

Evaluation of a Pediatric Asthma High-risk Scoring Algorithm

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Asthma is a common reason for potentially preventable pediatric hospital admission and emergency department (ED) visits.^{1,2} Identification of patients at increased risk presents an opportunity for intervention. Risk stratification can inform decisions on prioritization of interventions such as care management, home visits, provider outreach, and specialist referral.³⁻⁶ The Chronic Care Model stresses the importance of decision support tools as part of clinical information systems to allow for a prepared, proactive practice team that can engage the patient in productive interactions.⁷ Delivering “just-in-time” information to health care providers on what makes the patient high risk can assist the provider in proactive outreach, assessment, counseling, and treatment decisions.

The Asthma Medication Ratio measure is promoted by the National Committee for Quality Assurance’s Healthcare Effectiveness Data and Information Set to assess asthma care quality.⁸ This measure considers asthma medication dispensing patterns in a cohort that meets criteria for persistent asthma. It does not account for other factors associated with increased risk for adverse asthma outcomes. In contrast, complex machine learning–based algorithms may identify patients who are high risk for reasons other than asthma and may not be generalizable outside of the setting and population that they were developed and validated on.

Texas Children’s Health Plan is a large, provider-sponsored, not-for-profit Medicaid managed care organization serving as health care payer for more than 500,000 members in eastern Texas. Texas Children’s Health Plan developed and implemented an asthma high-risk scoring algorithm in 2010. Each primary care provider in the health plan is provided with a list of their high-risk patients with asthma and details about what factors made the patient high risk. The list is updated monthly. In 2019 the risk score was added as a just-in-time best practice alert for the Texas Children’s Hospital pulmonary and general pediatric outpatient practices’ electronic medical record. The algorithm incorporates clinically relevant data readily available from computerized health plan claims databases. It was developed from risk factors that were identified from previous research on asthma hospitalization and ED visit risk. Children

ABSTRACT

OBJECTIVES: Identification of patients with asthma at increased risk for hospitalization and emergency department (ED) visits presents opportunity for intervention.

STUDY DESIGN: Retrospective analysis of computerized health plan claims data.

METHODS: Texas Children’s Health Plan, a large Medicaid managed care program, developed an asthma risk scoring algorithm using the clinically relevant parameters of hospitalization for asthma, ED visits for asthma, short-acting β agonist medication dispensing, inhaled corticosteroid medication dispensing, number of prescribing providers, loss to follow-up, and oral corticosteroid dispensing. The risk score performance was evaluated using 2016–2018 risk scores to predict 2017–2019 asthma hospitalizations and ED visits.

RESULTS: We identified 107,811 unique members aged 1 to less than 18 years with an asthma diagnosis. For those aged 3 to less than 18 years, the area under the receiver operating characteristic curve (AUC) for risk score predicting hospitalization ranged from 0.72 to 0.79. For those aged 1 to less than 3 years, the AUC ranged from 0.65 to 0.69. Those with a risk score of 1 or greater accounted for 20% to 23% of pediatric members 3 to less than 18 years with asthma but 53% to 56% of asthma hospitalizations in the follow-up year. Sixteen to eighteen percent of those aged 3 to less than 18 years with a risk score of 9 or greater were hospitalized in the follow-up year.

CONCLUSIONS: Texas Children’s Health Plan asthma risk score stratifies risk of asthma hospitalization and ED visits for Medicaid-insured children. The risk score performs better for children aged 3 to less than 18 years than for those aged 1 to less than 3 years.

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hospitalized for asthma are at high risk for rehospitalization in the following year, and those with 2 or more hospitalizations in a year are at very high risk.⁹⁻¹¹ Those with an ED visit are at high risk. More than 2 ED visits in 1 year suggests higher risk. Overuse of short-acting β agonist medication is associated with future ED visits and hospitalizations for asthma,^{12,13} and very high levels of overuse are associated with increased asthma mortality.¹⁴ Adherence to inhaled corticosteroid medications is associated with decreased asthma exacerbations and decreased asthma mortality, and their use attenuates the risk associated with short-acting β agonist overuse.^{12,15,16} Having 3 or more prescribing providers for asthma medications is associated with increased risk of asthma hospitalization and ED visits.¹⁷ Having 2 or more oral corticosteroid dispensing events in 1 year defines persistent asthma by National Asthma Education and Prevention Program criteria.¹⁸

The aim of this study is to evaluate Texas Children's Health Plan's scoring system by examining the relationship of the baseline-year risk score with asthma hospitalization and ED visits in the following year.

METHODS

All Texas Children's Health Plan pediatric members aged 1 year to less than 18 years who had a medical claim with a diagnosis of asthma (*International Classification of Diseases, Tenth Revision* codes J45 and J46) from 2016 to 2019 were identified. Data for analyses were extracted from health plan computerized databases. For each year, count of hospital admissions and ED visits was determined. Hospitalizations and ED visits are considered as being for asthma if the primary diagnosis was asthma or if the secondary diagnosis was asthma and the primary diagnosis was a respiratory illness. For each year, counts of short-acting β agonist canister equivalents and inhaled corticosteroid low-dose equivalents dispensed were determined. One short-acting β agonist canister equivalent was defined as either as a dispensing of one 200-puff canister of short-acting β agonist medication or 50 unit doses of a short-acting β agonist medication solution for inhalation via nebulizer.¹⁹ A low-dose equivalent of inhaled corticosteroid medication was calculated as the amount of medication that delivers a 1-month supply of what the National Asthma Education and Prevention Program defined as the upper limit of a low dose for a child aged 5 to 11 years.¹⁸ This criterion was chosen to account for differences in inhaled corticosteroid dosing. An oral corticosteroid dispensing event is defined as a pharmacy claim submitted for dispensing of prednisolone, prednisone, or dexamethasone. Demographic data extracted included member date of birth, type of coverage (Medicaid, Children's Health Insurance Program [CHIP], other government-funded programs), and enrollment months. Ethnicity was determined as self-report of belonging to 1 of 5 categories (African American, Alaskan/American Indian, Asian/Pacific Islander, White, Hispanic) on program enrollment.

