Asthma Vital Signs at Triage

Home or Admission (ASTHmA)

Timothy Horeczko, MD, MSCR and Garen J. Wintemute, MD, MPH

Objectives: Commonly used acute asthma scoring systems assess severity of symptoms, whereas other clinical models aim to predict hospitalization; all rely on a measure of response to treatment and use the same criteria across age ranges. This may not reflect a child's changing physiology and response to illness as he or she grows older.

This study aimed to find age-specific objective predictors of hospitalization readily known at triage. The goal is to identify rapidly those who will likely need admission regardless of treatment administered or response to aggressive treatment in the emergency department (ED).

Methods: Children between 1 and 18 years of age with a final primary ED *International Classification of Diseases, Ninth Revision*, diagnosis of asthma or asthma-related spectrum of disease were studied using data from the National Hospital Ambulatory Medical Care Survey. The primary outcome was hospital admission (observation unit, ward, monitored, or pediatric intensive care unit).

Triage vital signs, mode of arrival, recent visits, emergency severity index score, as well as demographic and socioeconomic factors were incorporated into age-specific forward-selection multiple logistic regression models.

Results: In 2,454,983 ED visits for asthma or reactive airway disease among children 1 to 18 years of age, patterns of vital sign predictors for admission varied by age group. Across all ages, diastolic hypotension at triage was an early, consistent, independent predictor of admission, especially in 1- to 3-year-olds (odds ratio, 6.27; 95% confidence interval, 6.01–6.54) and 3- to 6-year-olds (odds ratio, 17.95; 95% confidence interval, 16.80–19.17).

Conclusions: Age-specific assessment is important in the evaluation of acute asthma or reactive airway exacerbation. Diastolic hypotension may serve as an early warning indicator of severity of disease and need for hospitalization. Variability by age group in vital sign predictor for admission calls for further development or refinement of age-specific asthma assessment tools.

Key Words: acute asthma, emergency department triage, asthma scores

(*Pediatr Emer Care* 2013;29: 175–182)

Clinicians are challenged daily with the accurate assessment of children experiencing acute exacerbations of asthma or reactive airway disease. Children present with varied baseline symptoms, tempo of progression of symptoms, recent treatment administered, comorbidities, and other environmental and resource backgrounds. Rapid identification of those at risk for deterioration or needing continuous treatment is the goal of most asthma severity scores.[1–3] Many in part rely on clinical features that may suffer from poor interrelater reliability[4] or simply from the practical notion that there is a natural lag in time between initial triage and assessment by the treating clinician.

From the Department of Emergency Medicine, University of California Davis Medical Center, University of California Davis School of Medicine, Sacramento, CA.
Disclosure: The authors declare no conflict of interest.
Reprints: Timothy Horeczko, MD, MSCR, Department of Emergency Medicine, 4150 V St, PSSB 2100, Sacramento, CA 95817 (e-mail: timothy.horeczko@ucdmc.ucdavis.edu).

ISSN: 0749-5161

Commonly used scoring systems such as the Pediatric Asthma Severity Score, Pulmonary Index, Pediatric Respiratory Assessment Score, Pulmonary Score, and the RAD score (respiratory rate; accessory muscle use; decreased breath sounds) assess severity of symptoms and response to treatment, not necessarily need for admission.[5–11] Other clinical models aim to predict hospitalization, focusing on response to treatment.[12,13] All previously constructed and studied models—in the interest of ease of use—use the same criteria across age ranges.[5–13] This runs contrary to the inherent age-related changes children experience in their respiratory and cardiovascular physiology and response to illness.[14]

Objective measurements and information readily available at first contact in triage include vital signs, mode of arrival, and historical information such as recent care or hospitalization. Although sources differ slightly in the exact range of normal pediatric vital signs, major pediatric texts and courses such as Pediatric Advanced Life Support, Advanced Pediatric Life Support, Pediatric Education for Prehospital Professionals, and Emergency Nursing Pediatric Course reflect consensus standards (Table 1).[15–18]

This study aimed to find objective, age-specific predictors of hospitalization readily known at triage. The goal was to identify rapidly those who will likely need admission regardless of treatment administered or response to aggressive treatment in the emergency department (ED).

METHODS

The protocol for the conduct of this study was approved by the institutional review board at the University of California at Davis and was granted exemption from review.

Study Subjects and Setting

Eligible children were between 1 and 18 years of age seen in an ED in the United States with an ED primary diagnosis of asthma or asthma-related spectrum of disease (*International Statistical Classification of Diseases, Ninth Revision, Clinical Modification*, diagnosis codes 493.00–493.92), which captures reactive airway disease. Infants younger than 1 year were excluded owing to the uncertainty of asthma or reactive airway disease as a diagnosis. This method and coding scheme specifically exclude bronchiolitis and croup.

