Pediatric Emergency Department Disposition: Predicting the need for unplanned critical care admission

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Abstract

Objectives: We sought to evaluate pediatric Emergency Department (ED) patients who fail ward disposition and identify patient-level ED risk factors that might predict deterioration following ward and subsequent PICU admissions.

Methods: Pediatric patient charts between May 1, 2008 and December 31, 2012 were retrospectively analyzed. The primary outcome was unplanned ICU admission defined as patient transferred to ICU after staying in the inpatient general ward unit for less than 24 hours. Analysis focused on patient-level data including vital signs. The association between patient characteristics and unplanned ICU admissions were assessed using a multivariable logistic analysis regression while controlling for other confounders.

Results: Out of 6,361 patients admitted to the ward from the ED, 80 failed ward admission and were admitted to the ICU within 24 hours of ward admission. Independent predictors of unplanned ICU admission included average length of stay in the ED (OR = 1.45, 95% CI= 0.92 to 2.29), resident specialty (OR = 2.03, 95% CI = 1.15 to 3.56), abnormal pulse oximetry (spO2) < 90% (OR = 2.95, 95% CI = 0.56 to 10.15). Lower triage acuity was associated with a lower likelihood of unplanned ICU admission (OR =0.50, 95% CI = 0.32 to 0.78). We did not find significant interactions the predictors of unplanned ICU admission.

Conclusion: We found that <24-hour unplanned ICU-admitted pediatric patients is associated with average length of stay in the ED, triage acuity, resident specialty, and abnormal pulse ox vitals. Although we were unable to identify with confidence the independent prediction factors due to sample size, these findings may help guide future research in pediatric disposition of patients presenting to the ED and should be considered when admitting patients to the general ward from the ED.

OCTRI

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1. Introduction

Disposition of patients from the ED is not always straightforward. Early identification of patients by Emergency Department(ED) personnel who may require ICU admission has the potential to improve patient outcomes.When patients require critical medical interventions (e.g. ventilation), the decision for intensive care unit (ICU) admission is easier than if those conditions were not present.

Patients who are transferred from the general wards to the ICU (commonly referred as unplanned ICU admission) have higher in-hospital mortality rates (24% vs. 19% and 53% vs. 30%) than patients admitted directly to an ICU. ((Kennedy, Joyce, Howell, Lawrence Mottley, & Shapiro, 2010) (Hillman, 2002; Goldhill, 1998).

Early ICU admission of the critically ill patient has been shown to be beneficial and effective at reducing mortality (Capuzzo, Moreno, & Alvisi, 2010).

A great many resources have gone into the development of early identification for the adult population and management of deteriorating patients in general hospital wards (Early Warning Score) or patterns of critical care admission in emergency department patients. (Armagan, 2008; Dawson, 1993 ; Groarke, et al., 2008) To date, scant published research has been conducted to determine the predictors for intensive care unit admission of patients first admitted to the general wards in children presenting

to the ED.

The decisions to admit and discharge patients depend on patient characteristics (e.g. physiological), departmental structure (e.g. department daily census/seasons) and physician-related (e.g. level of training) variables (Capuzzo, Moreno, & Alvisi, 2010).

Identifying patient predictors for unplanned ICU admission would allow ED providers to identify at-risk patients during the initial presentation to the ED and make better discharge decisions.

A preliminary adult study suggested that respiratory compromise, congestive heart failure, peripheral vascular disease, transient hypotension, transient tachycardia, and elevated creatinine were independently associated with unplanned ICU admission in ED patients with suspected infection (Kennedy, Joyce, Howell, Lawrence Mottley, & Shapiro, 2010). In 2008, Blecher et al showed that intercostal catheter insertion was a risk factor for unplanned ICU admission in chest trauma patients admitted to the ward following ED presentation (Blecher, Mitra, Cameron, & Fitzgerald, 2008).

Another study by Farley found that ED tachypnea appears to have a significant relationship with unplanned ICU or intermediate care admission (Farley, et al., 2010).

In a 2009 study of ED patients in Sydney, Australia, Frost et al conducted a study to identify factors associated with unplanned ICU admission and developed a risk tool to individualize the risk prior to a patient being transferred from the ED. They found that patients discharged by the hospital in the last 28 days prior to their ED re-presentation had a higher risk of unplanned ICU admission and found that patients who had at least one comorbid illness (e.g. liver disease, renal disease, history of pulmonary disease) had higher risk of unplanned ICU admission (Frost , Alexandrou, Bogdanovski, Salamonson , Parr, & Hillman, 2009). The author's use of administrative data to identify the risk factors showed the role of previous hospitalization and co-morbidity in the risk of unplanned ICU admission, however, the clinical precursors were not analyzed and might prove more effective objective criteria for the disposition of patients from the ED.

Patients presenting to emergency departments with non-specific symptoms such as nausea, vomiting and diarrhea might still be at high risk of requiring critical care admission (Frost , Alexandrou, Bogdanovski, Salamonson , Parr, & Hillman, 2009).

The latest adult study concerning non-ICU admissions transferred to the ICU within 24 hours had the following admitting diagnoses most associated with unplanned transfer, listed by descending prevalence: pneumonia, myocardial infarction (MI), chronic obstructive pulmonary disease (COPD), sepsis, and catastrophic conditions. Other significant predictors included: male sex, Comorbidity Points Score >145, Laboratory Acute Physiology Score ≥7, arriving on the ward between 11 PM and 7 AM. (Delgado, Liu, Pines, Kipnis, Gardner, & Escobar, 2013)

There is scant published research in the pediatric population determining the intensive care unit (ICU) admission risk factors of emergency department (ED) patients primarily admitted to the general wards. To our knowledge, no data have been evaluated specifically comparing those risk factors in the pediatric population.

Therefore, the goal of this study is to identify clinical factors associated with deterioration on the inpatient floor within 24 hours after admission for pediatric ED patients initially admitted to a general ward resulting in unplanned ICU admission. We hope to characterize pediatric ED patients who fail ward disposition (i.e. resulting in unplanned ICU admission) and identify patient-level ED risk factors that might predict deterioration following ward and subsequent PICU admissions. We will focus on patients admitted through the Emergency Department, which typically exhibit high uncertainty in the volume and severity, and data available to the emergency physician.

The identification of pediatric patients at high risk for unplanned ICU admission at the time of transfer from the ED to the general ward offers an important opportunity on which to base ED disposition decision either by (Frost , 2009):

(1) reviewing the appropriateness of the ward level when discharged from the ED

or (2) flagging patients for follow-up on the general ward to assess for deterioration.

2. Methods

This retrospective cohort study includes pediatric subjects aged from 0 to 18 years, up to but not including their 19th birthday. The study was approved by the Oregon Health & Science University (OHSU) Institutional Review Board (IRB).

OHSU sees about 876,553 patient visits per year (2011-2012 fiscal year stats) which includes 32,486 ED visits, of which 8,036 are pediatric. (Oregon Health & Science University, 2013). The OHSU Pediatric ED is one of only two pediatric level 1 trauma centers in Oregon with specially trained pediatric emergency medicine doctors and nurses who treat only children. Most of the attending doctors working in the OHSU ED are board certified in pediatric emergency medicine and the pediatric emergency nurse practitioners have special pediatric training.

