of multiple patients achieving WCA by a particular visit, acknowledging that the event likely occurred within the visit interval.

The generalized estimating equations method was used to analyze factors associated with WCA at follow-up visits 1 to 6 after control was first achieved (MC analysis). After adjustment for other significant contributory variables, factors that significantly influenced likelihood of WCA were investigated by categorical contrast comparisons. The probability of maintaining WCA was

Morbidity Pre vs. Post Year of Entry

Among study patients who entered and received ongoing care (≥ 1 year) in regions operating programs during the 5 year period (2002-2006)

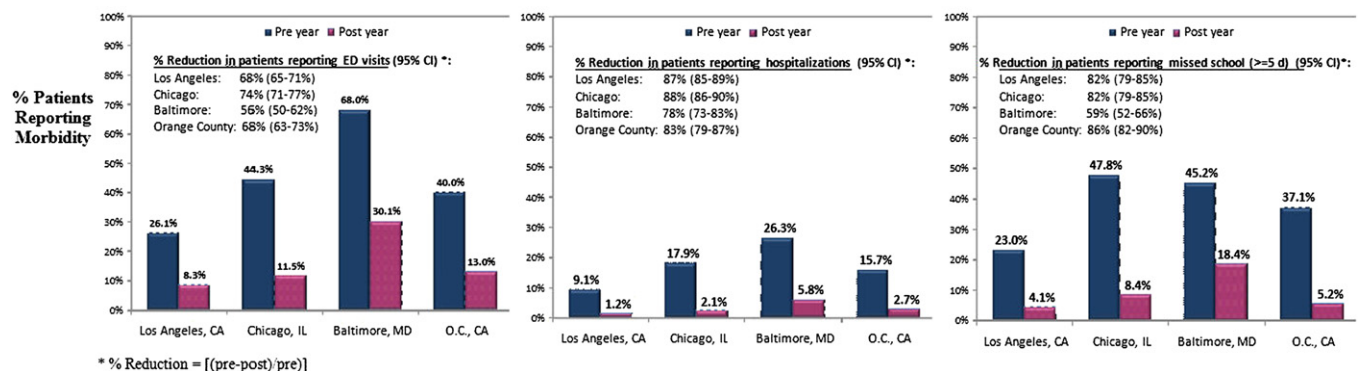


FIG 2. Morbidity reductions (pre vs postyear). Patients who entered and received ongoing care (≥ 1 year) in regions operating programs from 2002 to 2006 evaluated. Average reduction in percent of patients reporting emergency department (ED) visits, 66% (regional range, 56% to 74%); hospitalizations, 84% (78% to 88%); and school absenteeism (≥ 5 d/y), 78% (59% to 86%). Baseline (preyear) morbidity profile of patients excluded from this analysis because of inadequate follow-up was similar to those in the program ≥ 1 year, with the following exceptions of percent of patients reporting: preyear ED visits in Baltimore (58% vs 68%; $P < .05$), hospitalizations preyear entry in Chicago borderline significant (14% vs 18%; $P = .06$), and missed school days ≥ 5 /y preyear entry in Los Angeles (30% vs 23%; $P < .05$). O.C., Orange County.

estimated on the basis of the average value of covariates included in the final model within each severity stratum. Analyses were adjusted for potential clustering effects of care site and cohort effects of year of program entry.

SAS version 9.1 software was used for Cox regression and generalized estimating equations analyses, and remaining analyses were conducted with SPSS version 12.0 software (SPSS, Inc, Chicago, Ill).

RESULTS

Patient demographics

Table I describes the patient populations with regional variations noted ($P < .05$). Subjects had a mean age of 8.6 years (SD, 3.4) and a median number of 4 program visits/year (interquartile range, 2-5); the median visit interval length was 56 days (interquartile range, 42-91 days; visit data not presented in Table I). Ethnicity and race varied by site (overall, 67% Hispanic vs 33% non-Hispanic; 22% African American, 5% Caucasian, and 6% other). Nearly half of patients had a BMI ≥ 85 (similar trends observed across regions). Most subjects (74%) had persistent asthma at baseline. Estimated socioeconomic status of the subjects was 51.3% middle-upper income and 48.6% poor or near poor (compared with 69.2% and 30.7% in US general population, respectively). Health insurance for the majority of patients (57%) was Medicaid/public program, and 23% reported no insurance coverage. California programs reported the highest uninsured rates (range, 16.2% to 37.1%).

