



## Retrospective chart review: Readmission prediction ability of the High Acuity Readmission Risk Pediatric Screen (HARRPS) Tool

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### ABSTRACT

**Background:** Nurse Case Managers utilize adult based readmission risk tools upon admission to identify readmission risk. An evidence-based pediatric readmission tool could not be identified to replicate in the pediatric space, therefore the High Acuity Readmission Risk Pediatric Screen (HARRPS) Tool was developed to fill this gap. The research aim was to develop a risk score algorithm that accurately predicts pediatric readmissions and provide a predictive validation of the HARRPS Tool.

**Method:** This was a single-centered, retrospective chart review study which compared pediatric patients with thirty-day readmissions to those without thirty-day readmissions over a twelve-month period. Sample size ratio of 1:2 was determined via power analysis with an overall sample size of 5371. Each category from the HARRPS Tool was appropriately weighted based upon data from this study to then produce an overall, patient-level risk score, which was summed [allowable range: 0, 14] across all components. Cross validation was used to ascertain the readmission risk predictability.

**Results:** Of the 5306 patients included in the final analysis, 1343 (25.3%) had a thirty-day readmission. Out of nine risk components analyzed, eight were consistent with the literature review findings. Patients with a score of seven or higher had a 54.9% predicted probability of a thirty-day readmission, compared to 13.6% for patients with a risk score of zero. The c-statistic score of the HARRPS Tool was determined to be 0.68 [95% CI, 0.67, 0.69]. Overall, the HARRPS Tool was favorable and provides initial credibility of the tool's predictive power for the general pediatric population.

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### Introduction

Hospital readmissions are considered a quality metric reflective of a hospital's discharge process. Hospitals who serve the Medicare population already face financial penalties through federal programs for selected 30-day readmissions. Adult hospital case managers currently use a variety of readmission risk stratification tools (Kansagara et al., 2011). A readmission risk tool performed at time of admissions allows for the right patients to receive the right services at the right time, and truly allows for discharge planning to begin at time of admission.

There are approximately 13 readmission risk stratification tools available for adult populations; however, these tools have low sensitivity in predicting readmission. Despite the low sensitivity, low versus high risk scores on these tools do have an association in readmission rates (Kansagara et al., 2011). This means that although adult tools are correlated to readmission rates, they have approximately a 63–76% chance of actually detecting a patient who will have a readmission

(Choudhry et al., 2013; Low et al., 2015; Robinson, 2016; Wallace, McDowell, Bennett, Fahey, & Smith, 2016).

Use of an adult-based tool is inappropriate for the general pediatric population, as these tools primarily rely on a comorbidity list specific to adult conditions not typically seen in the pediatric population, such as dementia and chronic obstructive pulmonary disease. Adult tools neglect the comorbidities that place pediatric patients at risk for readmission, therefore are not valid for the overall pediatric population. Readmissions are an indicator of quality of care and screening pediatric patients early in their stay can lead to targeted interventions leading to a successful discharge. Implementation of a readmission risk stratification tool at Children's Mercy Hospital is a stepping-stone in the effort to reduce pediatric readmissions. The High Acuity Readmission Risk Pediatric Screen (HARRPS) Tool, identifies hospitalized pediatric patients who are at risk for inpatient readmissions.

*Available knowledge: Pediatric readmissions impact*

It is estimated that preventable 30-day readmissions for the overall pediatric population has a nationwide annual cost of \$1.5 billion (Gay et al., 2015). If preventable readmissions can be identified early during the index admission, transitional care activities can occur in attempts

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to reduce the risk of readmission and the overall costs of readmissions. In addition to system costs, readmissions create unnecessary risk to patients, are inconvenient for families, and often reflect a poor ability of the hospital to effectively transition patients to their medical neighborhoods. Pediatric patients at risk for readmission must be identified by Nurse Case Managers during inpatient admissions.

