Predicting Subsequent High-Frequency, Low-Acuity Utilization of the Pediatric Emergency Department

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ABSTRACT

OBJECTIVE: To derive and test a predictive model for high-frequency (4 or more visits per year), low-acuity (emergency severity index 4 or 5) utilization of the pediatric emergency department.

METHODS: The study sample used 3 years of data (2012–2014) from a single tertiary-care children's hospital for patients <21 years of age. Utilization in 2013 defined the index visit; prior utilization was drawn from 2012; and 2014 was used for outcome measurement. Candidate predictor variables were those that would be available at the time of triage. Data were split into derivation and test sets randomly; variables with a significant univariate association in the derivation set were included for multivariable modeling. The final model from the derivation set was then tested in the validation set, with calculation of a receiver operating characteristic curve.

RESULTS: There were 90,972 visits in 2013, of which 61,430 were first (index) visits. A total of 590 (1%) had 4 or more triage level 4 or 5 visits in the following year (2014). The final model included site of primary care, age, acuity, previous utilization, race, and insurance, and had an area under the receiver operating characteristic curve of 0.84.

CONCLUSIONS: Data available to the emergency department provider at the time of initial visit triage can predict utilization for low-acuity complaints in the subsequent year. Future work should focus on validation and refinement of the model in additional settings, and electronic calculation of risk status for targeted intervention to improve appropriate utilization of health care services.

KEYWORDS: emergency department; low-acuity; predictive model; utilization

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WHAT'S NEW

Prior retrospective studies have found conflicting risk factors for high-frequency, low-acuity emergency department (ED) utilization. This study focused on identifying risk factors, identifiable at the patient's initial visit, that predict subsequent high-frequency ED utilization, as a first step toward intervention.

MULTIPLE STUDIES HAVE identified that patients with frequent, low-acuity, utilization of the emergency department (ED) account for a disproportionate amount of health care resources. In one study, using data from children's hospitals that submit data to the Pediatric Health Information System, children with 4 or more ED visits per year (of any acuity) represented 8% of the cohort but 24% of visits and 31% of costs.[1] Patients with frequent utilization, particularly infants without a chronic medical condition, were the least likely to require medications, testing, or hospital admission.[1] Another pediatric study, conducted in 2 EDs, found that those with frequent low-acuity utilization of the ED represented <2% of all patients but almost 10% of all visits.[2]

A variety of risk factors for high-frequency utilization, and high-frequency, low-acuity utilization in particular, have been described. Socioeconomic vulnerability, chronic disease, and high utilization of other health care services[3] were associated with frequent ED use in adults. A recent large Pediatric Emergency Care Applied Research Network study found that repeat visits to the pediatric ED were associated with younger age, black or Hispanic race or ethnicity, and public insurance.[4]

However, interventions to address patterns of frequent low-acuity utilization have been limited by our inability to prospectively identify patients at risk during their ED visit. Ideally, one would be able to identify those patients at risk of developing a pattern of high-frequency, low-acuity utilization and target appropriate interventions at them before the high-cost, low-efficiency period of use has taken place.

The goal of this project was to derive and test a predictive model for high-frequency, low-acuity utilization, using

only variables available at the time of ED triage, to enable identification of these patients for timely intervention. The eventual goal of this project is to create a model that could be part of the electronic medical record (EMR) to automatically flag patients at risk of future high-frequency, low-acuity visits. This would enable the efficient testing of interventions such as improved linkage to primary care, case management, or referrals to address unmet social needs to determine what combination of intervention is most effective.

METHODS

DATA

The study sample was generated from 3 years of data from the EMR 2012–2014 at a single tertiary-care children's hospital. The first year of data (2012) was used for a description of prior ED utilization. The second year (2013) was used as the index year. Demographic data, such as age and insurance status, was abstracted from the first visit in 2013. The third year (2014) was used for outcome measurement, during which the frequency of high-frequency, low-acuity utilization was measured. This structure reduces the potential for seasonal variation or misinterpretation of utilization patterns within a single year of data. We chose to use utilization in the subsequent calendar year, rather than 365 days after the initial visit, to avoid confounding by a single episode of care and examine a patient's broader pattern of utilization. The protocol was approved by the Children's Hospital of Philadelphia institutional review board (14-011300).

