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Derivation and Preliminary Validation of a Risk Score to Predict 30-Day Emergency Department Revisits for Sickle Cell Pain

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Abstract

Background—ED revisits and 30-day readmissions have been proposed as markers for quality-of-ED-care for Sickle Cell Disease (SCD).

Objective—To create a scoring system that quantifies the risk of 30-day revisit after ED discharge for SCD vaso-occlusive pain

Methods—This was a dual-center retrospective derivation and validation cohort study. The derivation was performed at an academic, tertiary care center and the validation at an urban community hospital. The primary outcome was revisit to the ED within 30-days after an ED discharge for SCD pain. Recursive partitioning was used to derive a scoring system to predict 30-day revisits.

Results—Of a total 1456 ED visits for SCD pain, there were 680 ED discharges (admission rate of 53%) in 193 unique individuals included in the derivation cohort. There were 240 (35.3%) 30-day revisits. Of a total 126 ED visits for SCD there were 79 ED discharges in 41 unique individuals in the validation cohort. The final risk score included 4 variables: 1) age, 2) insurance status, 3) triage pain score and 4) amount of opioids administered during the ED visit. Possible scores range from 0–6. The areas under the receiver operating characteristic curves were 0.746 (95% CI 0.71–0.78 - derivation cohort) and 0.753 (95% CI 0.65 – 0.86 – validation cohort). A cutoff of 4 or greater identified 60% of 30-day ED revisits in the derivation cohort and 80% of revisits in the validation cohort.

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Conclusions—A risk score can identify ED visits for SCD pain with high risk of 30-day revisit.

Keywords

Sickle Cell Disease; Risk Score; Pain

1. Introduction

Sickle Cell Disease (SCD) is an inherited blood disorder that affects approximately 100,000 individuals in the United States.[1] While manifestations occur in every organ system, painful episodes are the most common complication of SCD [2,3] and acute care visits due to pain account for the majority of hospital admissions and healthcare expenditures.[4–7] Efforts to improve emergency care for sickle cell pain have focused on hospital readmission rates and ED revisit rates as markers for quality of care.[8–8]

While there are no published investigations of factors associated with ED revisits, previous studies, limited mostly to large administrative data, have identified important factors associated with higher 30-day readmission rates for SCD pain including: socio-economic deprivation, age, and use of corticosteroids.[9,10] Multi-center retrospective analyses demonstrated that hospital and provider type are not significantly associated with readmission rates.[10–12] Factors associated with lower rates of readmission included inpatient transfusion and successful outpatient follow-up.[10,13] Several reports of quality improvement interventions for SCD pain management exist in the literature with some showing a positive effect on readmission rates,[14–20] however; these were generally implemented for all ED visits rather than focusing on high risk individuals or visits with high risk features.

Understanding factors that are associated with ED revisits for SCD pain is important as this can lead to targeted interventions of potentially modifiable risk factors. Currently there are no established tools available to identify ED visits for SCD pain with high risk of return after discharge.

With this dual center derivation and preliminary validation study, we sought to develop a simple scoring system to predict 30-day ED revisits for acute sickle cell pain. Our hypothesis was that factors associated with an index ED visit (the first visit) could be used to identify visits with high risk for revisit within 30 days. Secondary aims of the study were to determine if admission to the hospital or successful outpatient follow-up had any effect on ED revisit rates in our population. The ability to identify high risk situations can facilitate efficient resource allocation and higher intensity interventions to reduce revisits and readmissions.

2. Methods

2.1 Study Design and Setting

This was a dual-center derivation and validation cohort study of patients with SCD who were discharged from the ED with a diagnosis of SCD pain episode. The derivation cohort was performed at the Mount Sinai Medical Center (MSMC), an academic, tertiary care,

level 2 trauma center in New York City with approximately 106,000 visits annually to the ED. The MSMC SCD clinics have a combined census (adult & pediatric) of 294 patients with an additional 89 individuals who utilize only the ED. The validation cohort was performed at St. Joseph's regional medical center in Paterson, New Jersey. St. Josephs is a busy, urban community hospital with approximately 160,000 annual ED visits. St. Josephs does not have a dedicated SCD clinic, however; several hematologists in the area see patients with SCD. There is no overlap between providers who practice at the two medical centers. The protocol for this study was approved by the Mount Sinai School of Medicine Institutional Review Board and the St. Josephs Regional Medical Center Institutional Review Board. A waiver of informed consent was granted for this observational study.