Readmission rates within adult and pediatric hospitals are considered a national quality measurement both by the Centers for Medicare and Medicaid Services and the Pediatric Quality Measures Program (Bardach et al., 2013; Berry et al., 2013; Eichler, 2013; Gay et al., 2015; Hain et al., 2013; Nakamura et al., 2014; Nelson & Pulley, 2015; Payne & Flood, 2015; Tuso et al., 2013). It is estimated that approximately 20% of all pediatric readmissions are preventable, and actions should be implemented during an index admission to decrease the occurrences of all preventable readmissions (Hain et al., 2013; Nakamura et al., 2014; Payne & Flood, 2015). In fact, the federal Partnership for Patients initiative has encouraged all pediatric hospitals to decrease their readmission rate by 20% (Berry et al., 2013). The evidence available for how to prevent pediatric readmissions is very minimal, but some suggest implementation of care coordination during index admissions and focusing on high risk children (Bardach et al., 2013; Hain et al., 2013; Hudson et al., 2014; Nakamura et al., 2014; Nelson & Pulley, 2015; Tuso et al., 2013).

### Rationale

Nurse Case Managers possess the skills and expertise to facilitate care coordination and transition of care from the inpatient to outpatient setting. Not every inpatient admission needs a Nurse Case Manager, and an essential skill of a Case Manager is the patient selection process. For adult Case Managers, it is considered best practice to utilize a readmission screen tool upon index admission. According to Nelson and Pulley (2015), the Pra tool (Probability of repeated admission tool) and the LACE index are the best tools to predict adult 30-day inpatient readmissions and emergency department visits. Eichler (2013) found the LACE tool allows hospitals to focus their resources where most needed and has potential to be modified into a screening tool to identify high-risk patients needing more intensive care coordination (Leng Low, Yun Tan, & Hock Lee, 2013). Although readmission risk instruments are considered best practice for adult Case Managers, there is not an evidence-based pediatric readmission risk instrument that is multifactorial. Current research has shown some correlation between admission diagnosis and readmission probability. Jovanovic, Radovanovic, Vukicevic, Van Poucke, and Delibasic (2016) and Gay et al. (2015) concluded that pediatric readmission risk can be determined by predictive models looking at admission diagnosis. Berry et al. (2013) examined 568,845 admissions from 72 different children's hospitals and concluded high levels of variation when looking at readmission rates associated to admission diagnosis. The HARRPS tool examined additional risk factors outside of the admission diagnosis.

### Study aims

The aim of the study was two-fold: Cross-validate current literature review findings to identify if the factors within the HARRPS tool were attributed to higher rates of readmission; and to assign statistically significant numeric values to each factor to produce a stratified risk score.

### Methods

The retrospective chart review was conducted from May 1, 2017 through June 1, 2018 at Children's Mercy Hospital, a freestanding Mid-west urban pediatric hospital system with over 15,000 pediatric admissions annually. The study collected data over an entire year to account for seasonal variations in patient clinical symptoms throughout any given year. For this study, index admission was defined as the initial

admission preceding a readmission visit. Inclusion criteria included patients aged <18 years of age at time of index admission, classified as inpatient and/or observation at time of index visit and patients with a completed HARRPS Tool during index admission. Patients with subsequent readmissions were included. Exclusion criteria included patient charts with incomplete HARRPS Tool questions and patients who expired between index admission and 30-day data collection period.

### Interventions

The HARRPS tool was developed in 2016 via a thorough literature review of current factors associated to pediatric readmissions. The literature at the time of the review demonstrated the following factors were attributed to pediatric readmissions: admission diagnosis; quantity of chronic conditions; readmission history; admission to an intensive care unit; type of insurance; caregiver language; and presence of home medical equipment, nursing, or therapy. Prior to the current research study, the HARRPS tool included questions related to the factors above and did not include a stratified risk score. The tool was completed by Nurse Case Managers within 24-h for all inpatient and observation status hospitalizations. Specific nurse case management interventions were not associated to the outcome of the screen tool's results during the study.

### Study of interventions

The research study was a retrospective chart review of all HARRPS tools completed within a 12-month period. The study group included pediatric patients readmitted to the hospital within 30 days of an index (initial) admission. The control group were patients not readmitted within 30 days of an index admission. Readmission was defined as a subsequent visit within 30 days for the admission types of inpatient and observation. The findings from the study were used to attribute numerical values to each component of the HARRPS Tool, thus creating a risk stratification tool able to calculate a readmission risk score attributed to a low, medium, and high-risk group. No case management interventions were performed during the research phase that might have unintentionally skewed the data related to predicting readmissions.