2.1 Inclusion Criteria

All pediatric patients (≤ 18 years) admitted to the pediatric general ward from the ED between 5/1/2008 and 12/31/2012 including patients transferred from ED to certain inpatient units (general ward – *see Figure 1 below*.

2.2 Exclusion Criteria

- All patients discharged home from the ED
- Patients that died in the ED
- Patients admitted to the ICU from the ED

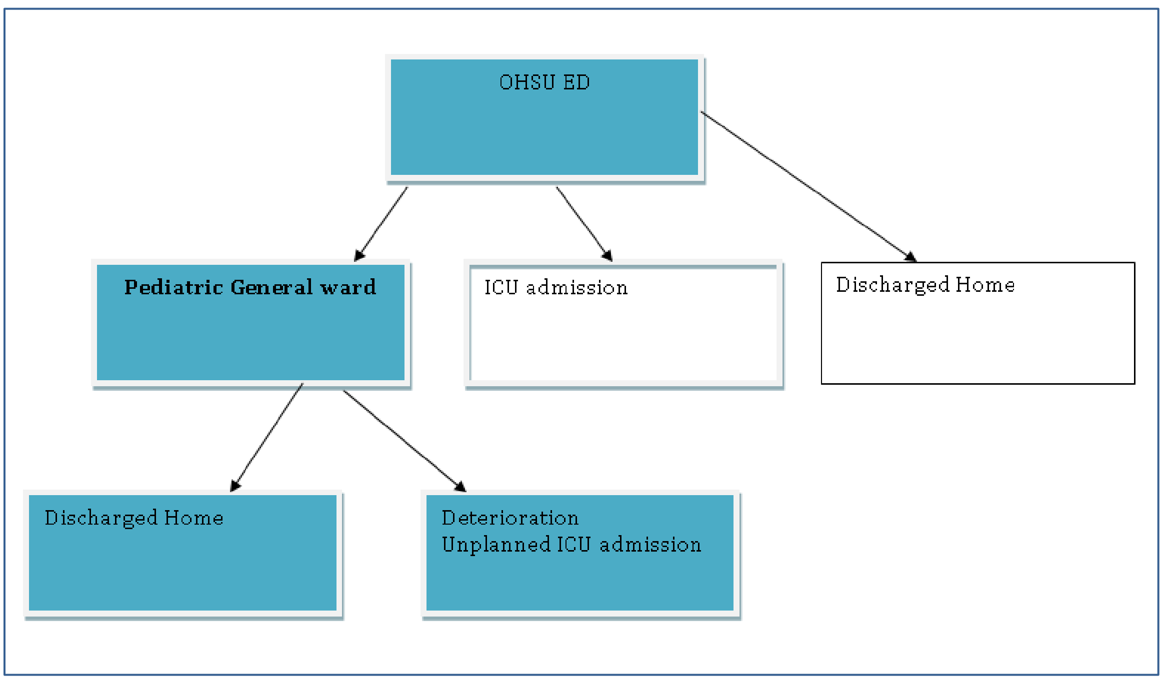

Figure 1. Data Selection

2.3 Data collection and abstraction.

These records were obtained from the OCTRI RDW (Oregon Clinical & Translational Research Institute Research Data Warehouse).

Patient study cases: patient transferred to ICU after staying in the inpatient general ward unit for less than 24 hours. – *see* Figure 1 *above.*

The time limitation (i.e. less than 24 hours) was included to focus on characteristics that may have been present during ED presentation. This is also thought to reduce information bias related to the disease processes related to hospital admission or bed rest.

2.4 Measures

The primary study outcome variable was the occurrence of an unplanned ICU admission within 24 hours of admission from the ED to the general ward.

Predictor variables were selected according to previous studies in adult population evaluating predictors of *unplanned ICU admission with 24 hours* as well as clinical significance. Independent variables of interest were classified as system level, physician level and patient level.

Patient level predictors included ED and inpatient encounter data i.e. patient demographic characteristics, admit and discharge dates and times, and triage score. Patient demographic variables included gender, age, race, insurance and primary care provider status. Age was categorized into five categories: 0-1; 1-5; 5-10; 10-15 ;> 15 to capture differences in outcome by specific age groups. Race was combined to create 2 categories: white and other. Insurance was collapsed in 2 groups: sponsored vs non-sponsored. Whether the patient had a primary care physician or was an English-speaker were included as a 2-level variable. Triage score was used as proxy for severity of illness instead of classifying admission diagnosis due to the complexity of accurately classifying of diagnoses in the pediatric population. Triage score was described as the immediacy with which a patient should be seen by a physician and severity of illness was classified into 2 categories. The patient's length of stay (LOS) in the ED was classified into less than average ED LOS (311.5minutes) or more to capture patients with emergent conditions. Patient's discharge disposition was recorded as deceased. Patient's hospital status were also included as whether the patient was sent to the ED observation unit or hospitalized within 31 days in the system.

Patient ED vital signs included first pulse oximetry, systolic blood pressure (sBP), pulse, temperature in °Celsius and respiratory rate (RR). During data management, only 2135 patients were found to have full vital signs, characterized by both sBP and diastolic blood pressure . As infants and children grow and age, the normal range of blood pressure, pulse rate, and respiratory rate changes. (Benjamin C. Wedro, 2013) Therefore, normal vital signs for the pediatric population were reviewed and the blood pressure, pulse rate, and respiratory rate categorized as a 3-level variable: abnormal or normal vitals according to patient's age category and missing vital signs. Vital signs not recorded in the dataset were coded as missing and presumed as 'normal'. Missing vital signs were not collected in the ED as the vital signs were most likely normal and therefore were not relevant to the patient's condition in the ED. To develop our simplified abnormal vs. normal blood pressure, pulse rate and RR categories, we used the normal range of the sBP, pulse and RR vital signs listed for a given age, Appendix - Table 1. Similarly, the pulse ox (Sp02) and temperature values were categorized into abnormal, normal and missing as follows: hypoxemia (defined as SpO2 <90%), fever defined as temperature greater than 37.5°C.

The *physician-level predictors* included ED provider type (nurse practitioner (NP), pediatric board certified ED attending, non-pediatric board certified ED attending and other) and if the patient was seen by only an attending versus an attending and resident. Resident physicians' speciality wasalso classified as ED resident versus non-ED resident or NP.

System-level variables included ED arrival time, inpatient admit time and season of service.

Time of ED arrival was collapsed into 3 categories (6 AM-3 PM, 3 PM -11PM and 11PM 6AM) roughly reflecting staffing variations and volume. The inpatient admission time was collapsed into similar categories for comparability. Season of service was divided into the 4 seasonal categories: winter, spring, summer and autumn. Season was therefore considered a four level variable with "winter" considered as the reference level. The patient's stay in the ED according to their ED admission date was classified into less than average daily census (28.6 patients) or more to capture ED staffing conditions.

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2.5 Arranging the data

MS EXCEL worksheets and STATA 12.1 were used to arrange the preliminary data. If needed, the patient's electronic medical record was reviewed to verify inconsistent values for accuracy. The first of complete set of ED vitals were used in the model.

A review of the cell sizes of the categorical variables was performed and the categories were collapsed if there were not an adequate number of events for each level of our categorical independent variables.