Asthma-related morbidity data

Fig 2 describes asthma-related morbidities (pre/postenrollment) for all patients who received ongoing care (≥ 1 year) at sites operating during the 2002 to 2006 study period. Overall, participation in the Breathmobile program was associated with reductions in percentage of patients reporting emergency department (ED) visits (mean, 66%; range, 56% to 74%), hospitalization (mean, 84%; range, 78% to 88%), and school absenteeism (≥ 5 d/y, mean, 78%; range, 59% to 86%).

Asthma control analysis

Fig 1 demonstrates the level of asthma control across 34,339 follow-up visits for all sites. Overall, 62.4% of patients had WCA, 21.9% not well controlled asthma, and 15.7% poorly controlled asthma at follow-up visits. Orange County had the highest percentage of WCA patient follow-up visits (69.9%). Regions with higher proportions of African Americans had lower percentages of patient visits with WCA: Mobile (45%), Baltimore (54.6%), and Chicago (57.8%).

Fig 3 depicts the time required to achieve WCA at each site stratified by baseline severity. Provider-estimated adherence did not account for observed ethnic/racial differences in time to achieve WCA for patients with moderate-severe persistent baseline severity (non-Hispanic African American mean, 3 visits, vs Hispanic mean, 2 visits; $P < .05$). African American patients were 27% (95% CI, 12% to 41%) and 48% (95% CI, 31% to 61%) less likely to achieve WCA at any visit interval than Hispanic patients for moderate and severe persistent baseline disease, respectively ($P < .05$). Trends were similar at each study site, with slightly more variation observed among children with severe persistent baseline disease. Cumulative probabilities within each baseline severity stratum suggested that the median number of visits to achieve WCA were 2 visits for mild persistent, 2 to 3 visits for moderate persistent, and 3 visits for severe persistent asthma.

Factors affecting well controlled asthma

Table II details factors associated with WCA for each baseline severity. Patient adherence with prescribed controller therapy, rated independently of control assessment, influenced maintenance of WCA ($P < .05$). Adherent patients exhibited similar levels and trends for WCA over time, independent of baseline asthma severity: mild, regional mean, 78%, and range, 70% to 85%; moderate, regional mean, 71%, and range, 60% to 82%; and severe, regional mean, 78%, and range, 77% to 80%. In contrast, patients rated as nonadherent exhibited lower maintenance