TAKEAWAY POINTS

An asthma risk score using 7 clinically relevant parameters can stratify risk of hospitalization and emergency department visits for asthma in the following year. Risk scores can range from -1 to a maximum of 18.

We found in the group aged 3 to 17 years that:

- ▶ 16% to 18% of patients with a risk score of 9 or greater and 9.6% to 10% of patients with a risk score of 7 or 8 had an asthma hospitalization in the follow-up year, and
- ▶ 32% to 46% of patients with a risk score of 9 or greater and 34% to 38% of patients with a risk score of 7 or 8 had an asthma emergency department visit in the follow-up year.

Texas Children's Health Plan asthma risk score was initiated in 2010. Factors selected for inclusion were based on known risk factors for adverse asthma outcomes, including history of asthma hospitalization and ED visits,⁹⁻¹¹ overuse of short-acting β agonist medication,¹²⁻¹⁴ underuse of inhaled corticosteroid medication, fragmentation of care, and loss to follow-up.^{12,15-17} History of hospitalization for asthma was given greater weight because it is associated with high risk for rehospitalization.^{9,10} As inhaled corticosteroid adherence can decrease the risk associated with short-acting β agonist overuse,¹² additional points were added for patients with short-acting β agonist overuse in the context of inhaled corticosteroid nonadherence. The factor weights for the risk score were refined between 2010 and 2015 based on experience with algorithm performance and clinician feedback, with the goal of ensuring that those considered most at risk rose to the top of the risk score. Analyses were then performed to determine if further changes in factor weights would improve predictive validity of the algorithm. We were not able to identify modifications to factor weights that could improve the algorithm's predictive validity. Because 2 or more oral corticosteroid dispensing events per year are a criterion for persistent asthma per National Asthma Education and Prevention Program criteria,¹⁸ analyses for this study explored adding 1 point to the risk score for 2 or more oral corticosteroid dispensing events in the baseline year. We found that this improved the area under the receiver operating characteristic curve (AUC) for predicting asthma hospitalization in the follow-up year by a small amount (addition of 0.03, 0.01, and 0.01 to the AUC for the 2016, 2017, and 2018 baseline years, respectively). We retrospectively decided to add this criterion to the risk score. This change increased both the total number of patients identified as high risk (an additional 7% to 8% of patients with asthma) and increased the proportion of patients with hospitalization in the follow-up year who were identified by baseline-year asthma risk score (an additional 6% to 9% of hospitalizations).

Asthma risk scores (Table 1) were determined from events during the 12 months of the baseline years of 2016, 2017, and 2018. Outcomes were determined for the 1 year following the baseline year. We did not exclude from analyses patients who were included in analyses of a prior year's data. Years were defined as December 15 of the prior year to December 14 of the named year. Age was determined

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TABLE 1. Calculation of Asthma Risk Score

Criterion met in past 12 months	Asthma risk points added
4 to < 6 SABA canister equivalents ^a dispensed	Add 1 point
6 to < 10 SABA canister equivalents ^a dispensed	Add 2 points
≥ 10 SABA canister equivalents ^a dispensed	Add 3 points
> 4 SABA canister equivalents ^a and <4 ICS low-dose equivalents ^b dispensed	Add 1 point
≥ 6 SABA canister equivalents ^a and <6 ICS low-dose equivalents ^b dispensed	Add 2 points
1-2 ED visits for asthma ^c	Add 1 point
> 2 ED visits for asthma ^c	Add 2 points
1 hospitalization for asthma ^c	Add 4 points
≥ 2 hospitalizations for asthma ^c	Add 8 points
≥ 3 different prescribing providers + 1 or more of above criteria met	Add 1 point
Last primary care provider visit more than 6 months prior to report date + 1 or more of above criteria met	Add 1 point
≥ 6 ICS low-dose canister equivalents ^b dispensed	Subtract 1 point
≥ 2 oral corticosteroid dispensing events	Add 1 point
Asthma risk score = sum of risk points	

ED, emergency department; ICS, inhaled corticosteroid; SABA, short-acting β agonist.

^aSABA canister equivalents calculated as number of 200-puff SABA canisters dispensed. If a SABA unit dose of inhalation was dispensed, 50 unit doses were considered as equivalent to one 200-puff canister of albuterol.

^bAn ICS low-dose canister equivalent was determined as the amount of ICS dispensed that would yield a 1-month supply of what the National Asthma Education and Prevention Program Expert Panel Report 3 defines as the upper limit of a low-dose ICS for a patient aged 5 to 11 years.

^cED visits and hospitalizations were determined as being for asthma if (1) the primary diagnosis was asthma or (2) a secondary diagnosis was asthma and the primary diagnosis was a respiratory illness.

TABLE 2. Demographic Characteristics of Sample

	2016 baseline year (n = 53,528)	2017 baseline year (n = 53,000)	2018 baseline year (n = 55,056)
Aged 1 to < 3 years	9554 (17.9%)	9424 (17.8%)	9142 (16.6%)
Aged 3 to < 6 years	12,082 (22.6%)	11,985 (22.6%)	12,582 (22.9%)
Aged 6 to < 12 years	20,719 (38.7%)	19,939 (37.6%)	20,811 (37.8%)
Aged 12 to < 18 years	11,173 (20.9%)	11,652 (22.0%)	12,521 (22.7%)
African American	9708 (18.1%)	9141 (17.3%)	9280 (16.9%)
Alaskan or American Native	105 (0.2%)	114 (0.2%)	111 (0.2%)
Asian/Pacific Islander	1351 (2.5%)	1303 (2.5%)	1205 (2.2%)
White	6678 (12.5%)	6081 (11.5%)	5878 (10.7%)
Hispanic	27,195 (50.8%)	26,039 (49.1%)	25,941 (47.1%)
Ethnic group not reported	8491 (15.9%)	10,322 (19.5%)	12,641 (23.0%)
Medicaid	46,156 (86.2%)	46,368 (87.5%)	48,443 (88.0%)
Children's Health Insurance Program	6841 (12.8%)	6494 (12.3%)	6372 (11.6%)
STAR Kids (includes other government-funded programs such as Supplemental Security Income)	531 (1.0%)	138 (0.3%)	241 (0.4%)

as age on December 14 of the named year. The asthma risk score was based on health services utilization history in the past 12 months. The risk score calculation algorithm is described in Table 1. The risk score can range from -1 to a maximum of 18 points. The risk score was recalculated for these analyses in 2020 to ensure that a consistent scoring algorithm was applied and to account for claims lag.