The population studied was based on ED visits from 2007 to 2009 in the National Hospital Ambulatory Medical Care Survey (NHAMCS). National Hospital Ambulatory Medical Care Survey is a national, representative, 4-stage probability sample of visits to US EDs.[19] The time frame was chosen because 2007 was the first year to include all vital signs in triage (heart rate, respiratory rate, blood pressure, temperature, and pulse oximetry); 2009 is the most recent year for which data were available. This period includes 3 years of patient visits as

TABLE 1. Normal Pediatric Vital Signs as Applied to the Study Population

Age	Heart Rate, beats per minute*	Blood Pressure, mm Hg*	Respiratory Rate, breaths per minute*	Temperature, °F[†]	Pulse Oximetry, %[†]
1–3 y	70–110	90–105/55–70	20–30	96–100.4	95–100
3–6 y	65–110	95–110/60–75	20–25	96–100.4	95–100
6–12 y	60–95	100–120/60–75	14–22	96–100.4	95–100
12 y and older	55–85	110–135/65–85	12–18	96–100.4	95–100

*Modified from Mathers and Frankel.[16]
[†]Modified from Gilboy et al.[15]

TABLE 2. Triage Characteristics of Children Presenting With Acute Asthma (n = 2,454,983)

	1–3 y				3–6 y			
	Discharged (n = 550,542)		Admitted (n = 41,402)		Discharged (n = 462,025)		Admitted (n = 31,264)	
	n	%	n	%	n	%	n	%
Triage vital signs								
Tachycardia	465,915	84.6	38,127	92.1	349,312	75.6	31,264	100.0
Systolic hypotension	361,000	65.6	30,104	72.7	268,312	58.1	16,101	54.5
Diastolic hypotension	382,446	69.5	37,231	89.9	265,740	57.5	20,229	64.7
Tachypnea	293,643	53.3	24,426	59.0	251,744	54.5	30,945	99.0
Hypothermia or fever	82,997	15.1	10,668	25.8	42,233	9.1	319	1.0
Hypoxemia	222,478	40.4	12,372	29.9	159,513	34.5	7,470	23.9
Arrival by EMS								
Yes	360,912	65.6	33,354	80.6	5,052	2.9	26,199	80.3
No	189,630	34.4	8,048	19.4	153,597	88.9	5,065	16.2
Unknown	0	0.0	0	0.0	0	0.0	0	0.0
Blank	0	0.0	0	0.0	14,064	8.1	0	0.0
Male sex	404,256	73.4	28,890	69.8	310,465	67.2	25,110	80.3
ESI triage level*								
Level 1: immediate	12,424	3.4	0	0.0	7,769	2.7	0	0.0
Level 2: 1–14 min	53,056	14.70	0	0.0	41,805	14.5	2,857	10.9
Level 3: 15–60 min	133,093	36.9	26,257	78.7	135,627	46.9	23,023	87.9
Level 4: >1–2 h	50,004	13.9	1,865	5.6	55,175	19.1	0	0.0
Level 5: >2–24 h	16,196	4.49	1,167	3.5	0	0.0	0	0.0
Unknown	95,817	26.6	4,065	12.2	46,732	16.2	319	1.2
No triage	322	0.1	0	0.0	2,204	0.8	0	0.0
Seen in same ED in the last 72 h								
Yes	6,614	1.2	0	0.0	6,406	1.4	0	0.0
No	427,834	77.7	33,725	81.5	357,062	19.0	25,918	82.9
Unknown	103,137	18.7	7,677	18.5	87,975	19.0	5,346	17.1
Blank	12,957	2.4	0	0.0	10,582	2.3	0	0.0
Discharged from any hospital within 7 days								
Yes	952	0.2	0	0.0	5,192	1.1	0	0.0
No	309,186	56.2	13,051	31.5	254,903	55.2	8,865	28.4
Unknown	227,447	41.3	28,351	68.5	191,348	41.4	22,399	71.6
Blank	12,957	2.4	0	0.0	10,582	2.3	0	0.0
Insurance status/expected source of payment								
Private insurance	195,215	35.5	7,461	18.0	206,104	44.6	11,208	35.9
Medicaid	221,298	40.2	29,026	70.1	195,172	42.2	20,299	64.9
Medicare	10,679	1.9	0	0.0	10,679	2.3	0	0.0
Self-pay	70,671	12.8	2,931	7.1	27,433	6.2	38	0.1
Other payment	19,550	3.6	0	0.0	0	0.0	0	0.0
No charge	11,399	2.1	1,167	2.8	0	0.0	0	0.0
Unknown source of payment	55,526	10.1	3,746	9.1	0	0.0	0	0.0
Any ancillary testing done	0	0.0	30,000	72.5	206,336	44.7	0	0.0
Total visits in this category	550,542	93.0	41,402	7.0	462,025	93.7	31,264	6.3

*NHAMCS-defined time goals for ESI levels.

recommended by NHAMCS to ensure reliability and stability of the estimation procedures.[19–22]

Measurements and Analysis

The primary outcome—admission to the hospital—included those patients admitted directly to a hospital bed (ward, monitored, or pediatric intensive care) or to an observation unit.