Based on data analysis from a previously performed quality improvement project, there was an average of 167 readmissions each month, which led to the study group sample size of approximately 2000 patients. The study group included those patients readmitted within 30 days. Appropriate sample size was determined by using a two-sample comparison based on the 12-month period and the assumption of an alpha of 0.05 ( $p < .05$ ) and power of 80%. The key takeaways from the power analysis demonstrated increasing the number of controls beyond a 1:2 ratio would not gain much statistical benefit, therefore a 1:2 sample size provides 80% power. Over the course of 12-months, the 30-day readmission (study group) sample size equaled 1358 patients, and the non-readmission (control group) sample size equaled 3992. *P*-value was determined by running the likelihood ratio chi-square test for the categorical bivariate analysis.

### Measures

The data source for this study was the Cerner Electronic Health Record, which is the electronic health record system for all patients who visit Children's Mercy Hospital, as well as where the electronic version of the HARRPS Tool is located. The data were de-identified through the Business Objects reporting tool, pulling all selections made on the HARRPS Tool for both the study group and control group. The study group included all pediatric patients readmitted within 30 days, and the control group included a random sample of pediatric patients not readmitted within 30 days.

The random sample was obtained by initially running a report of all eligible patients, and then randomly selecting the correct number of patients (4000 patients over one year, or 334 patients each month). Once the medical record numbers were randomly selected from Excel, the Data Analyst re-ran the report only using the identified medical record numbers. The final report provided to the research team was de-identified to exclude patient health information.

### Analysis

Data analysis occurred in a tiered approach that involved validating the responses from each factor on the HARRPS tool, assigning numeric scores to statistically relevant factors, summing the scores to produce a total stratified risk score, identifying a high-risk threshold, identifying a moderate risk threshold, and cross-validating the overall risk score with the readmitted population. All data analysis was performed using SAS 9.4 statistical software (SAS Institute Inc., Cary, NC).

Unadjusted logistic models were used to evaluate each response on the tool. The factors of insurance type, home medical equipment, home nursing, and home therapy had the potential of having multiple options. Therefore, frequency tables were also used with these factors to identify if higher rates of readmission were associated to specific overlaps or quantity of services. Based on these findings, weighted scores were assigned to each category to produce an overall stratified risk score.

Logistic regression models were used to understand the relationship between risk score, modeled as a continuous predictor, and the likelihood of 30-day readmissions. The coefficients from the logistic model were used to contrast risk scores in order to determine cut-points and derive risk categories. These cut points ultimately produced the three risk categories of low, moderate, and high risk.

K-fold analysis was completed for cross validating the odds of pediatric 30-day readmissions based on the risk score; ten folds ( $k$ ) were used with  $k-1$  folds serving as the training set while the remaining fold was the validation set. Predicted probability of readmission and  $c$ -statistics were calculated for all logistic models.

### Ethical considerations

The study received a non-human subjects research determination by the local Institutional Review Board (IRB). No conflicts of interest were identified.

### Results

The following categories associated to pediatric readmission prevalence were analyzed during the research study: Admission diagnosis; chronic condition indicator; readmission history; admission acuity level; insurance type; caregiver language; and presence of durable medical equipment, nursing, or therapy. Out of nine categories analyzed, eight were found to have statistical significance with the readmission study group compared to the non-readmission control group. Caregiver language did not demonstrate statistical significance between the two study groups. Based upon  $p$ -values, prevalence rates, and logistic procedure models, values were attributed to each category. The sum of all values results in a maximum HARRPS score of 14. Logistic regression modeling demonstrated that a score of seven or higher indicated an increased likelihood of pediatric readmission (55.4%,  $p < .0001$ ) when compared to patients with a score between three and six (34.3%,  $p < .0001$ ), while a score less than three was indicative of a lower likelihood (17.6%,  $p < .0001$ ). The overall HARRPS Tool had a  $c$ -statistic score of 0.65 [0.64, 0.66] in predicting pediatric readmission risk. As the overall risk score increases, so does the probability for readmission (Fig. 1).