2.6 Constructing the model

We first conducted an analysis to look at the association between each independent variable with the dependent variable *unplanned ICU admission with 24 hours* uni-variately. We conducted an analysis of each independent variable with the dependent variable *unplanned ICU admission with 24 hours* uni-variately (Appendix Table 2 and Appendix Table 3) . We did not have a primary independent variable of interest in this analysis.

A two sample t-test was used to compare continuous variables between the dependent variable and inpatient admit time, ED length of stay. The continuous predictors were recoded into relevant categorical variables (Appendix Table 2 and Appendix Table 3). Pearson's χ^2 test was used for categorical variables; Fisher's exact test were also used due to relatively small sample size. A review of the cell sizes of the categorical variables was performed and the categories were collapsed if there was not an adequate number of events for each level of our categorical independent variables.

Upon completion of the univariate analyses, variables were selected for the multivariate analysis. Any variable whose univariable test has a p-value less than 0.25 was a candidate for the multivariable logistic regression model along with all variables of clinical importance.

Following the fit of the multivariate model, the importance of each variable included in the model was verified by examination of the WALD statistic and a comparison of each estimated coefficient with the coefficient from the model containing only that variable.

Variables that did not contribute to the model based on these criteria were eliminated. The preliminary main effects model was then compared to the full containing all initial predictors model using the likelihood ratio test. Also, the estimated coefficients for the remaining variables were compared to those from the full model. In order to refine the main effects model, we then assessed interaction terms or effect modification with age. Confounding was assessed based on the definition of as a change of greater than or equal to 10% of the odds ratio estimate. For this analysis, we use 0.05 as the cut-off for significant statistical association.

Once we have a model with significant and important variables, we finished the analysis by performing the logistic regression diagnostics. When the model building stage was completed, a series of steps was undertaken to assess the fit of the model. We evaluated the fitness of the model using the Deviance test.

All analyses were performed using STATA 12.1.

3. Results

3.1 Study Population

Of the 6,361 unique patients in the study analysis, 80 patients (1.3%) had *unplanned ICU admission within 24 hours*. In our sample of 6361 patients, the mean age of subjects at presentation, and the mean number of previous hospitalization from those patients in the cohort were 7.09 years and 1.8 respectively.

80 patients (56% male) of mean age 6.9 years met our primary outcome of interest. The median time to ICU transfer was 10.3 hours (IQR = 4.4-18 hours). In terms of triage acuity, 34% had a triage level ≤ 2 and 66% with a triage level of >2. Approximately equal proportions were either white (20%) or other (80%) in the unplanned ICU group versus those patients directly admitted to ward.

Among the unplanned ICU admission patients, 16 of 80 patients (20%) were treated by a ED resident physician at some point during their ED course.

The mortality rate for patients with *unplanned ICU admission* was 5% (4 of 80), compared to a mortality rate of 0.3% (17 of 6281) among those admitted directly to the inpatient ward from the ED (p <0.01). Of 6361 patients requiring inpatient admission during the study period, none were excluded owing to incomplete documentation.

The most common admission diagnoses (based on *International Classification of Disease, Ninth Revision, Clinical Modification*) were fever, acute appendicitis without mention of peritonitis, neutropenia, abdominal pain, dehydration and pneumonia.

3.2 Multivariate Analyses

The analysis of each independent variable showed that the time in ED less than average ED LOS (p=0.20), ED triage level (p=0.005), PCP status (p=0.079), inpatient admission time (p=0.05**),** ED resident (p=0.04), seen by an attending and resident (p<0.01), season (p=0.075), new pediatric ED implementation (p=0.027), and vital signs (pulse, temperature, pulse oximetry, respiratory rate and sBP) were significant at 0.25 level and were considered in the multivariable model in the next step (3). Age (p=0.90) was considered clinically meaningful and was also included.

The results of fitting the univariable logistic regression models to these data are given in Table 4 below.

Table 4 Univariable logistic regression models (N=6361)

Variables	OR	(95% CI)	p
Gender			
Female	1		
Male	1.04	(0.67-1.62)	0.866
Age categories			
0-1 (yrs)		1	0.898
1-5 (yrs)	0.98	(0.5,1.9)	
5-10 (yrs)	1.28	(0.7,2.5)	
10-15 (yrs)	0.94	(0.5,1.9)	
> 15 (yrs)	0.96	(0.4,2.1)	
Time in Peds ED less than average LOS			
Yes	**1**		
No	**1.35**	**(0.86,2.12)**	**0.192**
Race			
White	1		
Other	1.15	(0.68-1.95)	0.606
ED triage level			
≤ 2	**1**		
> 2	**0.53**	**(0.34,8.83)**	**0.005**
PCP status			
Yes	**1**		
No	**0.37**	**(0.12, 1.17)**	**0.079**
ED Arrival Time			
6:00AM – 2:59PM	1		
3:00PM – 10:59PM	0.98	(0.60-1.60)	0.431
11:00PM – 05:59 AM	0.63	(0.29-1.34)	

Variables [continue(2)]	**OR**	**(95% CI)**	**p**
Inpatient Admit Time			
6:00AM – 2:59PM	**1**		**0.05**
3:00PM – 10:59PM	**2.3**	**(1.04,5.09)**	
11:00PM – 05:59 AM	**1.5**	**(0.66, 3.53)**	
Language –English			
Yes	1		
No	1.06	(0.56-2.03)	0.534
Unknown	0.71	(0.38-1.34)	
Resident			
Non-ED Resident	**1**		
ED Resident	**2.16**	**(1.24,3.76)**	**<0.01**
Unknown	**0.35**	**(0.12-1.04)**	
ED provider			
1; NP	1		
2; EM Attending (PEds Board certified)	0.87	(0.12-6.48)	0.352
3; EM Attending, NON-PEDS certified	0.65	(0.09-4.85)	
4; Other, non, EM attending	1.12	(0.14-8.63)	
Seen by Attending and Resident			
Both	**1**		
Attending only	**0.2**	**(0.07, 0.55)**	**<0.01**
Prior hospitalization			
Yes	1		
No	0.99	(0.58-1.71)	0.99
Implementation of new Pediatric ED			
Yes			
No	**0.41**	**(0.17, 0..92)**	**0.027**
ED observation status			
Yes	1		
No	1.02	(0.41-2.54)	0.966

Variables [continue(3)]	OR	95% CI	p
Season			
Winter		**1**	**0.075**
Spring	**0.45**	**(0.22,0.87)**	
Summer	**0.58**	**(0.32,1.05)**	
Autumn	**0.68**	**(0.39, 1.2)**	
Less than average daily census *(28.6 days)*			
Yes	1		
No	0.99	(0.64-1.55)	0.973
Temp (°C)			
Normal	**1**		**0.03**
Abnormal	**1.69**	**(0.85,3.38)**	
Missing	**0.71**	**(0.43, 1.17)**	
sBP			
Normal	**1**		**0.02**
Abnormal	**1.83**	**(0.91,3.69)**	
Missing	**0.88**	**(0.46,1.67)**	
SpO2			
Normal	**1**		**<0.01**
Abnormal	**3.75**	**(1.11,12.60)**	
Missing	**0.58**	**(0.37,0.92)**	
Pulse			
Normal	**1**		**0.07**
Abnormal	**1.02**	**(0.49,2.11)**	
Missing	**0.60**	**(0.30,1.20)**	
RR			
Normal	**1**		**0.04**
Abnormal	**1.13**	**(0.59,2.15)**	
Missing	**0.60**	**(0.35,1.03)**	

OR = 1, reference group.
**Variables with a value of P < 0.25*
Predictors in bold type are statistically significant.