SUBJECTS

Patients were excluded if they were older than 21, as many patients have transitioned to a general ED setting at that point, and those continuing to receive care at a pediatric center represent a population that is more likely to have significant underlying chronic disease. To be included in the final model, patients had to have nonmissing values for all variables.

VARIABLES

Candidate predictor variables were identified on the basis of a review of the literature for variables that would be available to an ED provider at the time of triage and were vetted by the 72-hour revisit quality improvement committee at our institution. They were as follows: in-network primary care in the year preceding the index visit; in-network specialty care in the year preceding the index visit; gender; age; acuity; season; utilization in prior year; race; insurance; shift of presentation; and day of week. In-network primary or specialty care was a binary variable indicating any visit to a primary or specialist within our health care system at any point in the EMR history. Prior utilization was defined as the number of visits of any acuity level in the preceding year (2012). Because of the known difficulty in distinguishing "nonemergency" ED visits from a presenting complaint,[5] we chose to define a low-acuity visit as one assigned an emergency severity index (ESI) triage level 4 or 5. High-frequency, low-acuity utilization was defined as 4 or more triage level 4 or 5 visits in the outcome year (2014). We chose to use more than 4 visits to be as consistent as possible with previous definitions,[1,4] because we are attempting to identify the children who are going to develop the most problematic patterns of utilization to maximize opportunities for early intervention.

ANALYSIS

The data were randomly split into a derivation set and a validation set, with 50% of patients in each group. In the derivation set, univariate associations were identified between candidate predictor variables and high-frequency, low-acuity utilization. Variables with a significant ($P < .05$) univariate association on chi-square testing were included in an initial multivariable logistic regression model in the derivation set. The model was refined using a backward stepwise process. Likelihood ratio tests were used to compare candidate models. The model from the derivation set was then tested in the validation set, with calculation of a receiver operating characteristic (ROC) curve. Analyses were conducted by Stata 13.1 software (StataCorp, College Station, Tex).

RESULTS

There were 90,972 visits in 2013, of which 61,430 were index visits. After excluding patients who were >21 years of age or who had unknown gender or triage scores, there were 60,799 visits. Of those, 590 (1%) had 4 or more triage level 4 or 5 visits, thus meeting our definition of high-frequency, low-acuity utilization. The maximum number of visits in 1 year was 29. Among the patients without high-frequency, low-acuity utilization, the top 5 chief complaints were respiratory distress (15.2%), trauma/extremity (10.7%), other (7.4%), trauma/face/head/torso (6.6%), and abdominal pain (5.6%). Among those with high-frequency, low-acuity utilization, the top 5 chief complaints were respiratory distress (27.3%), fever (17.5%), rash (7.1%), vomiting (6.8%), and other (4.8%).

Table 1 shows the cohort demographics for the entire cohort and unadjusted associations with utilization for the derivation set. The following variables had a significant ($P < .05$) association on chi-square testing and were included in an initial multivariable logistic regression model in the derivation set: in-network primary care; in-network specialty care; age; acuity; utilization in prior year; race; and insurance. In the final model, presence of in-network care, younger age, lower acuity index visit, previous high utilization, black race, and government insurance or self-pay were associated with high-frequency, low-acuity utilization (Table 2). The performance of the final multivariable model was then tested in the validation set with calculation of an ROC curve (Fig) with an area under the curve (AUC) of 0.84 (95% confidence interval, 0.81–0.86). Using an empirical cut point estimation yields an optimal cut point of 0.0997 (AUC 0.78), with a sensitivity of 0.77 and a specificity of 0.78 (Table 3).