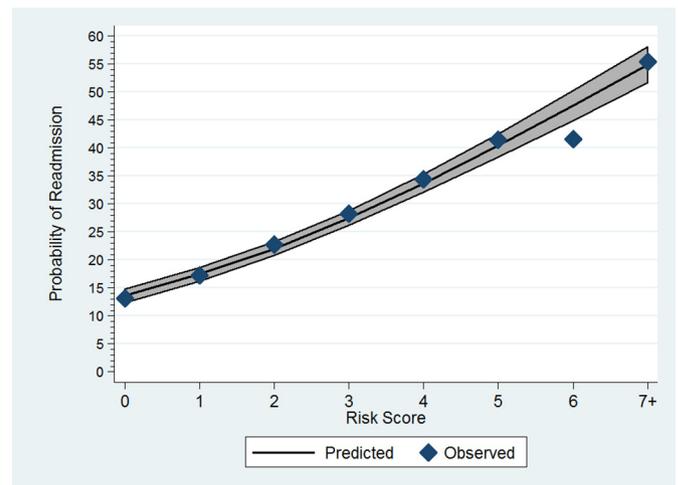


Fig. 1. Predicted versus observed probability of readmission by HARRPS risk score.

### Results by category

The single-site study found six out of the ten admission diagnoses had a  $p$ -value  $< .05$ . Confidence intervals and logistic linear coefficients were compared between a HARRPS tool with admission diagnosis being included and without admission diagnosis being included. Overall the results were similar and the original HARRPS tool including admission diagnosis remains robust in predicting readmission risk (Table 1).

Research findings demonstrated that the Chronic Condition Indicator, as defined by the Agency of Healthcare Research and Quality (Agency for Healthcare Research and Quality, 2018) has a strong predictive power in identifying pediatric patients at risk for readmission. This research demonstrated that there is an increased probability of readmission as a patient's chronic condition indicator increases (Tables 1 & 2).

The acuity factors of being admitted to an intensive care unit (neonatal intensive care unit or pediatric intensive care unit), as well as having an inpatient admission within the last six months of an index admission, demonstrated increased statistical probability of readmission. However, patients who were marked as having "significant psychosocial concerns" and "medical transport from outside facility" did not have increased probability for readmission (Tables 1 & 2).

Pediatric patients with Medicaid or self-pay had a higher probability of readmission compared to those patients with commercial or private insurance. Due to some patients having both commercial and Medicaid insurance, a frequency table was also used to identify those patients with one or both insurances in order to analyze the predictive probability of readmission. Medicaid-only patients made up 48.85% of the overall sample population, self-pay made up  $< 8\%$ , and patients with both commercial and Medicaid made up 3.43% of the overall sample population. Overall, readmission risk was higher for those patients who are self-pay or who have Medicaid insurance, regardless if the Medicaid insurance plan was the patient's primary or secondary insurance (Tables 1 & 2).

Patient or caregiver's primary language was not found to have statistical significance associated to the readmission study group ( $p > .899$ ). Study participants were evaluated to see if their primary language was English, Spanish, or other. Caregiver or patient language does not contribute to the overall HARRPS score.

Data were collected on specific pieces of equipment each patient had in the home at the time of hospital admission. Findings demonstrated no increased readmission probability associated to any one piece of specific equipment. However, there was statistical significance associated to the number of pieces of equipment a patient has in the home. The odds ratio between 1 (0.98,  $p = .903$ ) and 4 or more (2.21,  $p < .0001$ )