Exclusion criteria included being 18 years or older at end of baseline year and the presence of a severe chronic disease, including cystic fibrosis, emphysema, other nonasthma severe chronic lung diseases, malignant neoplasms, glycogen storage and other storage diseases, severe neuromuscular diseases, severe brain damage, and major organ transplantation. These severe chronic diseases would likely have complex comorbidities unrelated to asthma. Members who had 8 months or less of health plan membership in the follow-up year and who were not a health plan member in December of the follow-up year were excluded from analyses for that year.

Statistical Methods

Statistical significance of bivariate comparisons for both ordinal and continuous variables was determined using the Wilcoxon rank sum test because their distributions were highly skewed. The χ^2 test was used to determine the statistical significance of differences in proportions. The AUC for receiver operating characteristic curves assessing baseline-year asthma risk score in predicting events in the follow-up year was determined. Logistic regression procedures were used to test for interactions (effect-modifying variables) and to determine odds ratios. Hospitalization and ED visits were reduced to bivariate (yes/no) data for analyses of outcome events in the follow-up year. Statistical significance was accepted as 2-tailed $P < .05$. Statistical analyses were conducted using Stata 10.0 (StataCorp). The study was approved by the institutional review board of Baylor College of Medicine.

RESULTS

We identified 107,811 unique members aged 1 year to less than 18 years with an asthma diagnosis for the years 2016 to 2018, of whom

52,583 (48.8%) self-identified as Hispanic, 17,716 (16.4%) as African American, 12,712 (11.8%) as White, 2559 (2.4%) as Asian/Pacific Islander, and 214 (0.2%) as Native American. A total of 22,027 (20.4%) declined to state a racial/ethnic group. In their first year of health plan membership between 2016 and 2018, 96,899 (89.9%) were enrolled under Medicaid (STAR), 10,542 (9.8%) were enrolled under CHIP, and 357 (0.3%) were enrolled under other government-paid insurance programs such as Supplemental Security Income (STAR Kids). Of those unique members, 53,528 met inclusion criteria for the 2016 baseline year; 53,000 for the 2017 baseline year; and 55,056 for the 2018 baseline year (Table 2). Risk scores ranged from -1 to 15. Of health plan members with an asthma diagnosis, 0.3% to 0.5% had a hospitalization for asthma and 2% to 4% had an ED visit for asthma during the follow-up years of 2017 to 2019.

In bivariate analyses, we found that hospitalization in baseline year was associated with increased risk of both hospitalization and ED visits in the follow-up year. Short-acting β agonist dispensing and number of oral corticosteroid dispensing events in the baseline year were higher in patients who required asthma hospitalization or ED visit in the follow-up year. The number of prescribing providers was higher in the baseline year for patients who required an asthma hospitalization or ED visit in the follow-up year. Similar results were found for each baseline and follow-up year analyzed (eAppendix Table 1 [A-D] [eAppendix available at ajmc.com]).

The Texas Children’s Health Plan asthma risk score was able to predict risk of asthma hospitalization and ED visits in the follow-up year with AUCs for hospitalization in the follow-up year of 0.76, 0.72, and 0.71 (2016, 2017, and 2018 baseline years, respectively) and for ED visits in the follow-up year of 0.69, 0.67, and 0.67 (2016, 2017, and 2018 baseline years, respectively) (eAppendix Table 2 and eAppendix Figure).

We analyzed for differences in effect by subgroups. For asthma risk score predicting asthma hospitalization in the follow-up year, the AUC for the group aged 1 to less than 3 years was lower than for older age groups for baseline years 2016 and 2017 ($P < .05$ for interaction); the difference was not statistically significant for 2018. With stratification by age group, the AUCs for hospitalization in the follow-up year for the group aged 3 to less than 18 years were 0.79, 0.74, and 0.72 for the 2016, 2017, and 2018 baseline years, respectively (Table 3).

The risk score was able to stratify patients with asthma by level of risk of asthma hospitalization. For the 3 baseline/follow-up years analyzed, in the group aged 3 to less than 18 years, relative to those with a risk score of 0 or -1 in the baseline year, the odds ratios for asthma hospitalization in the follow-up year ranged from 2.30 to 3.49 for those with a risk score of 1 or 2 and odds ratios of 130 to 157 for those with a risk score of 9 or greater, with 16% to 18% of patients having an asthma hospitalization in the follow-up year (Table 4). Those with a risk score of 1 or greater accounted for 20% to 23% of pediatric members with asthma, but for those in the group aged 3 to less than 18 years, 59% to 71% of asthma hospitalizations in the follow-up year. For those in the group aged 1 to less than 3 years,

TABLE 3. AUC for Baseline-Year Asthma Risk Score Predicting Events in the Follow-up Year, Analyses Stratified by Age Group

	Aged		P ^a
	1 to <3 years	3 to <18 years	
2016 risk score and 2017 hospitalization AUC (95% CI)	0.693 (0.621-0.766)	0.786 (0.745-0.826)	.03
2017 risk score and 2018 hospitalization AUC (95% CI)	0.646 (0.565-0.727)	0.741 (0.697-0.784)	.04
2018 risk score and 2019 hospitalization AUC (95% CI)	0.669 (0.557-0.781)	0.722 (0.670-0.775)	.4
2016 risk score and 2017 ED visit AUC (95% CI)	0.671 (0.638-0.704)	0.687 (0.638-0.704)	.4
2017 risk score and 2018 ED visit AUC (95% CI)	0.657 (0.626-0.689)	0.673 (0.659-0.687)	.4
2018 risk score and 2019 ED visit AUC (95% CI)	0.674 (0.637-0.712)	0.666 (0.651-0.680)	.7

AUC, area under the receiver operating characteristic curve; ED, emergency department.