Predictor variables were chosen based on clinical relevance, literature support, and availability at triage. Triage vital signs, mode of arrival, recent medical attention or admission for asthma-related conditions, emergency severity index (ESI) score, and demographic and socioeconomic factors (eg, sex, insurance status, access to care) underwent univariate analysis. Candidate predictors with a P value of 0.15 or less in univariate analysis were considered for entry into the prediction model. Predictors were incorporated into an investigator-built forward-selection multiple logistic regression model with a manual stay criterion of $P < 0.05$.

It was not the objective of this study to find a stand-alone model to replace thorough clinical assessment to predict hospitalization based solely on triage findings; nevertheless, in the interest of a robust approach, a hierarchically well-formulated model[23,24] was constructed for each age group. The goal of the hierarchically well-formulated model was to control simultaneously for all available triage parameters, to generate adjusted odds ratios for admission, that is, to find early, independent,

6–12 y				12–18 y			
Discharged (n = 806,273)		Admitted (n = 76,426)		Discharged (n = 416,407)		Admitted (n = 70,644)	
n	%	n	%	n	%	n	%
613,183	76.1	49,843	65.2	313,255	24.8	69,823	98.8
277,506	34.4	34,168	44.7	82355	19.8	12,520	17.7
330,476	41.0	37,912	49.6	117,116	28.1	21,456	30.4
368,138	45.7	42,752	55.9	285,678	68.6	60,066	85.0
124,783	15.5	26,974	35.3	20,260	4.9	14,652	20.7
272,377	33.8	27,362	35.8	81,744	19.6	30,343	43.0
22,888	6.7	3,744	9.9	271,866	65.3	63,808	90.3
292,018	84.9	19,755	52.1	144,541	34.7	6,836	9.7
23,934	7.0	14,398	38.0	0	0.0	0	0.0
5,038	1.5	0	0.0	0	0.0	0	0.0
568,055	70.5	64,271	84.1	182,472	43.8	52,015	73.6
14,958	3.2	3,776	9.8	18,341	6.8	0	0.0
123,923	26.8	1,473	3.8	62,308	22.9	17,786	27.9
138,131	29.9	11,735	30.5	104,735	38.5	30,531	47.9
98,156	21.2	5,531	14.4	27,431	10.1	7,698	12.1
7,054	1.5	3,950	10.3	16,694	6.1	0	3.4
80,173	17.3	5,870	15.2	41,250	15.2	7,793	12.2
0	0.0	6,194	16.1	1,107	0.4	0	0.0
24,520	3.0	3,744	4.9	3,903	0.9	0	0.0
573,467	71.1	51,280	67.1	288,334	69.2	47,352	67.0
195,442	24.2	21,402	28.0	121,272	29.1	23,292	33.0
12,844	1.6	0	0.0	2,898	0.7	0	0.0
12,094	1.5	3,776	4.9	7,140	1.7	0	0.0
392,613	48.7	47,561	62.2	204,836	49.2	24,655	34.9
388,722	48.2	25,089	32.8	199,208	47.8	45,989	65.1
12,844	1.6	0	0.0	5223	1.3	0	0.0
265,558	32.9	26,160	34.2	170,756	41.0	27,064	38.3
372,438	46.2	19,705	25.8	165,467	39.7	30,831	43.6
839	0.1	0	0.0	0	0.0	0	0.0
145,084	18.0	3,776	4.9	61,212	14.7	6,836	9.7
7,042	0.9	0	0.0	5,277	1.3	0	0.0
4,741	0.6	0	0.0	7,645	1.8	0	0.0
64,017	7.9	29,406	38.5	19,211	4.6	2,167	3.1
343,935	42.7	72,650	95.1	208,628	50.1	48,429	68.6
806,273	91.3	76,426	8.7	416,407	85.5	70,644	14.5

TABLE 3. Triage Vital Signs in Subsequently Discharged and Admitted Patients Presenting With Acute Asthma