**Table 1**  
HARRPS tool prevalence table.

Category	Variable	Control group prevalence <sup>a</sup>	30-day readmission prevalence	p-Value
Admitting diagnosis		n = 3992	n = 1358	
	Other Diagnosis	2898 (72.60%)	974 (71.72%)	0.5354
	Anemia/Neutropenia	24 (0.60%)	18 (1.33%)	0.0135
	Appendectomy	116 (2.91%)	22 (1.62%)	0.0067
	Asthma	238 (5.96%)	19 (1.40%)	<0.0001
	Bronchiolitis	325 (8.14%)	126 (9.28%)	0.1969
	Gastroenteritis	53 (1.33%)	16 (1.18%)	0.6703
	Pneumonia	122 (3.06%)	44 (3.24%)	0.7368
	Seizure	135 (3.38%)	72 (5.30%)	0.0022
	Sickle Cell Crisis	30 (0.75%)	33 (2.43%)	<0.0001
	Upper Respiratory Tract Infection	79 (1.98%)	31 (2.28%)	0.5004
	Ventricular Shunt	19 (0.48%)	14 (1.03%)	0.0327
Chronic condition indicator		n = 3982	n = 1350	
	0	2192 (55.05%)	444 (32.89%)	<0.0001
	1	940 (23.61%)	302 (22.37%)	0.3517
	2	282 (7.08%)	152 (11.26%)	<0.0001
	3	120 (3.01%)	90 (6.67%)	<0.0001
	4+	448 (11.25%)	362 (26.81%)	<0.0001
30-day readmission history		n = 4000	n = 1353	
	Readmitted within 30 days	327 (8.18%)	350 (25.87%)	<0.0001
6 month readmission history		n = 3978	n = 1349	
	Inpatient Admit in last 6 months	702 (17.65%)	621 (46.03%)	<0.0001
Acuity of admission		n = 3978	n = 1349	
	No admission acuity identified	2954 (74.26%)	711 (52.71%)	<0.0001
	ICN/PICU Admission	381 (9.58%)	217 (16.09%)	<0.0001
	Significant psychosocial concern	201 (5.05%)	54 (4.00%)	0.1118
	Medical transport from outside facility	581 (14.61%)	178 (13.19%)	0.1971
Other	13 (0.33%)	13 (0.96%)	0.0069	
Insurance type		n = 3998	n = 1358	
	Self-Pay	327 (8.18%)	102 (7.51%)	0.4303
	Medicaid	1992 (49.82%)	816 (60.09%)	<0.0001
	Commercial/Private	1799 (45.00%)	504 (37.11%)	<0.0001
Caregiver language		n = 4002	n = 1359	
	English	3796 (94.85%)	1289 (94.85%)	0.9961
	Spanish	149 (3.72%)	50 (3.68%)	0.9409
	Other	57 (1.42%)	20 (1.47%)	0.8993
Medical equipment/Supplies count		n = 4008	n = 1363	
	0	3427 (85.50%)	870 (63.83%)	<0.0001
	1	196 (4.89%)	80 (5.87%)	0.163
	2	196 (4.89%)	153 (11.23%)	<0.0001
	3	58 (1.45%)	86 (6.31%)	<0.0001
	4+	131 (3.27%)	174 (12.77%)	<0.0001
Home nursing		n = 4008	n = 1363	
	Private Duty Nursing	105 (2.62%)	113 (8.29%)	<0.0001
	Skilled Nursing	31 (0.77%)	31 (2.27%)	<0.0001
Home therapy		n = 4008	n = 1363	
	Home Occupational Therapy	67 (1.67%)	70 (5.14%)	<0.0001
	Home Physical Therapy	71 (1.77%)	71 (5.21%)	<0.0001
	Home Speech Therapy	40 (1.00%)	43 (3.15%)	<0.0001

<sup>a</sup> Variances in n values due to missing data from automated data pull. Since data was de-identified, lost ability to manually review charts for missing data information.

pieces of equipment incrementally increased, demonstrating increased probability of readmission as the quantity of equipment increases. The frequency of readmissions started to taper off around four pieces of equipment; therefore, the cut point was placed at four or more pieces of equipment.

Detailed data were also collected on every patient related to the type of home nursing and/or therapy present in the home at time of the hospital admission. Research compared the readmission probability, as well as frequency tables for skilled nursing, private duty nursing, physical therapy, occupational therapy, and speech therapy. Based on frequency tables, readmission probability did increase if the patient had any one kind of home nursing or any one type of therapy. Increased readmission risk ( $p < .0001$ ) was present for all types of nursing and therapy; therefore, a single point was attributed to the presence of nursing, regardless of nursing type. Similarly, a single point was attributed to the presence of any type of therapy, regardless if the therapy was physical, occupational, or speech therapy.

#### Cross validation of risk score

Proceeding evaluation of the individual factors, values were attributed to each category producing a total stratified risk score of 14. Statistical models were performed to first identify what score is attributed to having a high risk for readmission. The prevalence of 30-day readmissions gradually increased from zero to seven, with prevalence plateauing after seven (Fig. 2). When compared to a score of seven, the logit coefficients for scores of eight or higher was non-distinguishable. These findings demonstrated that patients with a score of seven or more were homogenous and represented a high risk of readmission. Additional score distribution models were completed to identify if a low and moderate risk category existed. Findings demonstrated a score distribution difference between the control group (mean = 2.05) and the 30-day readmission group (mean = 4.03). Therefore, three was determined to be the cut point between low and moderate readmission risk (Tables 3 & 4).