^aP value refers to the statistical significance of the difference in AUC between the group aged 1 to <3 years vs the group aged 3 to <18 years for each row.

those with a risk score of 1 or greater accounted for 45% to 55% of asthma hospitalizations (Table 4).

Relative to those with a risk score of 0 or -1 in the baseline year in the group aged 3 to less than 18 years, the odds ratios for asthma ED visit in the follow-up year ranged from 2.84 to 3.15 for those with a risk score of 1 or 2 and from 22.6 to 43.6 for those with a risk score of 9 or greater. For those with a risk score of 9 or greater, 32% to 46% had an ED visit for asthma in the follow-up year. The 20% to 23% of pediatric members with a risk score of 1 or greater accounted for 53% to 56% of ED visits in the follow-up year for the group aged 3 to less than 18 years and 47% to 51% of ED visits in the follow-up year for the group aged 1 to less than 3 years (Table 5).

DISCUSSION

Texas Children’s Health Plan’s asthma high-risk score differentiates patients with low-risk compared with high-risk asthma and stratifies patients by their level of risk for hospitalization and ED visits in the follow-up year. The results are consistent year to year. The risk score was developed and validated in a pediatric Medicaid managed care population. It uses 7 variables that would be available in the claims and pharmacy databases of most managed care organizations. The risk score was built from clinically relevant variables with weights based on what is known about risk for adverse asthma outcomes. Identification of patients at risk for potentially preventable asthma hospitalizations provides opportunity for targeted intervention. Rather than fixed cutoffs, we identified a continuum of risk, which can be useful in clinical decision-making and in resource allocation decisions.

The risk score, along with the factors that make the patient high risk, can be provided as just-in-time information to providers to assist medical decision-making.²⁰ A high-risk asthma panel report

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TABLE 4. OR for Baseline Year Risk Score* Predicting Asthma Hospitalization in the Follow-up Year, Stratified by Age Group

A. Group aged 1 to <3 years					
2016 risk score	n	Hospitalized in 2017, n	OR for 2017 hospitalization	95% CI	Positive predictive value
-1 to 0	7573	25	Reference group		0.003
1 to 2	1552	14	2.75	1.43-5.30	0.009
3 to 4	325	9	8.60	3.98-18.6	0.028
5 to 6	665	26	17.3	5.85-50.9	0.039
7 to 8	18	1	17.8	2.28-138	0.056
9 to 14	12	2	60.4	12.6-290	0.17
2017 risk score	n	Hospitalized in 2018, n	OR for 2018 hospitalization	95% CI	Positive predictive value
-1 to 0	7551	24	Reference group		0.003
1 to 2	1578	9	1.80	0.83-3.88	0.006
3 to 4	228	5	7.03	2.66-18.60	0.022
5 to 6	45	3	22.40	6.50-77.25	0.067
7 to 8	12	1	28.51	3.54-230	0.083
9 to 15	10	2	78.41	15.82-389	0.20
2018 risk score	n	Hospitalized in 2019, n	OR for 2019 hospitalization	95% CI	Positive predictive value
-1 to 0	7323	13	Reference group		0.002
1 to 2	1581	5	1.78	0.64-5.01	0.003
3 to 4	173	4	13.3	4.30-41.2	0.023
5 to 6	43	0	-	-	0
7 to 8	13	1	46.9	5.67-387	0.077
9 to 14	9	2	161	30.5-848	0.22
B. Group aged 3 to <18 years					
2016 risk score	n	Hospitalized in 2017, n	OR for 2017 hospitalization	95% CI	Positive predictive value
-1 to 0	34,054	46	Reference group		0.001
1 to 2	5964	28	3.49	2.18-5.58	0.005
3 to 4	3115	40	9.62	6.29-14.7	0.013
5 to 6	74	4	30.1	18.5-49.0	0.054
7 to 8	109	11	83.0	41.7-165	0.10
9 to 14	63	10	130	62.4-270	0.16
2017 risk score	n	Hospitalized in 2018, n	OR for 2018 hospitalization	95% CI	Positive predictive value
-1 to 0	33,922	56	Reference group		0.002
1 to 2	7043	36	3.11	2.04-4.73	0.005
3 to 4	2096	27	7.89	4.98-12.5	0.013
5 to 6	385	18	29.7	17.3-50.9	0.047
7 to 8	79	8	68.1	31.3-148	0.10
9 to 15	51	9	130	60.2-279	0.18
2018 risk score	n	Hospitalized in 2019, n	OR for 2019 hospitalization	95% CI	Positive predictive value
-1 to 0	35,972	47	Reference group		0.001
1 to 2	7681	23	2.30	1.39-3.78	0.003
3 to 4	1853	21	8.76	5.23-14.7	0.011
5 to 6	294	11	29.7	15.3-57.9	0.037
7 to 8	73	7	81.1	35.3-186	0.096
9 to 14	41	7	157	66.4-373	0.17

OR, odds ratio.

*Risk scores of 9 or greater were collapsed into 1 category due to small numbers of patients with the highest risk scores.

can allow a provider group to reach out to high-risk patients. A health plan can consider the highest-risk patients with asthma for care management and/or home visits.^{3,21}

The risk score reflects the previous 12 months of utilization. A patient who had a risk-defining event will stay on the high-risk list until 12 months have passed even if actions have been taken to bring their asthma under control. Respiratory viral infections are an important trigger of asthma exacerbations^{22,23}; large variation in prevalence of respiratory viral infections (such as seen during the COVID-19 pandemic) may affect predictive ability of the risk score.

We found that the risk score performed better for those aged 3 to less than 18 years than for those aged 1 to less than 3 years. However, in children aged 1 to less than 3 years, the score was able to stratify risk in a clinically important manner.