We then performed a multiple logistic regression with all our variables of interest to verify the importance of each variable in the multivariate model. The results of fitting the multivariable model are given in Appendix - Table 5.

We decided to keep age in the model since the literature shows that age may also interact with the other variables. This gave us our preliminary main effect models with the following independent variables: age, greater than average ED LOS, ED triage level, ED resident, and SpO2. The variables identified using stepwise selection is fairly similar n, but with less variables. We keep the variable *greater than average ED LOS* in the model due to its clinical significance.

We investigate interactions among the variables in the model. The results of applying stepwise variable selection to interactions from the main effects model indicate that no significant interaction entered the model using the 10 percent level of significance and no interaction term was included in the model.

Table 6 shows the OR and 95% CI and p-values for the final logistic regression model:

Table 6 illustrates the results for the final logistic regression model ($p<0.01$)

Variable	OR	95% CI (OR)	p
Age categories			p=0.82
0-1 (yrs)		Reference	~~p=0.82~~
1-5 (yrs)	1.04	(0.53,2.01)	0.922
5-10 (yrs)	1.44	(0.73,2.85)	0.286
10-15 (yrs)	1.14	0.55,2.38)	0.718
> 15 (yrs)	1.05		0.899
Time in Peds ED less than average LOS			p=0.12
Yes		Reference	~~p=0.12~~
No	1.45	(0.92, 2.29)	0.116
ED triage level			p<0.01
≤ 2		Reference	~~p<0.01~~
> 2	0.50	(0.32, 0.78)	0.002
ED Resident			p<0.01

ED Resident		Reference	~~**p<0.01**~~
Non-ED Resident	2.03	(1.15,3.56)	0.014
Unknown	0.34	(0.11,1.00)	0.049
SpO2			**p=0.02**
Normal		Reference	~~**p=0.02**~~
Abnormal	2.95	(0.855, 10.15)	0.087
Missing	0.66	(0.42, 1.03)	0.070
Overall p-value in bold			

In conclusion, we found that <24-hour unplanned ICU-admitted pediatric patients is associated with average length of stay in the ED, triage acuity, resident specialty, and abnormal pulse ox vitals. Independent predictors of unplanned ICU admission included average length of stay in the ED (OR = 1.45, 95% CI= 0.92 to 2.29), resident specialty (OR = 2.03, 95% CI = 1.15 to 3.56), abnormal pulse oximetry (spO2) < 90% (OR = 2.95, 95% CI = 0.56 to 10.15). Lower triage acuity was associated with a lower likelihood of unplanned ICU admission (OR =0.50, 95% CI = 0.32 to 0.78). We did not find significant interactions the predictors of unplanned ICU admission.

3.3 Model Diagnostics

From the Deviance test (p= 0.88), we do not reject the null hypothesis that the observed and expected values are close. Also, examining the observed and estimated expected frequencies within each decile of risk, we see that only 3 of the estimated expected frequencies is less than 5. There is reason to believe that the calculation of the p-value is accurate enough to support the hypothesis that the model fits.

Assessing the discriminative ability, we find that the area under the ROC curve is 0.69. Model has acceptable discriminative ability, Appendix - Figure 3. Finally, the examination of the residual plots indicate that 7 observations has outlying values, and we refit the model by deleting those observation, none of the some of these estimates have changed markedly, and we kept these observations. Thus we conclude that the model fits the data reasonably well.

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4. Discussion

4.1 Conclusion

Pediatric ED visits have been increasing, with approximately 30 million children receiving emergency care in the United States annually with children comprising more than a quarter of all ED visits (Bekmezian, Chung , Cabana, Maselli , Hilton, & Hersh, 2011) and it is possible that we will see a further reduction in ICU bed availability given our current economic climate. This underscores the importance of appropriate ED disposition for pediatric patients.

Unplanned ICU transfer in our patient population was a relatively rare event (less than 2%). This model investigated only 22 potential predictors of unplanned ICU admission.Patient-level and physician-level predictors were independently associated with unplanned ICU admission. The exploratory analyses that we conducted suggested that less than 24-hour unplanned ICU-admitted pediatric patients is associated with average length of stay in the ED, triage acuity, resident specialty, and abnormal pulse ox vitals in the ED. Our findings do show as initially posited that longer length of ED stay, higher acuity patients, resident training and vital signs are associated with unplanned pediatric ICU admission. These results have significant clinical face validity, and consideration of these factors may assist the ED physician when determining whether a pediatric patient should be admitted to an ICU or inpatient ward.

Many EDs in the United States and Canada still do not have some of the basic equipment and supplies needed to care for children of all ages (Institute of Medicine, Committee of the Future of Emergency Care in the US Health System, 2006). Optimal emergency care for children is affected by the lack of availability of equipment, appropriately trained staff to care for children, and policies and procedures which justifies ED physician training variable as a good predictor for this outcome (American Academy ofPediatrics, Committee on Pediatric Emergency Medicine, 2007).

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4.2 Limitations

There were several limitations to our analysis. The study is limited in being a single-center, retrospective data analysis which has potential for incomplete and selective documentation in the clinical notes. Limitations of retrospective chart review methods may also contribute non-differential information bias both in the initial recording of data and in the data abstraction process itself. The decision to admit a patient to the ICU is internal to each hospital system and this can generate biases in estimating the predictors of unplanned ICU admission in regards to, more specifically, patient health severity which is observable by the hospital but unobserved in the data. Also, the use of administrative data may not coincide with the decision-making behavior of the ED providers, thereby resulting in information bias arising from misinterpretation of the medical record review. However, prior research has used observational data to measure the impact of ICU admission on patient outcomes (Sprung, et al., 1999) and due to the nature of the outcome; we cannot run a field experiment (e.g. randomized control trial) to examine predictors of unplanned ICU admission.

Also, sample size was small in a single hospital-center. Ideally, future studies will examine whether our findings are reproducible in a larger sample size and across varying practice patterns and settings. Prospective multi-center studies with a large data sample could help to eliminate the limitations of our approach.

Prospective data collection would be ideal but most likely unfeasible as a very low prevalence of unplanned ICU admission after inpatient ward-admission from the ED, is likely to remain the mainstay as it would require an extremely large sample and ample resources to prospectively collect theses data. A possibility is the use of rare outcome modelling strategies e.g.re-logit. (King, Zeng, & Tomz, 1999)

Future studies are needed to assess the predictive influence other baseline characteristics such as laboratory tests or other not well known clinical factors associated with the outcome variable. Collection of patient's reason for admission prospectively should also be considered for future studies.Use of ED triage level limitation to predict acuity of illness had its limitations due to lack of sensitivity with acuity.

We also have to take into consideration an additional source of information bias, namely the ED boarding selection bias. ED boarding time is defined as the *time between the decision to admit the patient until the patient is discharged from the ED and physically moved to the inpatient unit*. The decision on where to admit the patient (ICU versus general ward) is made somewhere in between, and might change during the ED boarding time. We need to control for the effect of ED boarding time in the outcome model. However, we have data on the actual discharge time, but not the time at which the final decision of where to admit the patient is made. We also do not have any information on how much of the boarding time is due to waiting for an available bed in the corresponding unit. Further studies can capture this effect by including total ED boarding time as an additional independent variable in the outcome model.