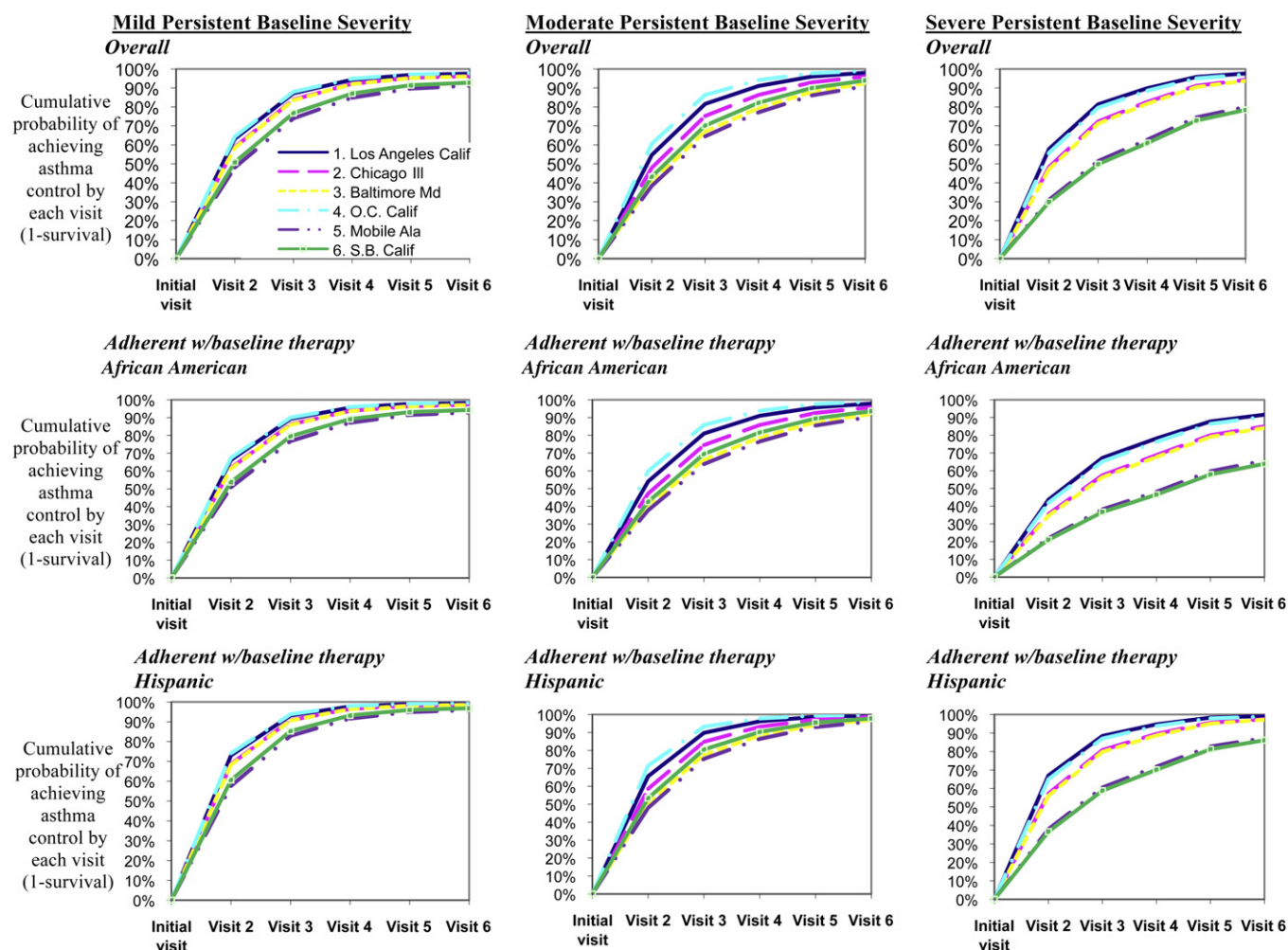


FIG 3. Time to achieve asthma control. The cumulative probability that patients with persistent asthma at initial visit will achieve WCA by each of the first 5 program follow-up visits (visits 2-6) stratified by underlying disease severity (covariate value for mobile unit weighted equally in regions with multiple units). Survivor estimates adjust for the following significant covariates: ethnicity, adherence with baseline therapy, winter entry, and 4-category term to represent interaction effect between BMI and poverty status. Overall cumulative probability estimates representative of distribution of each factor within severity category with exception of equal weight applied to site, 4 BMI and poverty status categories (interaction effect), and year of entry equally weighted across 2007 and 2008: distributions in mild patients: Hispanic (64%), African American (28%), Caucasian (4%), other (4%), winter entry (28%), and 69% adherent; distributions in moderate patients: Hispanic (64%), African American (26%), Caucasian (5%), other (5%), winter entry (29%), and 69% adherent; distributions in severe patients: Hispanic (70%), African American (18%), Caucasian (7%), other (5%), winter entry (29%), and 78% adherent. Estimates for Hispanic and African American patients adherent with baseline therapy were performed at values of remaining significant covariates where equal weight was applied to site, interaction term representing 4 BMI and poverty status categories was included, on average 29% of patients enter during winter, and the year of entry was equally weighted across 2007 and 2008. Trends were similar across regions with slightly more variation observed in patients with baseline severe persistent disease. Note: CIs wide around estimates for patients in newer programs (Mobile and San Bernardino) with severe persistent disease because of the limited number of patients in the stratum at the time of evaluation. O.C., Orange County; S.B., San Bernardino; w, with.

of WCA with increased baseline severity: mild, regional mean, 62%, and range, 47% to 76%; moderate, regional mean, 43%, and range, 29% to 59%; and severe, regional mean, 36%, and range, 34% to 36% ($P < .05$). African American patients were less likely than Hispanic patients to maintain WCA for intermittent (odds ratio [OR], 0.63; $P = .004$) and mild persistent (OR, 0.68; $P = .010$) baseline severities. In summary, factors associated with increased time to achieve WCA include medication nonadherence, African American race, BMI $\geq 85\%$ in combination

with zip codes $>50\%$ households poor or near poor, and winter entry into the program ($P < .05$).

Asthma control status was known in 97.1% of follow-up visits after WCA first achieved. Sensitivity analyses were performed for patients with complete data measures recorded through their last follow-up visit. Visit interval length (reflection of potential missed appointment) was investigated as a covariate in analyses. Patients had a median of 5 follow-up visits after WCA was first achieved (median visit interval length, 62-63 days, consistent

TABLE II. Factors that significantly contributed to well controlled asthma in persistent patients at follow-up visits (1-6) after control first achieved