Our finding that previous hospitalization, previous ED visits, short-acting β agonist overuse, and having multiple prescribing providers are associated with increased risk of asthma ED visit and hospitalization is consistent with previous research.⁹⁻¹⁵

Previous research from Kaiser Permanente found that risk prediction models incorporating hospitalizations, β agonist dispensing, anti-inflammatory dispensing, and number of prescribers performed better than use of 1 parameter alone and, although the asthma case definition differed from our study and their data were from 1994 and 1998, the AUC values obtained were similar to our study's findings.^{17,24}

A previous study examined the predictive ability of the ratio of asthma controller medication to total asthma medication (controller + reliever) dispensing in children aged 4 to 17 years found that those with a medication ratio of less than 0.5 for commercially insured and less than 0.7 for Medicaid-insured patients were at increased risk for asthma exacerbations.²⁵

A prediction model that was developed utilizing data from 1998 and 1999 from Kaiser Permanente Southern California, using backward stepwise logistic regression for potential predictors, identified significant predictors as history of prior-year hospitalizations, β agonist dispensing, anti-inflammatory dispensing, number of prescribers, and age, obtaining an AUC of 0.78 in that model.²⁶

Machine learning algorithms developed using more than 200 variables, utilizing data from Kaiser Permanente Southern California and from Intermountain Healthcare databases, achieved AUCs of 0.82 and 0.86, respectively.^{27,28} Many of the variables used in these models would not be available in the typical health insurance program's databases.

Limitations

Limitations of our study include that the risk score was validated on a managed Medicaid and CHIP-insured pediatric population. Further research is needed to evaluate risk score performance in commercially insured populations. Asthma diagnosis was based on diagnosis codes on insurance claims submitted to the health plan, thus it is likely that there is both overdiagnosis and underdiagnosis by health care providers. We have previously found that patterns of oral corticosteroid dispensing to pediatric members of Texas Children's Health Plan suggest overprescribing by primary care providers.²⁹ We speculate that the oral corticosteroid dispensing criterion may have greater predictive value in communities that are more selective in oral corticosteroid prescribing. Our study excluded those with less than 9 months of health plan membership in the follow-up year. Patients who have difficulty maintaining consistent health plan membership may be at higher risk. Fragmentation of care was assessed by multiple (3 or more) prescribing providers, but some providers may share a practice and such cooperative relationships would not be detected. Systemic corticosteroid medication administered at an ED visit or hospitalization would not be captured. Texas Children's Health Plan uses the asthma risk score to provide feedback to physicians and to prioritize care management interventions, with the asthma high-risk score added as a best practice alert in the Texas Children's Hospital electronic medical record in 2019. Different outcomes might have been observed if the information was not available to providers.

CONCLUSIONS

The Texas Children's Health Plan asthma risk score can identify children with asthma who have an increased risk of asthma ED visits and

TABLE 5. OR for Baseline-Year Risk Score^a Predicting ED Visit for Asthma in the Follow-up Year, Stratified by Age Group

A. Group aged 1 to <3 years					
2016 risk score	n	ED visit in 2017, n	OR for 2017 ED visit	95% CI	Positive predictive value
-1 to 0	7573	137	Reference group		0.02
1 to 2	1552	76	2.79	2.10-3.72	0.05
3 to 4	325	31	5.72	3.81-8.60	0.10
5 to 6	74	19	18.8	10.8-32.4	0.26
7 to 8	18	7	34.5	13.2-90.4	0.39
9 to 14	12	7	76.0	23.8-242	0.58
2017 risk score	n	ED visit in 2018, n	OR for 2018 ED visit	95% CI	Positive predictive value
-1 to 0	7551	149	Reference group		0.02
1 to 2	1578	83	2.76	2.10-3.63	0.05
3 to 4	228	32	8.11	5.40-12.2	0.41
5 to 6	45	13	20.2	10.4-39.2	0.29
7 to 8	12	3	16.6	4.4-61.8	0.25
9 to 15	10	2	12.4	2.6-59.0	0.20
2018 risk score	n	ED visit in 2019, n	OR for 2019 ED visit	95% CI	Positive predictive value
-1 to 0	7323	99	Reference group		0.01
1 to 2	1581	65	3.13	2.28-4.30	0.04
3 to 4	173	22	10.6	6.52-17.3	0.13
5 to 6	43	7	14.2	6.16-32.7	0.16
7 to 8	13	4	32.4	9.82-107	0.30
9 to 14	9	2	20.8	4.28-101	0.22
B. Group aged 3 to <18 years					
2016 risk score	n	ED visit in 2017, n	OR for 2017 ED visit	95% CI	Positive predictive value
-1 to 0	34,054	659	Reference group		0.02
1 to 2	5964	349	3.15	2.76-3.60	0.06
3 to 4	3115	276	4.93	4.26-5.67	0.09
5 to 6	665	137	13.1	10.7-16.1	0.21
7 to 8	109	37	26.0	17.4-39.0	0.34
9 to 14	67	31	43.6	26.8-71.0	0.46
2017 risk score	n	ED visit in 2018, n	OR for 2018 ED visit	95% CI	Positive predictive value
-1 to 0	33,922	770	Reference group		0.02
1 to 2	7043	436	2.84	2.52-3.20	0.06
3 to 4	2096	266	6.26	5.40-7.25	0.13
5 to 6	385	112	17.7	14.0-22.3	0.29
7 to 8	79	29	25.0	15.7-39.7	0.37
9 to 15	51	22	32.7	18.7-57.1	0.43
2018 risk score	n	ED visit in 2019, n	OR for 2019 ED visit	95% CI	Positive predictive value
-1 to 0	35,972	725	Reference group		0.02
1 to 2	7681	437	2.93	2.60-3.31	0.06
3 to 4	1853	228	6.82	5.83-7.98	0.12
5 to 6	294	66	14.1	10.6-18.7	0.22
7 to 8	73	28	30.3	18.8-48.8	0.38
9 to 14	41	13	22.6	11.6-43.8	0.32

ED, emergency department; OR, odds ratio.