Finally, we did not compare patients requiring unplanned ICU admission with those directly admitted to the ICU. This comparison is the necessary next phase of research to formulate admission decision models. Our intent was only to describe the patients requiring unplanned ICU admission and to determine whether there were obvious differences between pediatric patients who ultimately deteriorate on the inpatient ward shared similar outcomes prior to being admitted from the ED.

4.3 Recommendations

Healthcare organizations around the world are challenged by pressures to reduce costs, improve coordination and outcomes, provide ‘more’ with less and be more ‘patient-centric’ or patient –focused. A major challenge in managing critically ill or injured patients is to identify those who would benefit most from admission to ICU, without overwhelming the intensive care service. We do not know whether admitting patients early to the ICU may increase costs, and future analysis should investigate not only patient outcomes but also economic parameters. Unnecessary admissions to the ICU are equally problematic therefore future studies determining the benefit of early admission to ICU to assess mortality and a cost-benefit investigation is warranted.

Better targeting of admissions may result in a more effective use of intensive care facilities, with reduced length of stay in both ICU and hospital, with improved survival.

Another possibility of preventing unplanned ICU admission would be investigating whether the skills within the ICU being made available to the patient on the general ward at an earlier stage, which is beyond the scope of this project. Although our study is limited, it provides information to help design future studies.

5. Bibliography

1. Afessa, B. (2000, April). Triage of patients with acute gastrointestinal bleeding for intensive care unit admission based on risk factors for poor outcome. *J Clin Gastroenterol*, *30*(3), 281-5.
2. American Academy ofPediatrics, Committee on Pediatric Emergency Medicine. (2007). Access to optimal emergency care for children. *Pediatrics, 119*(1), 161-164.
3. Armagan, E., Yilmaz, Y., Olmez, O. F., Simsek, G., & Gul, C. B. (2008, December). Predictive value of the modified early warning score in a turkish emergency department. *Eur J Emerg Med, 15*(6), 338-40.
4. Bekmezian, A., Chung , P., Cabana, M., Maselli , J., Hilton, J., & Hersh, A. (2011, Feb). Factors associated with prolonged emergency department length of stay for admitted children. *Pediatr Emerg Care, 27*(2), 110-5.
5. Benjamin C. Wedro, M. F. (2013, November 18). *Children's Health Center*. Retrieved June 13, 2014, from eMedicineHealth: http://www.emedicinehealth.com/pediatric_vital_signs/article_em.htm
6. Blecher, G., Mitra, B., Cameron, P., & Fitzgerald, M. (2008, May). Failed emergency department disposition to the ward of patients with thoracic injury. *Injury, 39*(5), 586-91.
7. Bradman, K., & Maconochie, I. (2008, December). Can paediatric early warning score be used as a triage tool in paediatric accident and emergency? *Eur J Emerg Med*, *15*(6), 359-60.
8. Brandt , C. P., Coffee, T., Yurko, L., Yowler, C. J., & Fratianne, R. B. (2000, January). Triage of minor burn wounds: Avoiding the emergency department. *J Burn Care Rehabil, 21*, 26-8.
9. Capuzzo, M., Moreno, R., & Alvisi, R. (2010, October). Admission and discharge of critically ill patients. *Curr Opin Crit Care, 16*(5), 499-504.
10. Considine, J., Thomas, S., & Potter, R. (2009, April). Predictors of critical care admission in emergency department patients triaged as low to moderate urgency. *J Adv Nurs.*, *65*(4), 818-27.
11. Dawson, J. A. (1993, July). Admission, discharge, and triage in critical care. Principles and Practice. *Crit Care Clin.*, *9*(3), 555-74.
12. Dawson, S., & Runk, J. A. (2000, August). Right patient? right bed? A question of appropriateness. *AACN Clin Issues, 11*(3), 375-85.
13. Delgado, M. K., Liu, V., Pines, M. J., Kipnis, P., Gardner, N. M., & Escobar, G. J. (2013, January). Risk Factors for Unplanned Transfer to Intensive Care Within 24 Hours of Admission From the Emergency Department in an Integrated Healthcare System. *Journal of Hospital Medicine, 8*(1), 13-19.
14. Farley, H., Zubrow, M. T., Gies, J., Kolm, P., Mascioli, S., Mahoney, D. D., et al. (2010, July). Emergency Department Tachypnea Predicts Transfer to a Higher Level of Care in the First 24 hours After ED Admission. *Acad Emerg Med, 17*(7), 718–722.
15. Frost , S., Alexandrou, E., Bogdanovski, T., Salamonson , Y., Parr, M., & Hillman, K. (2009, February). Unplanned admission to intensive care after emergency hospitalisation: Risk factors and development of a nomogram for individualising risk. *Resuscitation, 80*(2), 224-30.

16. Garrouste-Orgeas, M., Montuclard, L., Timsit, J., Misset, B., Christias, M., & Carlet, J. (2003, May). Triaging patients to the ICU: A pilot study of factors influencing admission decisions and patient outcomes. *Intensive Care Med, 29*(5), 774-81.
17. Gerber, D. R., Schorr, C., Ahmed, I., Dellinger, R. P., & Parrillo, J. (2009, March). Location of patients before transfer to a tertiary care intensive care unit: Impact on outcome. *J Crit Care, 24*(1), 108-13.
18. Goldhill, D. R., & Sumner, A. (1998, August). Outcome of intensive care patients in a group of british intensive care units. *Crit Care Med, 26*(8), 1337-45.
19. Graf, J., & Janssens, U. (2005, April). Still a black box: What do we really know about the intensive care unit admission process and its consequences? *Crit Care Med, 33*(4), 901-3.
20. Groarke, J. D., Gallagher, J., Stack J, J., Aftab A, A., Dwyer, C., McGovern, R., et al. (2008, December). Use of an admission early warning score to predict patient morbidity and mortality and treatment success. *Emerg Med J, 25*(12), 803-6.
21. Hillman, K. M., Bristow, P. J., Chey, T., Daffurn, K., Jacques, T., & Norman, S. L. (2002, November). Duration of life-threatening antecedents prior to intensive care admission. *Intensive Care Med, 28*(11), 1629-34.
22. Institute of Medicine, Committee of the Future of Emergency Care in the US Health System. (2006). Emergency Care for Children: Growing Pains. *National Academies Press*.
23. Kennedy, M., Joyce, N., Howell, M. D., Lawrence Mottley, J., & Shapiro, N. I. (2010, October). Identifying infected emergency department patients admitted to the hospital ward at risk of clinical deterioration and intensive care unit transfer. *Acad Emerg Med, 17*(10), 1080-5.
24. King, G., Zeng, L., & Tomz, M. (1999, October 1). *RELOGIT: Rare events Logistic Regression*. Retrieved Feb 15, 2014, from Cambridge, MA : Harvard University: http://gking.harvard.edu/
25. Levin, P. D., & Sprung, C. L. (2001, September). The process of intensive care triage. *Intensive Care Med, 27*(9), 1441-5.
26. Levin, P. D., & Sprung, C. L. (2006, April). Intensive care triage--the hardest rationing decision of them all. *Crit Care Med, 34*(4), 1250-1.
27. Liu, V., Kipnis, P., Rizk, N., & Escobar, G. J. (2012, March). Adverse outcomes associated with delayed intensive care unit transfers in an integrated healthcare system. *Journal of Hospital Medicine, 7*(3), 224-230.
28. Oregon Health & Science University. (2013). *Healthcare Stats 2011-12 fiscal year*. Retrieved May 6, 2014, from Oregon Health & Science University: http://www.ohsu.edu/xd/health/who-we-are/
29. Oregon Health & Science University. (n.d.). *Healthcare Stats 2011-12 fiscal year*. Retrieved May 6, 2014, from Oregon Health & Science University: http://www.ohsu.edu/xd/health/who-we-are/
30. Richardson, J. D., Franklin, G., Santos, A., Harbrecht, B., Danzl, D., Coleman, R., et al. (2009, May). Effective triage can ameliorate the deleterious effects of delayed transfer of trauma patients from the emergency department to the ICU. *J Am Coll Surg, 208*(5), 671-8.