	1–3 y				3–6 y			
	Discharged		Admitted		Discharged		Admitted	
Triage vital signs	Mean	95% CI for Mean	Mean	95% CI for Mean	Mean	95% CI for Mean	Mean	95% CI for Mean
Heart rate, beats per minute	139	134.9–142.4	140	130.9–148.8	128	124.1–131.8	138	127.4–148.9
Systolic blood pressure, mm Hg	109	104.1–113.6	101	92.8–110.0	110	106.2–112.9	104	97.5–110.5
Diastolic blood pressure, mm Hg	67	63.1–71.2	57	41.3–71.9	67	64.7–70.2	63	49.5–75.7
Respirations per minute	35	32.7–37.0	39	30.6–46.6	28	27.1–29.9	41	32.5–48.5
Temperature, °F	99.1	98.80–99.31	99.7	98.84–100.6	98.7	98.51–98.90	98.8	98.40–110.51
Pulse oximetry, %	97	96.4–97.4	96	94.8–97.5	96	94.0–97.6	93	85.2–100.0

objective predictors of admission. Analyses were conducted using SAS software version 9.3 (SAS Institute Inc, Cary, NC).

Each age range was considered separately, and a separate model was built for each. In every age range, vital signs were considered main effects, and other triage parameters were assessed as covariates. Each vital sign (heart rate, systolic blood pressure, diastolic blood pressure, respiratory rate, pulse oximetry, and temperature) was dichotomized into normal or abnormal, based on age-specific standards (Table 1). Because these models were the predictors of interest, a 2-tiered approach to model building was made. Tier 1 included all vital signs added simultaneously to the model. All combinations of vital signs were assessed for 2-way interactions (eg, fever and pulse rate, fever and tachypnea, etc).

The second tier of the model-building process started with the predictors in the first-tier model and added the next likely important covariate (arrival by emergency medical services, socioeconomic markers, resource use parameters, and sex) one at a time in a manual forward selection. The predefined process was as follows: if the deviance, D (-2 log likelihood), changed significantly with the addition of the candidate covariate and its corresponding β-coefficient was significant, the covariate was included in the model; if not (ie, if the addition of that covariate did not affect the fit), it was excluded in a backward deselection. The ultimate goal was to minimize D in the final model in each group; each age-specific model was then assessed with the Hosmer-Lemeshow goodness-of-fit test. The final age-specific models provided adjusted odds ratios (ORs) for admission for each vital sign at triage.

RESULTS

Years 2007 to 2009 in NHAMCS represent 2,454,983 ED visits for asthma or reactive airways disease in children aged 1 to 18 years. Overall, there were 219,736 hospital admissions (9.0 %) and 2,235,247 were discharged home (91.0%). Admission rates by age group ranged from 6.3% to 14.5% (Table 2). In each age group, simple descriptive statistics (Table 3) demonstrate overlap in the mean values of vital signs for discharged versus admitted children.

In contrast, multiple logistic regression models reveal distinct vital sign predictors for admission that vary by age group (Table 4). Across age ranges, the vital signs in triage most predictive of admission included diastolic hypotension and tachycardia (Table 4). Abnormal respiratory rate was highly variable by age as a predictor for admission. Abnormal pulse oximetry in triage was an unreliable predictor of admission across age ranges. Tachycardia was found to display a trend of increasing importance in admission with increasing age. Patterns of strength of OR and combination of abnormalities also vary by age group (Fig. 1).

Diastolic hypotension in triage was a consistently reliable independent predictor of admission across all age ranges; it was especially predictive in patients 6 years or younger.

DISCUSSION

Early recognition of severity of disease is a primary goal in acute care and emergency medicine. In the pediatric population, this is markedly important for 2 reasons: (1) children compensate well to physiologic stress until they experience an often abrupt (and at times unexpected) deterioration and (2) they do not tolerate insufficient oxygenation. Although many asthma scores do well to balance objective findings with subjective clinical features, the general focus is on progression or improvement of symptoms. This study aimed to identify early objective findings that are independently predictive of admission, regardless of the treatment rendered.

Assessment of an acute asthma exacerbation has 2 components as follows: the static (or initial) assessment to determine the severity of the presentation and dynamic assessments to follow response to treatment.[25] Although symptoms and history may be helpful in the initial assessment, it is important to note that a significant portion of asthmatics have a poor perception of dyspnea. These patients are at a significantly higher risk of hospitalization, near-fatal asthma exacerbations, and death.[25,26] Furthermore, a child's symptoms are often obtained through a third-party filter—the caregiver. The child may be too young, frightened, or disabled to answer questions, especially on initial presentation.[27,28] Objective and reproducible assessments help to fill this gap.[28]

Accordingly, when following a child's response to treatment and making a disposition decision, it is important to consider the patient's initial presentation.[25] The child may be improving on objective measures and appearing better while undergoing aggressive ED management, but the underlying disease that brought him to the ED will for the most part continue when he or she is at home. Since the inflammatory cascade and bronchospasm will persist[1] (albeit now ameliorated with ED treatment), the child's disease state after disposition (either at home or in hospital) will be likely somewhere between his static (initial) assessment and his final (at disposition) dynamic assessment. Objective documentation of disease severity on presentation can be a powerful tool in an informed disposition decision, especially when used as a complement to the previously mentioned and established scoring systems.