^aRisk scores of 9 or greater were collapsed into 1 category due to small numbers of patients with the highest risk scores.

hospitalization in the following year. The risk score stratifies patients by level of risk. In predicting hospitalization in the follow-up year, the risk score performs better in the group aged 3 to less than 18 years than in the group aged 1 to less than 3 years. This knowledge can be used to inform targeted asthma quality improvement efforts. ■

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eAppendix Table 1. Bivariate Analyses

A. Hospitalizations and emergency department (ED) visits for asthma as baseline year events associated with follow up year events. (Percentages reported as row percent)

# Hospital Admissions 2016	Hospitalized 2017	ED visit 2017	P value
0 (N=53,208)	179 (0.3%)	1,665 (3.1%)	Reference group
1 (N=291)	32 (11.0%)	85 (29.2%)	<0.001
>=2 (N=29)	5 (17.2%)	16 (55.2%)	<0.001

p<0.0001

# Hospital Admissions 2017	Hospitalized 2018	ED visit 2018	P value
0 (N=52,700)	172 (0.3%)	1,844 (3.5%)	Reference group
1 (N=275)	20 (7.3%)	63 (22.9%)	<0.001
>=2 (N=25)	6 (24.0%)	10 (40.0%)	<0.001

p<0.0001

# Hospital Admissions 2018	Hospitalized 2019	ED visit 2019	P value
0 (N=54,769)	119 (0.22%)	1629 (3.0%)	Reference Group
1 (N=258)	14 (5.4%)	57 (22.1%)	<0.001
>=2 (N=29)	8 (27.6%)	10 (34.5%)	<0.001

p<0.0001

# Emergency Department Visit 2016	Hospitalized 2017	ED visit 2017	P value
0 (N=51,125)	153 (0.3%)	1,278 (2.5%)	Reference Group
1-2 (N=2,329)	59 (2.5%)	447 (19.2%)	<0.001
>=3 (N=74)	4 (5.4%)	41 (55.4%)	<0.001

p<0.0001

# Emergency Department Visit 2017	Hospitalized 2018	ED visit 2018	P Value
0 (N=50,697)	149 (0.3%)	1,401 (2.8%)	Reference Group
1-2 (N=2,212)	39 (1.8%)	464 (21.0%)	<0.001
>=3 (N=91)	10 (11%)	52 (57.1%)	<0.001

p<0.0001

# Emergency Department Visit 2018	Hospitalized 2019	ED visit 2019	P Value
0 (N=52,634)	99 (0.2%)	1,209 (2.3%)	Reference Group
1-2 (N=2342)	37 (1.6%)	456 (19.5%)	<0.001
>=3 (N=80)	5 (6.3%)	31 (38.7%)	<0.001

B. Association of short acting β agonist (SABA) canister equivalent dispensing in baseline year with adverse asthma outcomes in follow up year.

#SABA canister equivalents dispensed 2016	Hospitalized 2017 (%)	ED visit 2017	P value
<4 (N=49,961)	174 (0.35%)	1,494 (3.0%)	Reference Group
≥ 4 and < 6 (N=3,567)	42 (1.2%)	272 (7.6%)	<0.001
≥ 6 and < 10 (N=1,915)	31 (1.6%)	176 (9.2%)	<0.001
≥ 10 (N=774)	17 (2.2%)	90 (11.6%)	<0.001

#SABA canister equivalents dispensed 2017	Hospitalized 2018 (%)	ED visit 2018	P value
<4 (N= 49,669)	172 (0.35%)	1,620 (3.3%)	Reference Group
≥ 4 and < 6 (N=3,331)	26 (0.78%)	297 (8.9%)	<0.001
≥ 6 and < 10 (N=1,953)	25 (1.3%)	220 (11.3%)	<0.001
≥ 10 (N=759)	22 (2.9%)	99 (13.0%)	<0.001

#SABA canister equivalents dispensed 2018	Hospitalized 2019 (%)	ED visit 2019	P value
<4 (N=51,812)	122 (0.24%)	1,462 (2.8%)	Reference Group
≥ 4 and < 6 (N=3,244)	19 (0.59%)	234 (7.2%)	<0.001
≥ 6 and < 10 (N=1,788)	18 (1.0%)	175 (9.8%)	<0.001
≥ 10 (N=678)	13 (1.9%)	78 (11.5%)	<0.001

C. Oral corticosteroid dispensing events and hospitalizations in follow up year. (Percentages reported as row percent)

# Oral Corticosteroid Dispensing Events 2016	Hospitalized 2017	ED visit 201	P value
0 (N=30,290)	69 (0.2%)	799 (2.6%)	Reference group
1 (N=17,497)	65 (0.4%)	551 (3.2%)	0.001
2 (N=3,828)	38 (1.0%)	238 (6.2%)	<0.001
>=3 (N=1,875)	44 (2.3%)	178 (9.5%)	<0.001

# Oral Corticosteroid Dispensing Events 2017	Hospitalized 2018	ED visit 2018	P value
0 (N=29,285)	87 (0.3%)	955 (3.3%)	Reference Group
1 (N=18,073)	54 (0.3%)	541 (3.0 %)	1.0
2 (N=3,806)	27 (0.7%)	245 (6.4%)	<0.001
>=3 (N=1,836)	30 (1.6%)	177 (9.6%)	<0.001

# Oral Corticosteroid Dispensing Events 2018	Hospitalized 2019	ED visit 2019	P value
0 (N=31,107)	58 (0.2%)	853 (2.7%)	Reference Group
1 (N=17,906)	40 (0.2%)	516 (2.9%)	0.4
2 (N=3,961)	23 (0.6%)	173 (4.4%)	<0.001
>=3 (N=2,082)	20 (1.0%)	154 (7.4%)	<0.001

D. Risk of hospitalizations and emergency department visits by number of prescribing providers.

Number Prescribing Providers 2016	Hospitalized 2017 N (%)	ED visit 2017 N (%)	P value
<3 (N=48,883)	134 (0.27%)	1,283 (2.6%)	Reference Group
>=3 (N=4,645)	82 (1.77%)	483 (10.4%)	<0.001