31. Sax, F. L., & Charlson, M. E. (1987, May). Utilization of critical care units. A prospective study of physician triage and patient outcome. *Arch Intern Med, 147*(5), 929-34.
32. Song-Hee, K., Chany, C. W., & Olivares, M. (2014, April 23). *ICU Admission Control: An Empirical Study of Capacity*. Retrieved May 6, 2014, from http://www.columbia.edu/~cc3179/ICUadm_2014.pdf
33. Sprung, C. L., Geber, D., Eidelman, L. A., Baras, M., Pizov, R., Nimrod, A., et al. (1999, June). Evaluation of triage decisions for intensive care admission. *Crit Care Med, 27*(6), 1073-9.
34. Task force of the american college of critical care medicine, society of critical care medicine. (1999, March). Guidelines for intensive care unit admission, discharge, and triage. *Crit Care Med, 27*(3), 633-8.
35. Tomz, M., King, G., & Zeng, L. (1999, October). *RELOGIT:Rare Events Logistic Regression, Version 1.1 Cambridge, MA: Harvard University*. Retrieved from http://gking.harvard.edu/
36. Vanhecke, T. E., Gandhi, M., McCullough, P. A., Lazar, M. H., Ravikrishnan, K. P., Kadaj, P., et al. (2008 Mar, March). Outcomes of patients considered for, but not admitted to, the intensive care unit. *36*(3), 812-7.
37. Vlayen, A., Verelst, S., Beekering, G. E., Schrooten, W., Hellings, J., & Claes, N. (2011). Exploring unplanned ICU admissions: a systematic review. *9*. Retrieved from http://www.joannabriggslibrary.org/index.php/jbisrir/issue/view/85

6. Appendices

Table 1 Normal vital signs for the pediatric population

Age	sBP	Pulse	RR
0-3 mos	65-85	100-150	35-55
3-6 mos	70-90	90-120	30-45
6-12 mos	80-100	80-120	25-40
1-3 yr	90-105	70-110	20-30
3-6 yr	95-110	65-110	20-25
6-12 yr	100-120	60-95	14-22
≥ 12 yr	110-135	55-85	12-18
(Benjamin C. Wedro, 2013)			

Table 2 summarizes the categorical independent variables of patients admitted to ICU (unplanned) and non-ICU beds

categorical independent variables	Unplanned ICU admissions N (%)*	Non-ICU beds N (%)*
PATIENT-LEVEL VARIABLE		
Female	35 (1.2)	2,807 (98.8)
Male	45 (1.3)	3,474 (98.7)
Age categories (years)		
0-1	16 (1.2)	1,295 (98.8)
1-5	20 (1.2)	1,654 (98.8)
5-10	19 (1.6)	1,199 (98.4)
10-15	14 (1.2)	1,202 (98.8)
> 15	11 (1.2)	931 (98.8)
Time in Peds ED less than average LOS *(311.5min)*		
Yes	49 (1.1)	4277 (98.9)
No	31 (1.5)	2004 (98.5)
Race		
Other	18 (1.4)	1265 (98.6)
White	62 (1.2)	5016 (98.8)

categorical independent variables [continued (2)]	**Unplanned ICU admissions N (%)***	**Non-ICU beds N (%)***
ED triage level		
≤ 2	39 (1.8)	2114 (98.2)
>2	41 (1.0)	4167 (99.0)
PCP status		
Yes	77 (1.3)	5682 (98.7)
No	3 (0.5)	599 (99.5)
Prior hospitalization		
Yes	17 (1.3)	1331 (98.7)
No	63 (1.3)	4950 (98.7)
Mortality		
Yes	4 (19.0)	17 (81.0)
No	76 (1.2)	6264 (98.8)
Primary Language –English		
Yes	57 (1.3)	4254 (98.7)
No	11 (1.4)	773 (98.6)
Unknown	12 (0.9)	1254 (99.1)
ED observation status		
Yes	5 (1.2)	400 (98.8)
No	75 (1.3)	5881(98.7)
Temperature (°C)		
Abnormal	14 (2.4)	579 (97.6)
Normal	22 (1.4)	1496 (98.6)
Missing	44 (1.0)	4206 (99.0)
sBP		
Abnormal	24 (2.1)	1095 (97.9)
Normal	12 (1.2)	1004 (98.8)
Missing	44 (1.0)	4182 (99.0)
SpO2		
Abnormal	3 (6.0)	47 (94.0)
Normal	36 (1.7)	2114 (98.3)
Missing	41 (1.0)	4120 (99.0)

categorical independent variables [continued (3)]	**Unplanned ICU admissions N (%)***	**Non-ICU beds N (%)***
Pulse		
Abnormal	28 (1.7)	1607 (98.3)
Normal	10 (1.7)	585 (98.3)
Missing	42 (1.0)	4089 (99.0)
RR		
Abnormal	18 (1.9)	945 (98.1)
Normal	20 (1.7)	1189 (98.3)
Missing	42 (1.0)	4147 (99.0)
PHYSICIAN-LEVEL VARIABLE		
Resident		
ED Resident	16 (0.9)	1817 (99.1)
Non-ED Resident	60 (1.9)	3154 (98.1)
Unknown	4 (0.3)	1310 (99.7)
ED provider		
1; NP	1 (1.6)	63 (98.4)
2; EM Attending (PEds Board certified)	33 (1.4)	2383 (98.6)
3; EM Attending, NON-PEDS	31 (1.0)	2993 (99.0)
4; Other, non, EM attending	15 (1.8)	842 (98.2)
Seen by Attending and Resident		
Both	76 (1.5)	4971 (98.5)
Attending only	4 (0.3)	1310 (99.7)
SYSTEM-LEVEL VARIABLE		
ED Arrival Time		
6:00AM – 2:59PM	25 (1.4)	1819 (98.6)
3:00PM – 10:59PM	46 (1.3)	3415 (98.7)
11:00PM – 05:59 AM	9 (0.9)	1047 (99.1)
Inpatient Admit Time		
6:00AM – 2:59PM	7 (0.7)	992 (99.3)
3:00PM – 10:59PM	48 (1.6)	2960 (98.4)
11:00PM – 05:59 AM	25 (1.1)	2329 (98.9)

categorical independent variables [continued (4)]	**Unplanned ICU admissions N (%)***	**Non-ICU beds N (%)***
Season		
Winter	29 (1.8)	1547(98.2)
Spring	12 (0.8)	1441(99.2)
Summer	18 (1.1)	1649(98.9)
Implementation of new Pediatric ED at OHSU on April 1st 2009		
Yes	74 (1.4)	5226 (98.6)
No	6 (0.6)	1055 (99.4)
Less than average daily census *(28.6 days)*		
Yes	45 (1.3)	3521 (98.7)
No	35 (1.3)	2760 (98.7)
(*PERCENTAGE OF EACH GROUP; NOT BASED ON TOTAL SAMPLE)		