2.2 Selection of Participants

Derivation Cohort Methods—This study was a retrospective chart review of all visits to the MSMC ED related to SCD between 1/1/2007 and 1/1/2011. Chart abstraction methods and data integrity procedures for the derivation cohort have been described previously and were in accordance with established guidelines for chart reviews in Emergency Medicine.^[21,22] Briefly, individuals who visited the ED during the sampling frame were identified via search of the electronic medical record and a comprehensive review of each individual's medical record (inpatient, outpatient and ED) was performed. A list of 91 clinical and socio-demographic variables (Appendix A) were extracted from each individual's chart and maintained in an SPSS database (see supplemental appendix). Chart abstractors were blinded to the study hypothesis. Opioid doses were converted to IV morphine equivalents according to a standard protocol.^[23] While the initial chart extraction identified all ED visits for all people with SCD, the derivation used only visits for SCD pain (defined below) in which the patient was discharged from the ED.

Validation Cohort Methods—The validation was a retrospective chart review of all visits to the St. Joseph's ED between 4/26/2010 and 11/1/2010. Before the start of the study, definitions were created for all study variables and kept in a manual of operations for the study protocol. Only variables necessary to calculate the derived risk score were extracted for the validation cohort. Chart abstraction was performed by trained, blinded chart abstractors.^[21] Training included a review of study variable definitions, chart abstraction procedures and supervised abstraction of 10 charts. Data were abstracted directly from the electronic medical record into paper case report forms. As with the derivation cohort, in addition to regular meetings with chart abstractors to review study procedures, a 10% sample of charts were double extracted in order to calculate inter-rater reliability with a required kappa above 0.95.

2.3 Definition of Variables

Sickle Cell Disease—SCD was defined as HbSS, SC, S β Thalassemia or S with other hemoglobin variant confirmed by hemoglobin electrophoresis. All electrophoreses were reviewed by a physician trained in transfusion medicine who was blind to the study hypothesis. For individuals with no electrophoresis on file, a review of the patient's laboratory data (for signs of chronic hemolysis, anemia, and organ damage) was performed

by the principal investigator to determine if SCD was likely. Equivocal cases were adjudicated by a second hematologist and excluded if a conclusion could not be reached.

Painful Episode—A painful episode was defined as an ED visit that required treatment with opioids that could not be attributable to a cause other than SCD. For example, a visit for lower abdominal pain in which a urine infection is found would not be coded as a ‘pain episode.’ A visit in which the patient is diagnosed with a urine infection, but also complains of lower back and leg pain similar to prior SCD crises would be coded as ‘painful episode.’ In the event that the abstractor was not sure if a visit met criteria for a painful episode, the chart was reviewed by a second abstractor (an EM physician who was blinded to the study hypothesis).

30-Day Revisit—Revisits to the ED were defined as a return to the ED for acute sickle cell pain within 30 days of discharge. For patients discharged directly from the ED, 30 days were calculated from the time of ED departure. While the derivation included only patients discharged from the ED, secondary analyses included admitted patients. For admitted patients, 30 days were calculated from the time of hospital discharge.