Number Prescribing Providers 2017	Hospitalized 2018 N (%)	ED visit 2018 N (%)	P value
<3 (N=49,055)	134 (0.27%)	1,429 (2.9%)	Reference Group
>=3 (N=3,945)	64 (1.62%)	488 (12.4%)	<0.001

Number Prescribing Providers 2018	Hospitalized 2019 N (%)	ED visit 2019 N (%)	P value
<3 (N=50,507)	88 (0.17%)	1,228 (2.4%)	Reference Group
>=3 (N=4,549)	53 (1.17%)	468 (10.3%)	<0.001

eAppendix Table 2. Area Under the Receiver Operating Characteristic Curve (AUC)

Outcome: Hospitalization for asthma in the follow up year

Predictor: Baseline year Risk Score

	N of observations	AUC	95% CI
2016 Risk Score	53,528	0.760	0.725-0.796
2017 Risk Score	53,000	0.719	0.680-0.758
2018 Risk Score	55,056	0.713	0.665-0.760

Outcome: Emergency Department visit for asthma in the follow up year

Predictor: Baseline year Risk

	N of observations	AUC	95% CI
2016 Risk Score	53,528	0.685	0.672-0.698
2017 Risk Score	53,000	0.671	0.659-0.684
2018 Risk Score	55,056	0.667	0.654-0.681

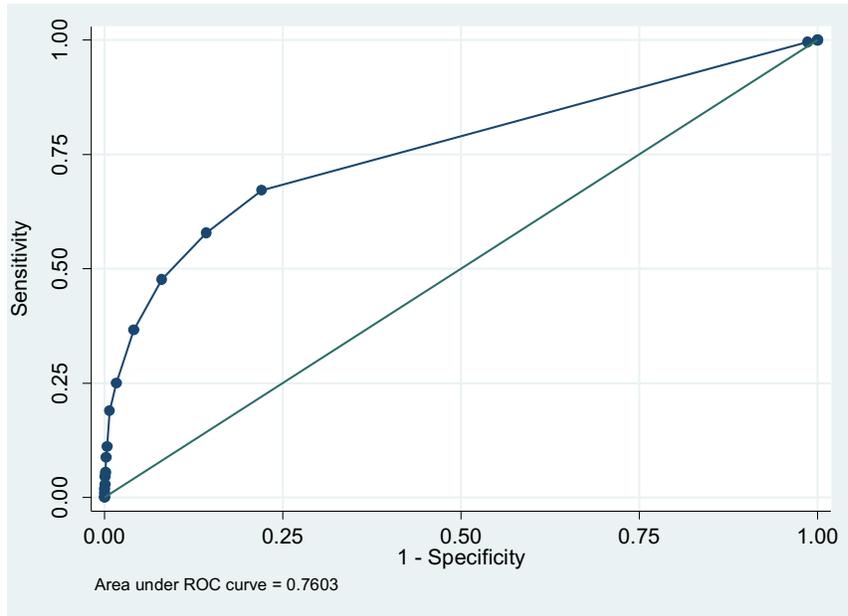
AUC: Area under the receiver operating characteristic curve

CI: Confidence Interval

eAppendix Figure. Receiver Operating Characteristic Curves

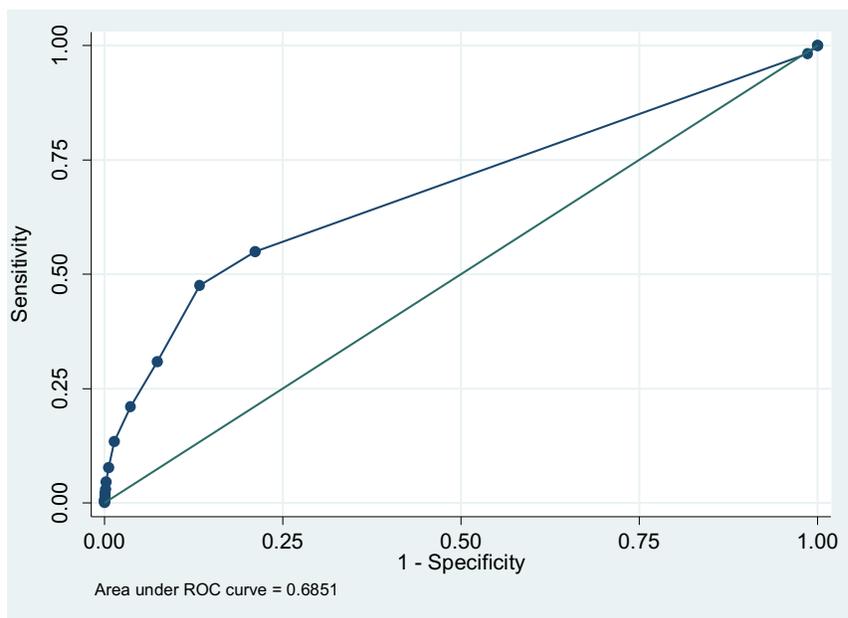
Outcome: Hospitalization for asthma 2017