Table 2 summarizes the Continuous Independent variables

Independent Variable *(continuous)*	**N**	**Mean**	**Std Deviation**	**Min**	**Max**
ED LOS(min.)	6361	311.48	271.79	17	6595
ED Pediatric daily census	1705	28.56	50.58	5	56
Temperature (°C)	2111	37.24	1.35	2.9	40.9
sBP	2135	68.21	13.75	7	146
Pulse	2230	121.57	32.77	44	220
RR	2172	26.94	11.18	10	120
Pulse ox	2200	98.35	3.35	35	100

Figure 2 Outline of patient selection and composition of patient groups

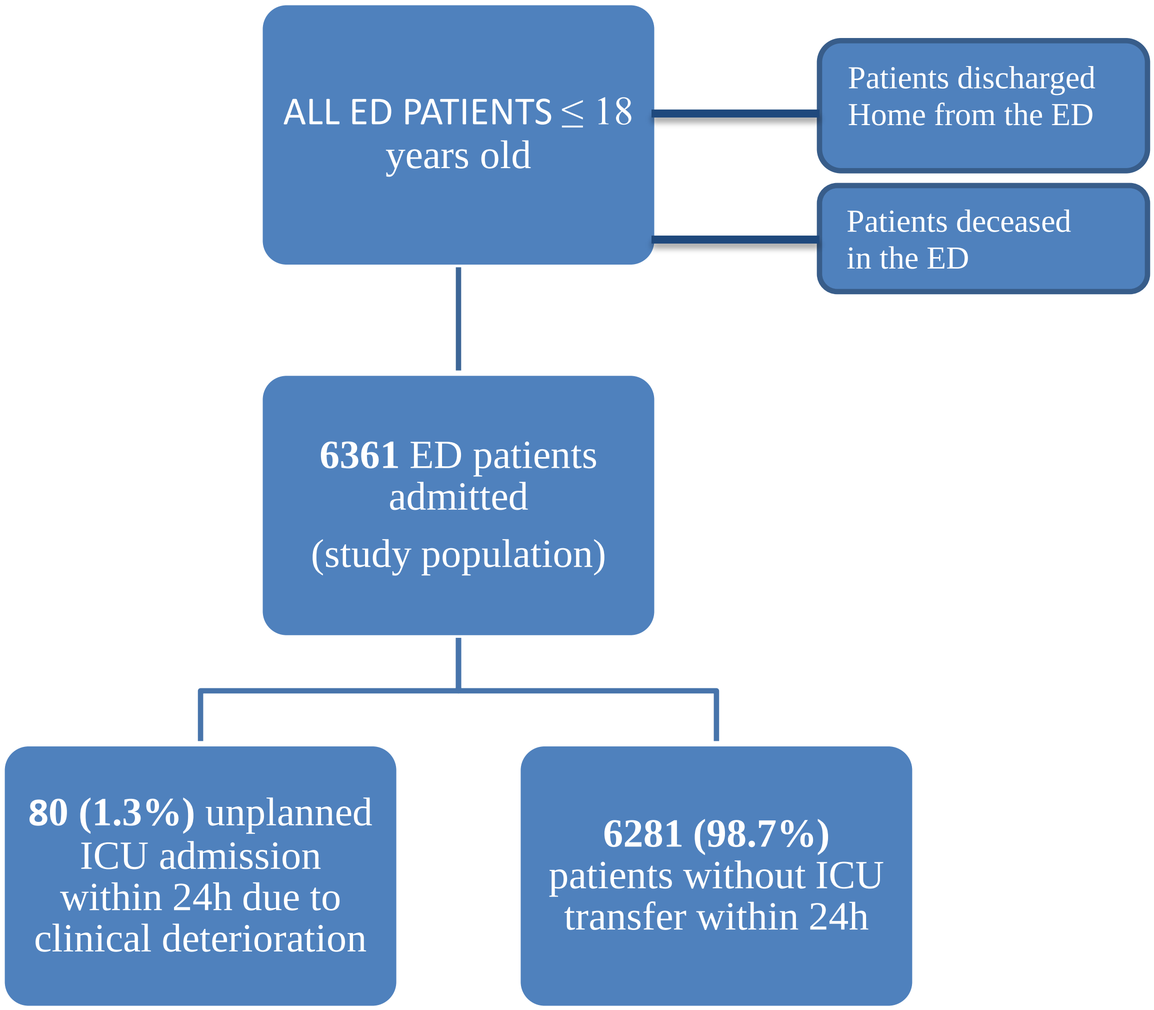

Table 5 Results of fitting a multivariable model containing the independent variables significant at the 0.25 level (N=6361)[#]

Variable	OR	95% CI (OR)	p
Age categories			
0-1 (yrs)		Reference ** ** **	
1-5 (yrs)	0.98	(0.50,1.93)	0.96
5-10 (yrs)	1.45	(0.73,2.89)	0.29
10-15 (yrs)	1.21	(0.57,2.57)	0.62
> 15 (yrs)	1.13	(0.50,2.54)	0.77
Time in Peds ED less than average LOS	1.56	(0.97,2.50)	0.07

Variable	OR	95% CI (OR)	p
ED triage level			
≥ 2		Reference ** ** **	
< 2	0.53	(0.33,0.84)	<0.01
Variable	**OR**	**95% CI (OR)**	**p**
PCP status	0.39	(0.12,1.25)	0.11
Inpatient Admit Time			
6:00AM – 2:59PM		Reference ** ** **	
3:00PM – 10:59PM	1.85	(0.81,4.22)	0.14
11:00PM – 05:59 AM	1.18	(0.50.2.82	0.70
ED Resident			
ED Resident		Reference ** ** **	
Non-ED Resident	1.86	(1.05,3.30)	0.03
Unknown	0.31	(0.10,0.95)	0.04
Seen by Attending and Resident	*	*	*
Season			
Winter		Reference ** ** **	
Spring	0.45	(0.23,0.91)	0.03
Summer	0.62	(0.34,1.15)	0.13
Autumn	0.71	(0.40,1.27)	0.25
Implementation of new Pediatric ED	0.45	(0.19,1.08)	0.08
Temp (°C)			
Normal		Reference ** ** **	
Abnormal	1.66	(0.78,3.51)	0.185
Missing	1.35	(0.41,4.48)	0.620
sBP			
Normal		Reference ** ** **	
Abnormal	1.87	(0.91,3.87)	0.090
Missing	1.93	(0.54, 6.94)	0.314
SpO2			
Normal		Reference ** **	