Table 1. Cohort Demographics and Nonadjusted Association With High-Frequency, Low-Acuity Utilization

Variable	Category	n	%	*P**
In-network specialty care utilization		21,278	35	<.001
In-network primary care utilization		20,789	34.2	<.001
Gender	Female	28,761	47.3	.927
	Male	32,038	52.7	
Age	<1 y	9203	15.1	<.001
	1 to <4 y	16,238	26.7	
	4 to <9 y	15,682	25.8	
	9 to <14 y	10,692	17.6	
	≥14 y	9085	14.9	
Acuity	1 and 2	11,383	18.7	<.001
	3	18,206	29.9	
	4 and 5	31,210	51.3	
Season	Jan–Mar	21,256	35	.45
	Apr–Jun	15,168	25	
	Jul–Sept	12,604	20.7	
	Oct–Dec	11,771	19.4	
Race	White	16,147	26.6	<.001
	Black/African American	35,035	57.7	
	Hispanic	4405	7.3	
	Other	5085	8.4	
Insurance	Commercial insurance	21,731	35.7	<.001
	Government insurance	35,787	58.9	
	Other	649	1.1	
	Self/pay	2632	4.33	
Shift	12 AM to 7:59 AM	7059	11.6	.389
	8 AM to 3:59 PM	24,710	40.6	
	4 PM to 11:59 PM	29,030	47.8	
Day of week	Weekday	44,129	72.6	.438
	Weekend	16,670	27.4	
FY 2012 utilization (all acuity levels)	<4 visits per year	58,969	96.4	<.001
	≥4 visits per year	2204	3.6	

Derivation set only.
**P* value for association with utilization.

DISCUSSION

In this cohort, a model based on variables available to the ED provider at the time of triage was able to predict low-acuity utilization in the subsequent year. As health care moves toward more integrated systems and novel payment models, effective risk stratification and intervention will become ever more important. Previous research has shown that past acute care visits are associated with subsequent

Table 2. Final Multivariable Model: Estimated Odds Ratios for Predicting High-Frequency, Low-Acuity Utilization in Derivation Set

Variable	Category	Odds Ratio	95% Confidence Interval
Primary care	Out of network (referent)	1.00	
	In network	1.48	1.17–1.87
Age group	Age <1 y (referent)	1.00	
	Age 1 to <4 y	0.21	0.16–0.28
	Age 4 to <9 y	0.11	0.07–0.15
	Age 9 to <14 y	0.11	0.07–0.18
	Age ≥14 y	0.03	0.01–0.08
Acuity	ESI 1 and 2 (referent)	1.00	
	ESI 3	1.57	1.02–2.40
	ESI 4 and 5	1.93	1.32–2.83
Prior utilization (2012)	Low (referent)	1.00	
	High	3.70	2.57–5.33
Race/ethnicity	White (referent)	1.00	
	Black	4.84	2.57–9.10
	Hispanic	1.53	0.64–3.67
	Other	2.19	0.99–4.85
Insurance	Commercial (referent)	1.00	
	Government	3.19	2.00–5.08
	Other	1.33	0.17–10.11
	Self-pay	2.65	1.28–5.49

ESI indicates emergency severity index.

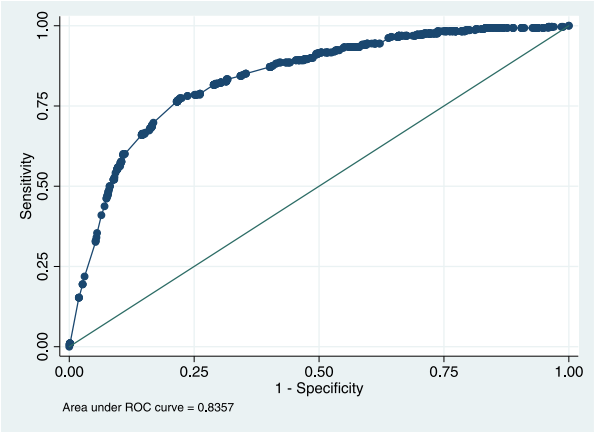

Figure. *Receiver operating characteristic curve for predicting high-frequency, low-acuity utilization in validation.*

visits, in a model examining care for asthma,[6] and our data also show an association between previous and subsequent utilization patterns. In addition, studies have shown an association between recurrent visits and younger age, black or Hispanic race/ethnicity, and public health insurance.[4] Our analysis found similar results, with the exception that there was no significant increase in risk for Hispanic patients, possibly as a result of the small sample sizes in this cohort.