This study found certain triage vital signs that, if abnormal, independently predicted admission for asthma or reactive

6–12 y				12–18 y			
Discharged		Admitted		Discharged		Admitted	
Mean	95% CI for Mean	Mean	95% CI for Mean	Mean	95% CI for Mean	Mean	95% CI for Mean
111	107.7–114.5	119	101.2–135.9	101	100.0–104.4	105	95.9–113.7
115	113.0–117.4	119	108.8–128.8	125	122.1–128.4	126	115.2–136.5
69	67.5–71.1	64	56.5–71.5	75	72.8–77.8	70	63.0–77.0
24	23.2–25.2	27	23.7–30.5	22	20.5–22.9	22	20.0–23.9
98.7	98.46–98.86	98.9	98.11–99.60	98.4	98.21–98.62	98.6	98.00–99.16
96	95.3–96.7	95	92.1–97.4	97	95.6–97.7	96	94.3–98.4

airway disease. Most notable was the finding that diastolic hypotension in triage is a strong predictor of admission for asthma. Diastolic hypotension in asthma may be an indicator of one or both of the following: (*a*) widened pulse pressure[16,29] or (*b*) a marker for recent substantial albuterol use.[30,31]

Given the first explanation, diastolic hypotension in triage could serve as a warning to the clinician to search for alternative and potentially life-threatening concomitant causes of widened pulse pressure, such as anemia, dehydration, heart disease (congenital or acquired), and sepsis.[16] Noting the triage diastolic blood pressure may serve as a clinical "second chance" to identify children who may have an unrecognized significant comorbidity and thus affect the appropriateness of outpatient management. This is especially compelling owing to the common nature of asthma exacerbation in the ED and the tendency to anchor prematurely to a conventional diagnosis, treatment plan, and disposition.[30,31]

Diastolic hypotension in asthma exacerbation may be simply a marker of disease severity. Sicker children will likely have tried medication at home before arriving to the ED. Large doses of albuterol have been shown to cause diastolic hypotension in children.[32,33] This finding highlights the importance of

TABLE 4. Odds* of Admission by Abnormal Vital Sign and Age of Children Presenting With Acute Asthma

	1–3 y†		3–6 y‡		6–12 y§		12–18 y‖	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Main effects								
Tachycardia	2.40	2.31–2.50	#	#	0.57	0.56–0.58	20.33	18.91–21.86
Systolic hypotension	0.47	0.45–0.48	0.43	0.41–0.44	1.66	1.61–1.72	0.59	0.57–0.61
Diastolic hypotension	6.27	6.01–6.54	17.95	16.80–19.17	1.10	1.06–1.13	1.29	1.26–1.32
Tachypnea	1.04	1.02–1.06	47.30	42.32–52.86	2.48	2.43–2.52	0.74	0.72–0.76
Hypothermia or fever	2.06	2.01–2.12	0.14	0.12–0.16	3.73	3.66–3.79	6.84	6.60–7.08
Hypoxemia	0.77	0.76–0.79	0.14	0.13–0.15	0.84	0.83–0.86	1.10	1.08–1.13
Covariates								
Male sex	1.42	1.38–1.45	¶	¶	1.94	1.90–1.98	4.50	4.41–4.60
Resource use parameters								
Arrival by EMS	2.05	2.00–2.11	¶	¶	#	#	7.02	6.82–7.24
ESI Level 1 or 2	#	#	¶	¶	1.02	1.00–1.04	#	#
Seen in last 72 h	**	**	**	**	#	#	#	#
Discharged <7 d before	**	**	**	**	#	#	**	**
Insurance status								
Private insurance	0.87	0.84–0.90	#	#	0.64	0.63–0.65	2.48	2.41–2.55
Medicaid	3.30	3.20–3.40	#	#	0.29	0.29–0.30	2.12	2.07–2.18
Medicare	**	**	**	**	¶	¶	**	**
Self-pay	1.26	1.20–1.31	¶	¶	#	#	#	#

*Adjusted OR values were generated by the simultaneous entry of covariates in age-specific logistic regression models (A, B, C, D).

†Hosmer-Lemeshow goodness-of-fit test $\chi^2 = 13.8$, $P = 0.09$, which indicates statistically significant "fit" (event = admission).

‡Hosmer-Lemeshow goodness-of-fit test $\chi^2 = 4551.40$, $df = 8$, $P < 0.0001$, which indicates statistically nonsignificant "fit" (event=admission).

§Hosmer-Lemeshow goodness-of-fit test $\chi^2 = 12.38$, $df = 8$, $P < 0.14$, which indicates statistically significant "fit" (event = admission).