Steady State Values—Steady state values for hemoglobin, fetal hemoglobin, and leukocyte counts were recorded. The standard definition of ‘steady state’ as defined by Ballas et al. was used.^[24]

Statistical Analyses

Statistical analyses were performed in SPSS and SAS 9.3. For the derivation cohort, univariate analyses were performed to determine distributional characteristics and assess for randomness of missing data (variables included in the final score had less than 5% missing values so imputation was not performed). For the derivation, only ED visits for SCD pain in which the patient was discharged from the ED were included. Bivariate analyses with the primary outcome (30-day ED revisit) were performed on candidate variables (selected by the principal investigator) with a clinically or biologically plausible relationship (based upon known SCD pathophysiology and literature) with the outcome variable. For continuous variables, cutoffs were derived using the chi-square interaction detection followed by manual adjustment to ensure cutoffs make sense clinically. Recursive partitioning was used to derive a final scoring system to predict 30-day ED revisits with the goal of minimizing the number of misclassified values in the final cell while maximizing simplicity of the score. Odds ratios at each decision node were rounded to the nearest integer to create the score. Operating characteristics of the derived risk score were calculated on both the derivation and validation cohort. While the initial derivation included all ED discharges for SCD pain, sensitivity analyses were performed to assess for bias from high utilizing patients including a) an analysis that excluded individuals with more than 3 and 12 visits per year, b) an analysis that censored multiple repeat visits within a 30-day time frame such that a maximum of 2 visits within 30 days was included in the analysis.

To determine if admitting a patient to the hospital reduced the likelihood of return visits to the ED for pain, a propensity-adjusted, log-binomial regression was performed using the

method described by Lanehart et al.^[25] A propensity score to quantify the likelihood of admission was derived from the 91 variables in the database including vital signs at admission, vital signs at disposition, laboratory values (with change from baseline) and demographic values. Variables with a p-value below 0.1 were included in a preliminary multi variable model. This propensity score was used to adjust for the fact that visits where patients were admitted differed from those directly discharged. Log-binomial regression with clustering adjustment at the patient level (predictor variables included the derived risk score, propensity of admission score and a binary disposition variable (admitted vs. discharged)) estimated the adjusted effect of admitting a patient on their likelihood of revisiting the ED. Similar analyses were performed to estimate the adjusted effect on revisit rate of successful follow up with a physician within 2 weeks of visiting the ED for pain (defined as any outpatient visit recorded in the medical record).

3. Results

3.1 Characteristics of the Derivation and Validation Cohorts

In the derivation cohort, there were 2,076 ED visits related to SCD by 247 unique individuals during the 4 year sampling frame. There were 1,456 visits for pain (1.40 per patient-year) of which 680 resulted in direct discharge from the ED (admission rate of 53%) with 240 (35.3%) 30-day revisits. The derivation was performed only on these 680 ED discharges (which occurred in 193 unique individuals) as the goal was to predict those who would revisit the ED after discharge (figure 1). In the validation cohort, there were 232 ED visits by 112 unique individuals during the six month sampling frame. There were 126 ED visits for pain (2.21 per patient-year) of which 79 were discharged from the ED (41 unique individuals with admission rate of 37.4%). Laboratory characteristics of the derivation cohort have been described previously.^[22] Demographic characteristics of both cohorts are listed in table 1. Inter-rater agreement was above 95% for all extracted variables.

3.2 Risk Score Derivation

Using recursive partitioning, a risk score involving 4 of the 91 candidate variables was derived (table 2). Final variables included 1) age, 2) insurance status, 3) triage pain score and 4) amount of opioids administered during the ED visit. With respect to insurance, those who were uninsured and those whose insurance was not accepted at the SCD clinic had elevated risk of revisit. Possible scores range from 0 to 6, and the risk of 30-day revisit increases with higher scores (figure 2). The area under the receiver operating characteristic (ROC) curve was 0.746 (95% CI 0.708–0.784 – figure 3). In the derivation cohort, a cutoff of 4 or greater identified 60% of 30-day ED revisits (143 of 240 total revisits, misclassification tables are provided in the supplement). Super high utilizing patients (i.e. those with more than 12 ED visits in one year) were included in the derivation, however in a post-hoc analysis, removal of high utilizers increased the calibration of the model (area under the curve = 0.780, 95% CI 0.739–0.820). An additional analysis was performed with removal of all patients with more than 3 visits in a one year period. This eliminated cases of clustered visits (i.e. an individual visit represents both revisit and an index visit) and did not substantially change the operating characteristics (area under the curve = 0.743, 95% CI 0.692–0.795). Removal of triage pain score from the scoring system (leaving only age,

opioid dose and insurance in the score) and exclusion of visits where the pain score was zero (as these visits were determined to involve medication refills) resulted in an AUC of 0.722 (95% CI 0.679–0.764). We identified 3 visits which were for sickle cell pain but opioids were not administered or prescribed. Inclusion of these additional visits did not change the AUC.