Our data suggest that a predictive model (AUC 0.84) can be achieved from variables routinely collected in the EMR, enabling the risk stratification of children at initial presentation to the ED. We present a potential sample cut point with resulting sensitivity and specificity values (Table 3), but decisions about the optimal cut point for defining high risk are complex and are likely to change on the basis of institutional resources and desired maximization of sensitivity or specificity. We plan to investigate the external validity of the model using data from other centers and publicly available administrative data, and examine varied cut points for stratification. If validated, the model could then be built into the EMR to flag patients at risk of future high-frequency, low-acuity use at the time of initial visit triage. In the ED, such a flag could trigger referral to case management for evaluation of unmet social[7] or educational needs[8,9] or linkage back to primary care.[10] For a primary care provider, such a flag could serve as an opportunity for education around care-seeking behavior and safe home management strategies. At the population health level, deployment of additional resources for unscheduled care visits could be guided by areas with high numbers of high-risk children. In each of these settings, interventions should be studied for differential efficacy by risk group to allow for efficient targeting of more expensive interventions to those most likely to benefit.

Table 3. Actual Versus Predicted Utilization of Patients Categorized Using Empirical Optimal Cut Point in Validation Set

Characteristic	High Utilization	Low Utilization	Total
Predicted high risk	223	6666	6889
Predicted low risk	65	23,367	23,462
Total	288	30,063	30,351
Sensitivity			0.77
Specificity			0.78
Likelihood ratio positive			3.49
Likelihood ratio negative			0.29

LIMITATIONS

The data for this study were drawn from a single tertiary-care pediatric center, potentially limiting generalizability to other populations. Importantly, we were only able to ascertain returns to our center, so we likely undercounted the overall pattern of frequent low-acuity utilization. Although the data were divided into a derivation and validation set for analysis, these findings will need to be validated in an external data set. While the analytical structure of using half the cohort for derivation and half for validation, as well as use of the subsequent calendar year for outcome ascertainment, reduces the potential for model fitting or seasonal bias, there remains the potential for bias based on age of entry to the cohort. Children who were aged <1 year in the index year have a reduced risk of previous visits to the ED depending on their date of birth, potentially increasing the apparent predictive value of young age. Additionally, although using the subsequent calendar year for outcome assessment removes some of the potential for bias by clustering episodes, a potential bias remains for visits at the very end of the index year, and one might expect the predictive value of the model to lessen when the outcomes are more remote from the predictive variables.

During the period of the study (September 2012), the ED changed triage scales from a 4-level internally developed scale to the 5-level ESI scale. To avoid confounding by changes in the triage scale and to ensure comparability with other studies, we chose only to include acuity from the index visit (2013, ESI scale). Because of this transition, we were unable to separate out prior utilization (2012) by acuity level.

Although we collected data on use of in-network specialty care, we were unable to separate out those who were generally healthy and using specialty care for an acute episode from those with complex chronic conditions requiring multiple subspecialists, as we did not have complete ICD-9 codes. Although we would not expect those children with complex conditions to have frequent visits with low-acuity triage levels, future validation studies should consider adjusting for the presence of children with complex chronic conditions. We were also unable to separate out the in-network care provided by faculty/attending practices from that provided by the resident clinics, or account for changes in primary care provider during the study period, and so it remains difficult to determine the underlying reasons for this association. Future research should attempt to control for primary care provider center or type to understand provider factors that may effect ED utilization. Furthermore, the association between in-network care, race, and insurance may also be confounded by geographical convenience and transfer patterns given the location of our center in an urban,

high-poverty, majority black neighborhood. Given the economic diversity and differences in transport access contained within single zip codes in our community, we did not think that adjusting for zip codes alone would sufficiently address this confounding.

CONCLUSION

Data available to the ED provider at the time of initial visit triage can predict utilization for low-acuity complaints in the subsequent year. Future work will focus on validation and refinement of the model, as well as the creation of an electronic calculation of risk status that can be incorporated into an EMR with automatic notification of the care team for high-risk patients. This will facilitate risk stratification and trials of targeted intervention to improve appropriate utilization of health care services.

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