‖Hosmer-Lemeshow goodness-of-fit test $\chi^2 = 6.04$, $df = 8$, $P = 0.64$, which indicates statistically significant "fit" (event = admission).

¶Exclusion from the model owing to univariate nonsignificance.

#Exclusion from the model owing to final model nonsignificance.

**Insufficient response or cell number to generate reliable population-based estimate.

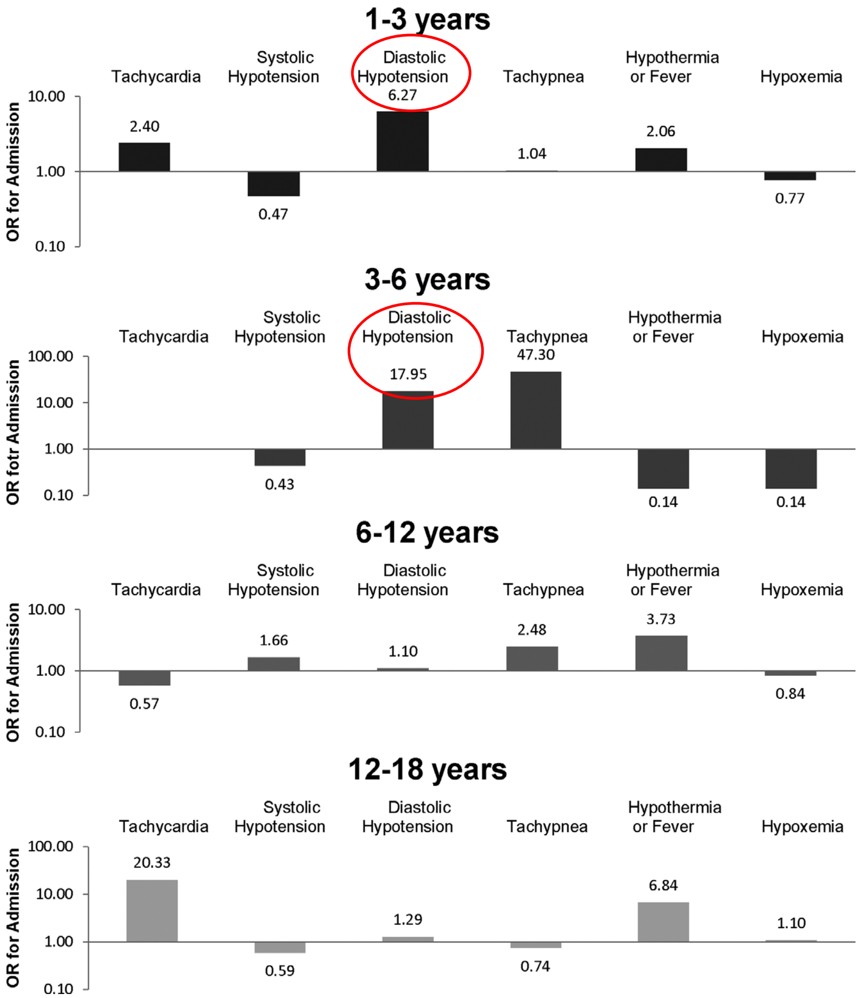

FIGURE 1. Comparison of ORs for admission by age in children presenting with acute asthma.

recognizing subtle (but readily detectable) hemodynamic changes when the child on maximal outpatient therapy presents to the ED with persistent or worsening symptoms. Furthermore, this suggests the need to elicit a detailed history to quantify bronchodilator use before arrival to the ED.

This study demonstrates the need for an age-specific context for the evaluation of children who present with acute asthma exacerbation. Owing to children's changing physiology with age, evaluation of "what is normal" can be a challenge for the average care provider. The all-comer environment of the ED adds layers of complexity to the child's evaluation because the provider attempts to account for varying development (or in some cases delay), comorbidities, socioeconomic backgrounds, access to care, previous recent treatment, and patient-specific response to treatment, among other known and unknown clinical variables. Although this study does not offer a perfect prediction model for children with acute asthma exacerbation, it highlights the further need for developing age-specific assessment tools.

Limitations

This study has 2 main limitations as follows: the retrospective nature of the analysis and the exclusive use of objective findings. In this retrospective analysis, we must recognize the inherent endogeneity of the information used in the decision to admit or discharge a given patient. That is, the treating provider would have been aware of the triage vital signs, which could have influenced treatment, which in turn could affect our study's outcome of interest, admission. Objective vital signs alone clearly do not fully encapsulate the patient's clinical condition or course. These limitations not only are linked to each other but also serve to demonstrate the study's intention. Although asthma is common, pediatric morbidity is relatively uncommon; a prospective design with an objective study protocol could not match the large number of exacerbations observed in this survey (2,454,983 visits).