		**	
Abnormal	3.08	(0.83, 11.40)	0.092
Missing	0.34	(0.051, 2.26)	0.263
Pulse			
Normal		Reference ** ** **	
Abnormal	0.77	(0.35, 1.71)	0.529
Missing	2.81	(0.40, 19.73)	0.299
RR			
Normal		Reference ** ** **	
Abnormal	0.83	(0.41, 1.67)	0.602
Missing	0.45	(0.068, 2.93)	0.401

#*Log likelihood = --396.0396* **omitted, collinearity* ~~** reference group~~

Table 7 Top 20 Reasons for admission of admissions to intensive care units (ICUs) from emergency departments (EDs)

Direct admissions to inpatient from EDs (n=6281)

ADMITTING_DX_NAME	n	%
Fever, unspecified	265	4.22
Acute appendicitis without mention of peritonitis	258	4.11
Neutropenia, unspecified	230	3.66
Abdominal pain, unspecified site	189	3.01
Dehydration	174	2.77
Pneumonia, organism unspecified	171	2.72
Mechanical complication of nervous system device, implant, and graft	111	1.77
Other convulsions	100	1.59
Acute bronchiolitis due to respiratory syncytial virus (RSV)	89	1.42
Unspecified asthma, with exacerbation	84	1.34
Acute bronchiolitis due to other infectious organisms	81	1.29
Vomiting alone	76	1.21
Closed fracture of supracondylar humerus	76	1.21
Headache	71	1.13
Acute appendicitis with generalized peritonitis	67	1.07
Intussusception	66	1.05
Drug induced neutropenia	63	1.00
Other disturbance of temperature regulation of newborn	60	0.96
Abdominal pain, right lower quadrant	60	0.96
Other postoperative infection	56	0.89

Indirect admissions to ICU from EDs (n = 80)

ADMITTING_DX_NAME	n	%
Fever, unspecified	4	5
Hypoxemia	4	5
Dehydration	3	3.75
Epileptic grand mal status	3	3.75
Mechanical complication of nervous system device, implant, and graft	3	3.75
Acute bronchiolitis due to respiratory syncytial virus (RSV)	2	2.5
Altered mental status	2	2.5
Hemolytic-uremic syndrome	2	2.5
Hyperosmolality and/or hypernatremia	2	2.5
Pneumonitis due to inhalation of food or vomitus	2	2.5
Unspecified septicemia	2	2.5
Acquired hypertrophic pyloric stenosis	1	1.25
Acute and subacute necrosis of liver	1	1.25
Acute bronchiolitis due to other infectious organisms	1	1.25
Acute myocarditis, unspecified	1	1.25
Acute pulmonary manifestations due to radiation	1	1.25
Atrial fibrillation	1	1.25
Autonomic dysreflexia	1	1.25
Cerebral aneurysm, nonruptured	1	1.25
Closed fracture of base of skull without mention of intracranial injury, brief (less than one hour) loss of consciousness	1	1.25

Figure 3 Receiver Operating Characteristic curve

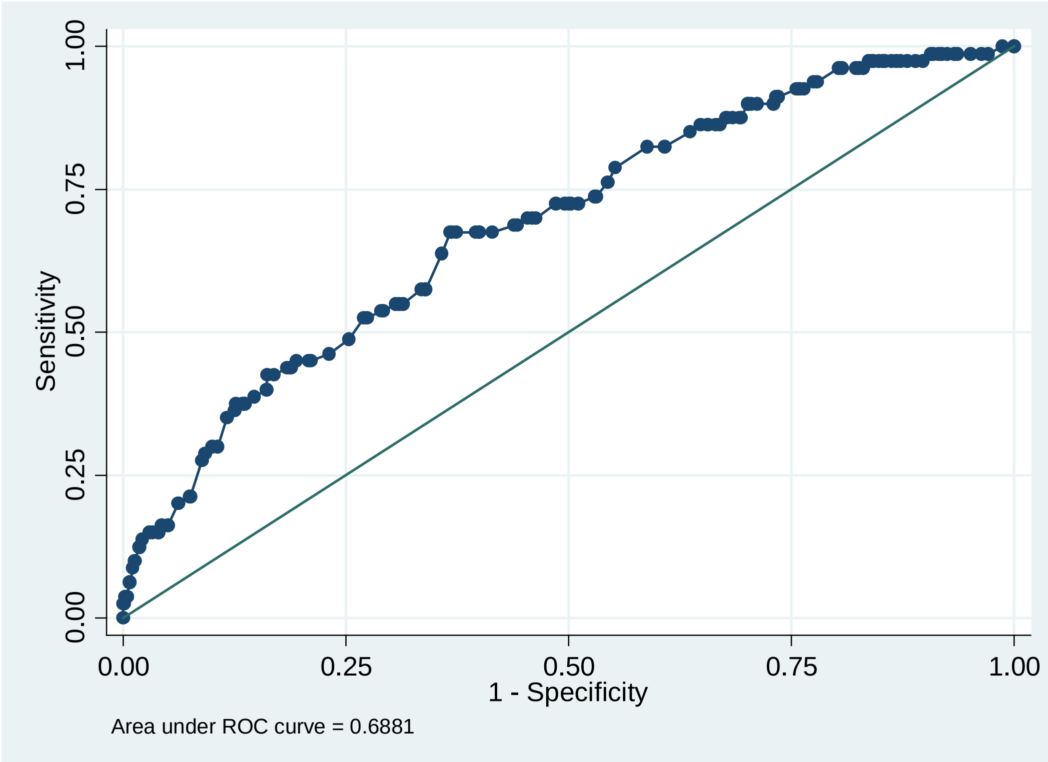

Table 8 Characteristics of Admitted Pediatric Patients 2008-2012 Based on Actual Sample Size of 6361 ED Visits

	Percent %	(Min, Max)
Age		
0-1	20.61	(0, 0.99)
1-5	26.32	(1, 4.99)
5-10	19.12	(5, 9.99)
10-15	14.81	(10, 14.99)
> 15	19.15	(15, 18.99)

Table 9 List of inpatient units and description with distribution outcome variable

Units	Unit description	Unplanned ICU admissions (n)	Non-ICU beds (n)
5A	Adult Abdominal Transplant, Plastics and Gyn	0	10
5C	Short Stay Surgical unit (both Peds and Adults)	0	6
7C	Trauma ICU	0	4
9N	This is primarily a Medical unit including Endocrine, Family Medicine, GI, Pulmonary and Neurology	37	2305
9S	Primarily a Surgical unit including Cardiology, Cardiothoracic Surgery, ENT,OMFS, Ortho, Peds Surgery, Plastics, Renal, Trauma and Urology	14	2279
10A	EGS unit	0	39
10K	NSU, ENT, Neurology and OMFS	0	20
10N	NSU and Pediatric patients who require a higher level of care	24	839
10S	Heme/Oncology and BMT	2	689
11K	Medical/Surgical Cardiac and Vasc	1	7
12C	DNCC or Neonatal Intensive Care new unit since last year	0	5
13A	Trauma and EGS	0	42
13C	Mother/Baby Unit	0	7
13K	Adult Oncology	0	8
14A	General Surgery	1	16
14C	Mother/Baby Unit	0	4
14K	Adult Bone Marrow Transplant Unit	1	1