**Table 2**  
The logistic regression model – analysis of maximum likelihood estimates.

Category	Variable	Odds ratio	p-Value	95% confidence interval	
				Lower	Upper
Admission diagnosis	<i>At-risk admission diagnosis present</i>	0.92	0.264	0.79	1.07
Chronic condition indicator score	0	-ref-	-	-	-
	1	1.43	0.003	1.13	1.81
	2	1.75	0.001	1.27	2.40
	3	1.41	0.004	1.12	1.78
Readmission history	<i>Previous 30-day readmission</i>	1.70	<0.0001	1.38	2.09
	<i>Inpatient admission in last 6 months</i>	2.12	<0.0001	1.76	2.54
Admission acuity	<i>ICN or PICU admit</i>	1.43	0.001	1.17	1.75
Insurance indicator	<i>Self-Pay or Medicaid</i>	1.21	0.007	1.05	1.39
Home medical equipment/Supplies	0	-ref-	-	-	-
	1	0.98	0.903	0.73	1.32
	2	1.43	0.011	1.09	1.88
	3	2.68	<0.0001	1.80	4.01
	4	2.21	<0.0001	1.53	3.19
Home nursing	<i>Skilled Nursing and/or Private Duty</i>	0.75	0.083	0.54	1.04
Home therapy	<i>Physical Therapy, Occupational Therapy, and/or Speech Therapy</i>	0.85	0.401	0.59	1.24

K-fold cross validation was performed between two sets of data to re-valuate probability of readmission between the predicted and the observed group. Based on a threshold criterion of 30%, the risk score variable correctly classified 73% of the outcome variable. The probability of readmission gradually increased as the score increased to seven. A score of one has a readmission probability of 17% ( $p < .0001$ ) compared to a score of seven that has a 55% ( $p < .0001$ ) readmission probability (Fig. 1).

## Discussion

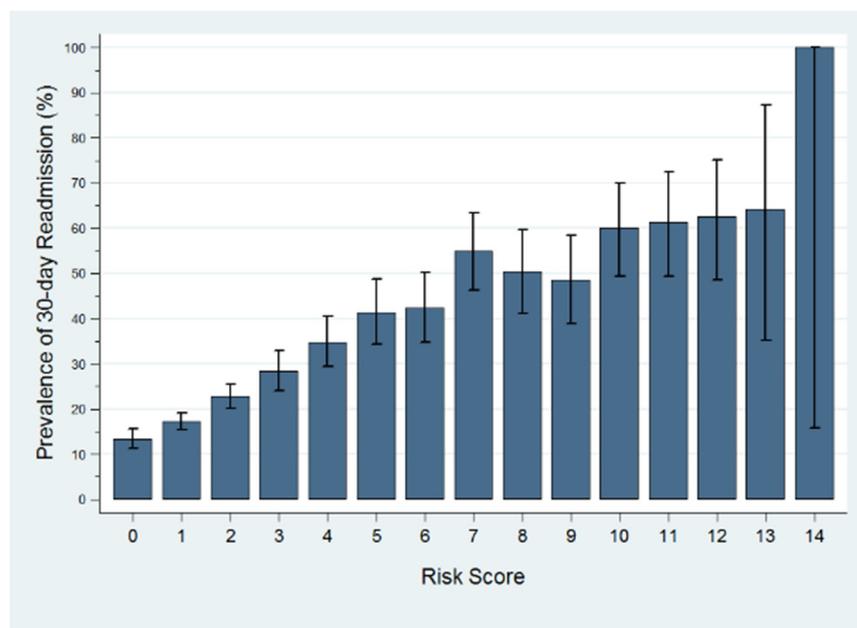
The aim of the study was to validate the initial version of the HARRPS Tool and to identify statistically significant values to contribute to an overall risk score, which then led to the development of the final version

of the HARRPS Tool (Table 5). Planned readmissions are typically associated to specific admission diagnosis, and although this is one category of the tool, it is not the only category of the HARRPS tool. The multiple categories that comprise the HARRPS tool have different weight values associated that help prevent planned readmissions from skewing the results.

Due to the proprietary nature, this was the first study to examine the tool's validity; therefore, no other literature is currently present to compare findings. Although there are currently no other pediatric tools with which to compare, the c-statistic score of the HARRPS Tool (0.65) is comparable to several adult risk tools, such as the modified LACE (0.63), Pra Risk tool (0.65), Cerner's Adult readmission calculation (0.69), and the HOSPITAL Score (0.76). The comparable predictability of the HARRPS Tool provides initial credibility that the HARRPS Tool will provide the same predictive power for the general pediatric population as those tools used for the adult population (Choudhry et al., 2013; Low et al., 2015; Robinson, 2016; Wallace et al., 2016).