Asthma scores combining objective and subjective findings have proven to be successful in assessing severity of disease.[5–11] However, the specific goal of this study was to find certain objective predictors for admission that purposely do not rely on experience or judgment. The thrust behind this approach is 3-fold: (*a*) some community settings may have less expertise in treating children,[34–36] (*b*) the treating clinician may not be available to assess the patient until later in the ED course,[37] and (*c*) these objective findings are independent of treatment rendered—they formalize and serve as a ready reminder of the patient's static (initial) assessment.[25] Identifying patients at risk for deterioration is a vital aspect of emergency care; in the current economic context of increasing ED visits with a concurrent decrease in EDs,[38] the case for fast, early, objective identification of patients at risk for needing hospitalization for asthma becomes more salient.

Our method of deeming a given vital sign "abnormal" if out of the normal range bears comment. We recognize that sources will vary (to a small degree) as to the exact range of normal for each age group; for this reason, we chose a major pediatric text's range[16] as a commonly agreed-upon standard. Children's vital signs in triage may be affected by anxiety related to the parent or caregiver, the environment, or the care provider.[17,18] The range of normal is derived from a population of children who are not acutely ill or injured: it captures only those who are truly normal (maximizes true-positive findings for normal, minimizes false-negative findings for normal). In this light, our estimates may be considered conservative.

CONCLUSIONS

In summary, this study shows the importance of age-specific assessment in the evaluation of acute asthma or reactive airway exacerbation. Incorporation of the static (initial) assessment in asthma severity scores may augment their accuracy and aid the clinician to determine need for admission. Most notably, diastolic blood pressure was found to be an early, consistent, independent predictor of admission in children who present to the ED with an acute asthma or reactive airway exacerbation. These early predictors may have potential implications for hospital-based quality improvement, resource use, and throughput benchmarks. In addition, variability by age group in vital sign predictor for admission calls for further development or refinement of age-specific asthma assessment tools.