3.3 Risk Score Validation

In the validation cohort, the risk score performed similarly with an area under the ROC curve of 0.753 (95% CI 0.645–0.860). A cutoff of 4 or greater identified 80% (29 of 36) of ED revisits for pain. Only 14 ED visits were followed by successful follow up with an outpatient physician within 2 weeks. The rate of ED revisits for those who did and did not follow up outpatient was not significantly different (38.4% vs. 35.7%, $p = 0.55$). There were only 2 cases where pain score equaled zero at triage. Removal of triage pain score from the scoring system (and removal of the two patients with pain score of zero) did not substantially change the AUC (0.741, 95%CI 0.630–0.852).

3.4 Admission to the Hospital is Not Associated with Fewer 30-Day ED Revisits

A secondary analysis involving both admitted and discharged patients (1456 visits in 247 unique individuals) was performed to assess the effect of admission to the hospital on the risk of 30-day revisit. A propensity score adjusted for clinical differences in visits where patients were admitted vs. discharged (i.e. higher acuity patients were more likely to be admitted). In the propensity-adjusted, multi-variable model, admission to the hospital was not associated with a lower rate of 30-day ED revisits as compared to individuals who were discharged directly from the ED (rate ratio 1.24, 95% CI 0.64–2.40). Additional analyses stratified by risk score, age and gender were performed to compare 30-day revisit rates for those admitted and discharged. Admission to the hospital was not associated with lower rates of 30-day revisit across any of the strata.

4. Discussion

With this dual center study, we report for the first time a derivation and preliminary validation of a tool to identify ED visits for SCD pain with high risk of 30-day return visit. The score is simple and easy to use with only 4 variables (age, insurance status, pain at triage and ED opioid dose) and performed similarly well at an academic medical center with a dedicated comprehensive SCD program and at a community hospital without a SCD program. Further validation will be necessary before the tool would have clinical utility however the findings are still important as this is the first report of which clinical and sociodemographic factors are associated with ED revisits.

The four variables in this risk score provide important insights about the nature of acute care utilization in SCD. Prior studies have demonstrated that age is one of the strongest predictors of ED utilization. Brousseau et al. demonstrated on a national scale that 18–30 year olds have the highest rate of ED utilization for pain and that mortality in this age group is actually rising.[3] Some of this has been attributed to failed transition from pediatric to adult care. With respect to pain score at triage, our analyses identified that any score above

zero was associated with higher rates of revisit. An internal review of records with triage pain of zero revealed that most of those visits were patients with mild sickle cell pain who had run out of medication and presented for refill. Exclusion of these visits and removal of pain score from the model did not substantially change the performance of the score, suggesting that the other factors in the score have greater predictive value for revisits. ED Opioid dose was also directly proportional to ED revisit rate. It is possible that individuals with higher opioid tolerance have more difficulty managing pain with oral medication at home and thus were more likely to return to the ED. It is also telling to note the variables which fell out of the predictive model. Indicators of clinical severity such as vital signs, respiratory symptoms [22,26,27] laboratory results and changes in hematological indices from baseline were strong predictors of the likelihood of admission, however they were not predictive of revisit rate. As the derivation only included discharged patients, this suggests that in both cohorts, clinician discharge of patients who were 'too sick to go home' did not contribute substantially to revisit rates.