Outcome: well controlled asthma predictor	Mild persistent adjusted OR (95% CI) P value	Moderate persistent adjusted OR (95% CI) P value	Severe persistent adjusted OR (95% CI) P value
Adherent vs nonadherent with controller therapy at previous visit	2.36 (1.96-2.85) P < .001	3.43 (2.89-4.08) P < .001	Interaction term adherence × visit interval significant 9.89 (6.13-15.84)* Adherent vs nonadherent: VI ≤60 d 4.47 (2.85-7.01)* Adherent vs nonadherent: VI 61-90 d 6.55 (4.36-9.87)* Adherent vs nonadherent: VI >90 d
Visit interval ≤60 vs >90 d	1.31 (1.07-1.61) P = .009	1.32 (1.12-1.56) P = .001	
Time to first achieve control ≤3 vs >3 visits	1.45 (1.09-1.93) P = .010		1.72 (1.25-2.36) P = .001
Age 5-11 vs 3-4 y	1.36 (1.07-1.72) P = .011	1.31 (1.06-1.63) P = .014	
Age 12-18 vs 3-4 y	1.39 (1.03-1.87) P = .029	1.50 (1.13-1.98) P = .005	
Hispanic vs Non-hispanic African American	1.47 (1.10-1.97) P = .010		
No insurance vs Medicaid/public	1.37 (1.00-1.86) P = .047	1.11 (0.89-1.38) P = .338	
Private vs Medicaid/public	1.30 (1.02-1.65) P = .031	1.38 (1.09-1.75) P = .007	
BMI (<85% vs ≥85%)	1.47 (1.22-1.78) P < .001		1.30 (0.99-1.71) P = .063

Only factors significant in adjusted model within each persistent severity stratum are presented. ORs and 95% CIs describe the likelihood of well controlled asthma at follow-up visits after control first achieved (baseline in intermittent patients) for each contributory factor relative to reference (vs) category. Contributory factors are based on *P* values from generalized estimating equations, GEE, analysis. Final model within severity strata controls for potential clustering effect of Breathmobile unit (region), cohort effect of year of visit, and potential time effects of visit number and month. Although not presented in the table, factors that significantly contributed to maintenance of well controlled disease in patients with intermittent baseline severity were as follows: visit interval (*P* = .013), sex (*P* = .004), age (*P* = .020), ethnicity (*P* = .027), insurance (*P* = .033), and BMI (*P* = .459). Interaction effects: BMI × insurance (*P* = .027), age × gender (*P* = .043).

VI, Visit interval.

**P* < .001.

across follow-ups). Regression coefficients and SEs (sensitivity analyses) did not appreciably differ from those in the overall set. Contributory factors maintained significance.

The number of children remaining at risk (uncontrolled asthma) was not presented in Fig 3 to retain clarity in the presentation of adjusted curves across several strata and covariate levels. In the unadjusted model, the following number of children remained at risk at each time point (initial visit, V2, V3, V4, V5, V6): mild (2443, 728, 273, 124, 66, 37), moderate (2311, 868, 364, 163, 83, 47), and severe (1036, 495, 280, 174, 99, 65).

DISCUSSION

African American and Hispanic children with asthma living in underserved areas have the highest asthma-related morbidity and mortality, yet have limited access to specialty-based asthma care to improve asthma-related outcomes effectively.^{10,19-27} Implementation of the Breathmobile program sought to remove barriers to care, providing preventive specialty-based asthma care to this high-risk population.^{11,13} Participation in this program is associated with reductions in asthma-related morbidities, evidenced by 2/3 reduction in the percentage of patients reporting ED visits and over 3/4 reduction in hospitalizations and ≥5 missed school days per year. The current study provides significant data about real-world patterns of asthma control in predominantly underserved populations.

Several randomized controlled trials targeting inner-city minority children with asthma have had limited effects, demonstrating difficulties in achieving improvement in this population despite intensive interventions.²⁸⁻³¹ It is unclear why African American patients tend to have more difficult to control asthma, as observed in our study and by other investigators.^{8,31} Further investigation is required to identify specifically which factors including environmental, socioeconomic, psychosocial, behavioral, or genetic explain this phenomenon. In this study, more visits were required, on average, first to achieve WCA in African American compared with Hispanic patients (3 vs 2 visits). This differential was significant for time to achieve control and only factored into maintenance of WCA in children with intermittent and mild persistent baseline severities. This is the first study to our knowledge that reports the impact of race, particularly African American race, as a noncontributory factor in maintaining WCA for patients with moderate and severe persistent asthma. These results suggest that more severe intrinsic disease may negate the role of race in maintaining asthma control. The ability of patients to achieve WCA following guideline care has been previously reported.^{32,33} Similarly, this study demonstrated the ability to achieve and maintain control in high-risk populations through intensive, accessible, guidelines-based care with close follow-up.