REFERENCES

1. National Heart, Lung, and Blood Institute. *Expert Panel Report 3: Guidelines for the Diagnosis and Management of Asthma*. Bethesda, MD: National Asthma Education and Prevention Program; 2007.
2. Harvey S, Forbes L, Jarvis D, et al. Accident and emergency departments are still failing to assess asthma severity. *Emerg Med J*. 2003;20:329–331.
3. Scribano PV, Lerer T, Kennedy D, et al. Provider adherence to a clinical practice guideline for acute asthma in a pediatric emergency department. *Acad Emerg Med*. 2001;8:1147–1152.
4. Angelilli ML, Thomas R. Inter-rater evaluation of a clinical scoring system in children with asthma. Inter-rater evaluation of a clinical scoring system in children with asthma. *Ann Allergy Asthma Immunol*. 2002;88:209–214.
5. Gorelick MH, Stevens MW, Schultz TR, et al. Performance of a novel clinical score, the Pediatric Asthma Severity Score (PASS), in the evaluation of acute asthma. *Acad Emerg Med*. 2004;11:10–18.
6. Becker AB, Nelson NA, Simons FE. The pulmonary index. Assessment of a clinical score for asthma. *Am J Dis Child*. 1984;138:574.
7. Carroll CL, Sekaran AK, Lerer TJ, et al. A modified pulmonary index score with predictive value for pediatric asthma exacerbations. *Ann Allergy Asthma Immunol*. 2005;94:355.
8. Ducharme FM, Chalut D, Plotnick L, et al. The Pediatric Respiratory Assessment Measure: a valid clinical score for assessing acute asthma severity from toddlers to teenagers. *J Pediatr*. 2008;152:476.
9. Smith SR, Baty JD, Hodge D. Validation of the pulmonary score: an asthma severity score for children. *Acad Emerg Med*. 2002;9:99.
10. Arnold DH, Gebretsadik T, Abramo TJ, et al. The RAD score: a simple acute asthma severity score compares favorably to more complex scores. *Ann Allergy Asthma Immunol*. 2001;107:22–28.
11. Gouin S, Robidas I, Gravel J, et al. Prospective evaluation of two clinical scores for acute asthma in children 18 months to 7 years of age. *Acad Emerg Med*. 2010;17:598–603.
12. Gorelick M, Scribano PV, Stevens MW, et al. Predicting need for hospitalization in acute pediatric asthma. *Pediatr Emerg Care*. 2008;24:735–744.
13. Keogh KA, Macarthur C, Parkin PC, et al. Predictors of hospitalization in children with acute asthma. *J Pediatr*. 2001;139:273–277.
14. Bolyut N, van der Lee JH, Moyer VA, et al. State of the evidence on acute asthma management in children: a critical appraisal of systematic reviews. *Pediatrics*. 2007;120:1334–1343.
15. Gilboy N, Tanabe T, Travers D, et al. *Emergency Severity Index (ESI): A Triage Tool for Emergency Department Care, Version 4. Implementation Handbook 2012 Edition. AHRQ Publication No. 12-0014*. Rockville, MD: Agency for Healthcare Research and Quality; 2011.
16. Mathers LH, Frankel LR. Pediatric emergencies and resuscitation. In: Kliegman R, Nelson WE, eds. *Nelson Textbook of Pediatrics*. 19th ed. Philadelphia, PA: Saunders; 2011.
17. Hohenhaus SM. Someone watching over me: observations in pediatric triage. *J Emerg Nurs*. 2006;32:398–403.
18. Hohenhaus SM, Travers D, Mecham N. Pediatric triage: a review of emergency education literature. *J Emerg Nurs*. 2008;34:308–313.
19. National Center for Health Statistics. *NHAMCS Scope and Sample Design. Centers for Disease Control and Prevention*. Atlanta, GA: Centers for Disease Control and Prevention (CDC); 2011.
20. National Center for Health Statistics. *NHAMCS Data Collection and Processing. Centers for Disease Control and Prevention*. Atlanta, GA: Centers for Disease Control and Prevention (CDC); 2011.
21. National Center for Health Statistics. *NHAMCS Estimation Procedures. Centers for Disease Control and Prevention*. Atlanta, GA: Centers for Disease Control and Prevention (CDC); 2011.
22. National Center for Health Statistics. *NHAMCS Reliability of Estimates. Centers for Disease Control and Prevention*. Atlanta, GA: Centers for Disease Control and Prevention (CDC); 2011.
23. Archera KJ, Lemeshow S, Hosmer DW. Goodness-of-fit tests for logistic regression models when data are collected using a complex sampling design. *Comput Stat Data Anal*. 2007;51:4450–4464.
24. Kleinbaum DG, Lein M. *Logistic Regression*. New York, NY: Springer Science; 2010.
25. Rodrigo GJ. Predicting response to therapy in acute asthma. *Curr Opin Pulm Med*. 2009;15:35–38.
26. Magadle R, Berar-Yanay N, Weiner P. The risk of hospitalization and near-fatal and fatal asthma in relation to the perception of dyspnea. *Chest*. 2002;121:329–333.
27. Horeczko T, Enriquez B, McGrath NE, et al. The pediatric assessment triangle: accuracy of its application by nurses in the triage of children. *J Emerg Nurs*. 2012;39. [Epub ahead of print].
28. Gausche-Hill M, Fuchs S, Yamamoto L, eds. *Advanced Pediatric Life Support: The Pediatric Emergency Medicine Resource*. Sudbury, MA: American Academy of Pediatrics, American College of Emergency Physicians, and Jones & Bartlett Publishers; 2012.
29. Gary D. Webb GD, Smallhorn JF, et al. Congenital heart disease. In: Bonow RO, Mann DL, Zipes DP, Libby P, eds. *Braunwald's Heart Disease—A Textbook of Cardiovascular Medicine*. 9th ed. Philadelphia, PA: Saunders/Elsevier; 2011.
30. Mamede S, Schmidt HG, Penaforte JC. Effects of reflective practice on the accuracy of medical diagnoses. *J Med Educ*. 2008;42:468–475.

31. Ely JW, Kaldjian LC, D'Alessandro DM. Diagnostic errors in primary care: lessons learned. *J Am Board Fam Med*. 2012;25:87–97.

32. Bennett JA, Smyth ET, Pavord ID, et al. Systemic effects of salbutamol and salmeterol in patients with asthma. *Thorax*. 1994; 49:771–774.

33. Wiley JF 2nd, Spiller HA, Krenzelok EP, et al. Unintentional albuterol ingestion in children. *Pediatr Emerg Care*. 1994;10:193–196.

34. American Academy of Pediatrics, Committee on Pediatric Emergency Medicine and American College of Emergency Physicians, Pediatric Committee. Care of children in the emergency department: guidelines for preparedness. *Pediatrics*. 2001;107:777–781.

35. American College of Emergency Physicians and the American Academy of Pediatrics. Care of children in the emergency department: guidelines for preparedness. *Ann Emerg Med*. 2001;37:423–427.

36. Athey J, Dean JM, Ball J, et al. Ability of hospitals to care for pediatric emergency patients. *Pediatr Emerg Care*. 2001;17:170–174.

37. Institute of Medicine of the National Academies, Committee on the Future of Emergency Care in the United States Health System, Board on Health Care Services. *Emergency Care for Children: Growing Pains*. Washington, DC: National Academies Press; 2007.

38. Hoot NR, Aronsky D. Systematic review of emergency department crowding: causes, effects, and solutions. *Ann Emerg Med*. 2008;52:126–136.