While this risk score is the first to report factors associated with ED revisits, unfortunately our analyses did not identify an intervention to reduce revisits. After adjusting for clinical severity and other patient attributes, admission to the hospital for pain control was not associated with lower rates of ED revisit for pain. In contrast to prior literature,¹³ successful outpatient followup within 14 days was not associated with lower revisit rates. This likely reflects the fact that there was no dedicated SCD clinic and that access to private hematologists was limited in the validation cohort. Prior quality improvement interventions have shown that improving quality of pain management in the ED has little effect on ED utilization however increased SCD clinic utilization [16] and SCD Day Hospitals [14,15] substantially effect ED utilization patterns. One potential use for this risk score would be to allocate additional resources to higher risk visits. The choice of score cutoff would also depend on the nature of the intervention. For example, visits with a score of 6 represented only a fraction of total visits (9% of visits in the derivation cohort and 11% in the validation cohort) but were at extraordinarily high risk for return and accounted for a quarter of all revisits. High intensity interventions could be focused on these situations. Potential implementation methods include incorporation of the score into the electronic medical record system, or calculation with a tablet or phone-based app.

This study has a number of limitations. Although there were rigorous data collection methods in place, this was a retrospective study and data were limited to what was documented during the course of standard care. It is possible that prospective data collection could yield a risk score with better calibration as our AUC was approximately 0.75. While this AUC falls into the 'fair' range, the score is still valuable as it can identify the majority of 30-day revisits while excluding the majority of non-revisits. Higher levels of calibration would be required in risk scores for life threatening diagnoses such as pulmonary embolism, cervical spine fracture or syncope. Clinical data regarding inpatient care were not available in this dataset, so the score could not include admitted patients. Additionally, the clinical value of this score is not certain as the performance of the score was not compared to clinician gestalt. A prospective comparison of risk score vs. clinician gestalt would indicate whether the score is appropriate for widespread use beyond using it to target high intensity interventions. Finally, while the score was derived and validated in two centers with

different patients and different providers, additional external validations would strengthen the generalizability of this score.

This study is an important contribution to our knowledge regarding ED utilization for SCD pain. The risk score is simple and has potential to be implemented in the context of an intervention to prevent revisits in high risk situations. Future research is necessary to identify interventions that can modify revisit patterns for high risk ED visits.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Gary Yu Dr.PH had access to the data and performed data analyses for the project including data cleaning, preliminary data analyses, data cleaning, recursive partitioning, and multivariable analyses on the derivation cohort. Dr. Yu did not participate in analyses of data from the validation cohort.

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Figure 1. CONSORT/STROBE diagram of patient flow
Flow diagram for the cohort.

Figure 2. Risk of 30-Day ED Revisit for SCD Pain

The x-axis shows the range of possible risk scores (0–6) and y-axis shows the percentage of patients with 30-day ED revisits for pain in each group. Dark bars indicate derivation cohort, light bars indicate the validation cohort. In both cohorts, a cutoff of 4 or greater identifies the majority of 30-day ED revisits.

Figure 3. Receiver operating characteristics of the 30-Day ED revisit risk score
Receiver operating characteristics of the 30-Day ED revisit risk score. *AUC – Area Under the Curve

Table 1

Demographic and Clinical Characteristics

	Derivation Cohort	Validation Cohort
N	247	112
Total ED visits for pain (discharges only)	1465 (680)	126 (79)
Pain visits/Patient-Year	1.40	2.21
Age in years (SD)	25.3 (13.8)	23.6 (15.8)
Gender (%male)	50.6%	47.3%
On Hydroxyurea	23.5%	NA
Type of Insurance		
Medicaid	71.0%	59.9%
Medicare	5.6%	8.2%
Private Insurance	12.1%	16.4%
Uninsured	11.3%	15.5%
IV morphine equivalents/ED visit (IQR [*])	13.3 mg (4–40)	13.3 mg (5–40)
Triage pain score (SD)	8.02 (2.63)	8.51 (2.01)

* Interquartile range

Table 2

Risk Score

Uninsured	+1
Insurance not accepted by institution's SCD clinic	+1
Triage pain score 1	+1
Age 15	+1
Opioid dose in IV morphine equivalents	
0mg	0
0.1–8mg	+1
8.1–24mg	+2
>24mg	+3