Our study population was poorer than the general population,^{17,34} largely nonwhite, and living primarily in urban

environments, which may be explained by the design of the programs. Children are treated regardless of insurance status and generally live in underserved areas, potentially representing a greater proportion of uninsured patients than expected. For the states represented in this study, overall percentages of uninsured children varied from the national average of 11.1%: Alabama (6.5%), California (12.5%), Illinois (8.7%), and Maryland (9.5%).³⁴ Nationwide, 60.4% of uninsured children come from low-income families.³⁴ Although sites represent varied demographic and geographic populations, findings were comparable across sites. Poverty assessment methods applied may have underestimated patients' true poverty levels because zip codes in urban areas could include more affluent neighborhoods. The majority of patients were insured by Medicaid/public program plans with almost one quarter of the children uninsured. Previous studies have shown that a lack of insurance affects asthma outcomes.³⁵⁻³⁷ However, lack of insurance was not a significant factor in achieving or maintaining WCA for subjects in this study, which may be attributed to the programs minimizing major economic barriers associated with being uninsured.

Despite significant improvement in asthma control from program enrollment, maintenance of WCA was highly variable and affected by several factors.³⁸⁻⁴⁵ In our study, adherence to prescribed controller therapy was the most significant factor associated with maintenance of WCA. Comparable findings have been widely reported.^{46,47} With optimal adherence, an estimated 20% to 30% of patients who previously had WCA, regardless of baseline severity, will not maintain WCA to their next visit. Other inner-city asthma studies have noted this phenomenon. Gruchalla et al⁴⁸ studied 546 inner-city children with asthma receiving NAEPP guideline-based asthma care. They found an average of 86.6% adherence with medications and guideline-based care at follow-up visits, yet 72% of subjects had 1 or more follow-up visits with poor asthma control during the 49-week study. Our results may have been affected by the subjectivity of clinician assessment of adherence and lack of pharmacy data to confirm medication adherence.⁴⁹ However, the primary outcome variable, asthma control, was assigned independent of provider assessment of adherence. Strategies such as patient education, community outreach, and maximal use of chronic disease management principles within the school-based mobile clinics should be optimized to improve adherence in high-risk populations and identify factors affecting asthma control.^{11-12,50} Gruchalla et al⁴⁸ demonstrated that inflammatory markers and measures of atopy were not predictive of asthma control. We did not investigate the roles of atopy or environmental exposures in relation to asthma control in this study.

We found that follow-up visit interval was a significant factor affecting asthma control. Interval >90 days was adversely associated with maintenance of WCA for all baseline severities, indicating the need for regular care to make therapeutic adjustments and optimize asthma control.^{48,51-57} Results reinforce that adherence and routine follow-up are critical to maintaining asthma control.

In the statistical analyses, when we examined factors contributory in the final model with specification of TIES=DISCRETE rather than TIES=EXACT, similar levels of significance were found across severity strata. To test potential bias caused by interval censoring on observed influence of adherence and race on time to achieve control, SAS macro % Interval Censoring test was used. This produced a generalized log-rank test II.^{58,59} The generalized log-rank test II results confirmed a statistically significant difference between the 2 adherence groups and race groups when

examined within each baseline severity group (compared with unadjusted score test statistic produced by PHREG procedure where midpoint imputation applied).

It is important to note that subjects were used as their own controls comparing baseline data reflecting the previous year with follow-up data without availability of a randomized control group. We acknowledge the possibility of regression to the mean phenomenon to explain outcomes partially. However, it is unlikely that regression accounts solely for the findings given the reproducibility of outcomes over time and the range of morbidity for patients entering the programs evaluated. The use of nighttime symptoms in our assessments as opposed to the use of nighttime awakenings in the guidelines¹ could overestimate worsening severity and asthma control. Interference with patient activities was defined broadly as missed school days, exercise symptoms, and ED visits/hospitalization during the follow-up visit interval. Asthma symptoms and β -agonist use are based on a recall period of 14 to 28 days, which minimizes potential recall bias. Despite these limitations, the trends were consistent for program sites nationwide, with a robust number of patients/follow-up visits. Program participation was associated with profound reductions in asthma-related morbidities. The Baltimore program has demonstrated cost-effectiveness attributable to these reductions in ED visits/hospitalizations.¹⁴

In conclusion, the results of this study describe outcomes for children with asthma participating in asthma disease-specific management programs. The results describe factors associated with the ability to achieve and maintain well controlled asthma. Our study reinforces the importance of preventative, regularly scheduled specialty-based care in programs like the Breathmobiles to achieve improved asthma control and reduced asthma-related morbidities in high-risk children with asthma.

Clinical implications: Results highlight the importance of regularly scheduled, preventative guidelines-based mobile clinic asthma care in association with reductions of asthma-related morbidities (ED visit/hospitalizations/missed school).

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