Classification: 2016 Texas Children's Health Plan Asthma Risk Score



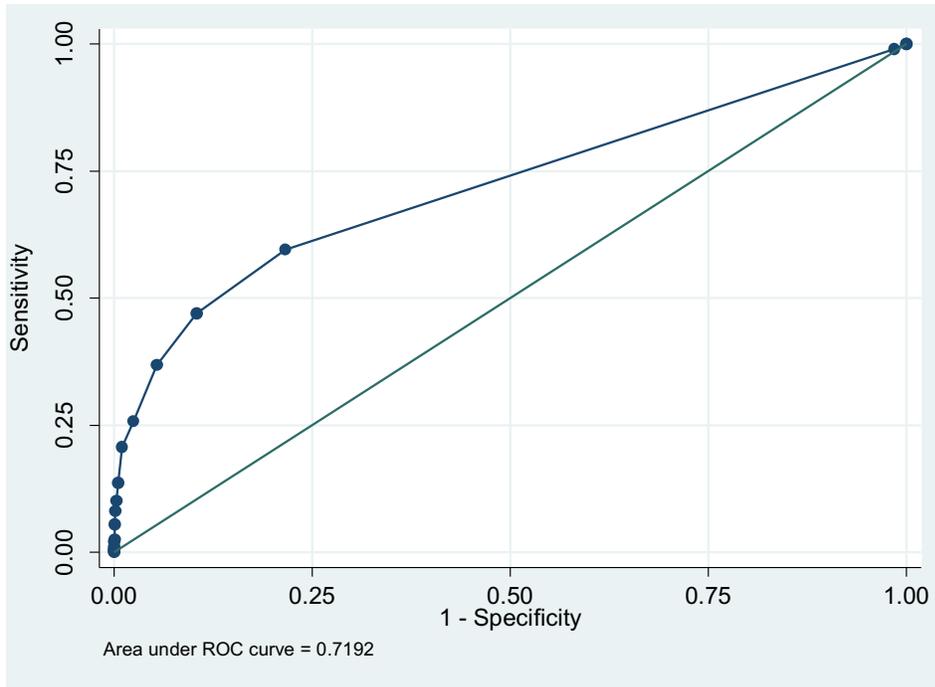
Outcome: Emergency Department visit for asthma 2017

Classification: 2016 Texas Children's Health Plan Asthma Risk Score



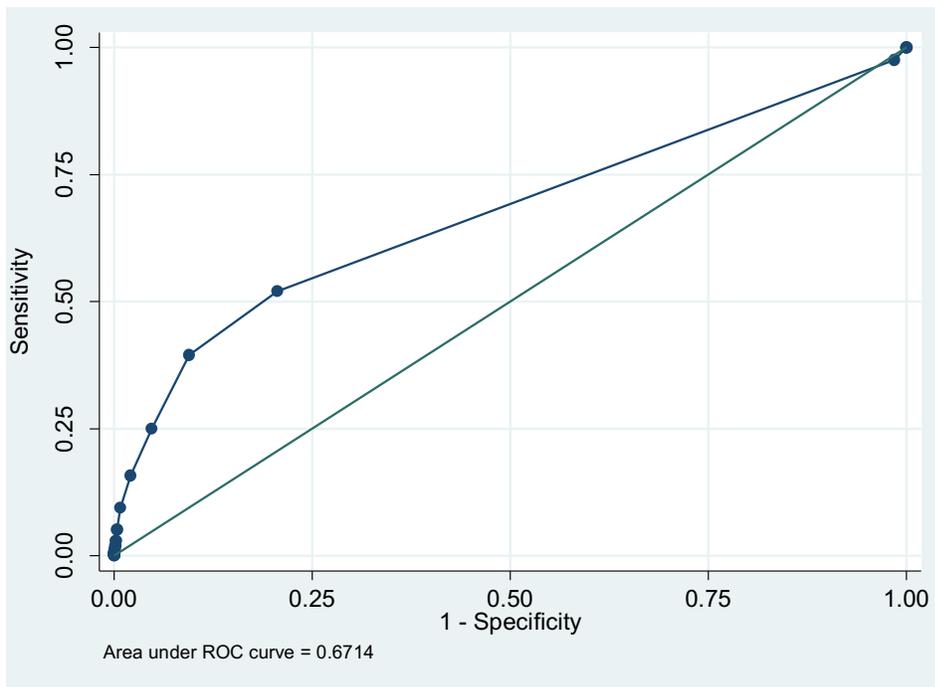
Outcome: Hospitalization for asthma 2018

Classification: 2017 Texas Children's Health Plan Asthma Risk Score



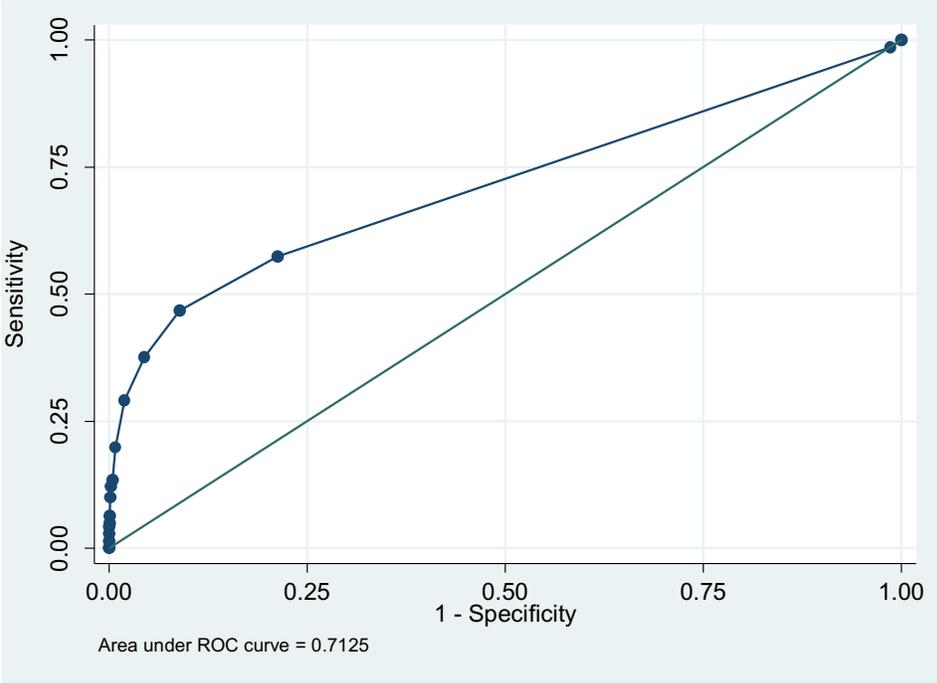
Outcome: Emergency Department visit for asthma 2018

Classification: 2017 Texas Children's Health Plan Asthma Risk Score



Outcome: Hospitalization for asthma 2019

Classification: 2018 Texas Children's Health Plan Asthma Risk Score



Outcome: Emergency Department visit for asthma 2019

Classification: 2018 Texas Children's Health Plan Asthma Risk Score