During data collection, length of stay for index admission was also tracked, and results demonstrated a statistically significant difference between the control group and the 30-day readmission group. The control group had a median of two days (IQR 1.0,3.0), while the 30-day readmission group had a median of three days (IQR 2.0, 6.0). The HARRPS Tool is currently designed to capture readmission risk at time of admission, when a patient's length of stay is unknown. A relationship between length of stay and admitting diagnosis was not evaluated during this validation study. However, these findings may have future impact if the tool were to be used later during an admission.

Much of the current literature around pediatric readmissions revolve around admission diagnosis. The list of admission diagnoses for the HARRPS Tool was pulled from the study by Gay et al. (2015) which evaluated 1,719,617 hospitalizations from 58 Children's Hospitals. The findings demonstrated that the top ten diagnoses made up 26.4% of all readmissions, suggesting that although these diagnoses are relevant in readmission prevalence, there are additional risk factors that contribute to pediatric readmissions. Our findings were similar in that admission diagnoses were shown to have slight statistical significance, but the other factors within the HARRPS Tool have more weight in predicting pediatric readmissions. Potentially preventable readmissions accounted for 27.6% of the overall study population, aligning with Berry et al. (2013) study where potentially preventable



**Fig. 2.** Prevalence of 30-day readmission by HARRPS risk score.

**Table 3**  
Relationship between HARRPS risk score and odds of 30-day readmission.

Risk score (possible = 14)	Odds ratio	p-Value	95% confidence interval	
			Lower	Upper
0	0.13	<0.0001	0.09	0.19
1	0.17	<0.0001	0.12	0.24
2	0.24	<0.0001	0.17	0.35
3	0.32	<0.0001	0.22	0.48
4	0.44	<0.0001	0.29	0.66
5	0.58	0.014	0.37	0.89
6	0.60	0.027	0.38	0.94
7	-ref-	-	-	-
8	0.83	0.459	0.51	1.36
9	0.77	0.319	0.47	1.28
10	1.23	0.448	0.72	2.08
11	1.30	0.372	0.73	2.29
12	1.36	0.339	0.72	2.57
13	1.47	0.507	0.47	4.62
14	>999.99	0.966	<0.001	>999.99

readmissions accounted for 27.7% of the overall pediatric readmissions. This list of potentially preventable pediatric diagnoses account for 27.3% of the total cost associated to pediatric readmissions (Gay et al., 2015), so although these diagnoses are attributed to high cost, the study suggests that the natural course of a specific diagnosis may not be the only cause of higher rates of readmission.

The purpose of this study was to validate the HARRPS Tool as it is today. Additional analysis was performed after the study to see if the HARRPS Tool's predictive probability would increase if the admission diagnosis was removed. The analysis showed similar results, providing further justification that the initial conclusions of the HARRPS Tool including admission diagnosis remain robust. However, this has led to discussion that a future research study may be of value to evaluate if the HARRPS Tool can be used in the ambulatory space without the need to evaluate an admission diagnosis.

Caregiver and patient's primary language did not have any predictive probability associated to readmissions within this study. Due to a literature review demonstrating readmission correlation between non-English speaking and English speaking, this category will remain on the expanded version of the HARRPS Tool with a value of zero. This will allow further research to continue to see if there is an overall risk difference and to see if future findings necessitate the need to modify the HARRPS risk score (Table 1).

Limited research was available discussing the relationship between readmissions and complex patients with home services and equipment. Therefore, the research team collected very specific data to allow for

detailed statistical evaluation of whether readmission is related to specific types of services or equipment or to the quantity of services in the home. When examining the frequency distributions, it was determined that there is readmission risk associated with the quantity of equipment in the home, rather than types of equipment in the home. These findings transitioned this category from examining specific equipment in the home to examining how many pieces of equipment are in the home at the time of admission (Tables 1 & 2).

As discussed in the results above, readmission probability increased when a patient had the presence of home nursing or therapy, regardless of the type. Findings demonstrated a readmission risk for patients that had either skilled or private duty nursing. There was not a statistical difference in risk between the two types of home nursing. Therefore, the screen question was simplified to ask if a patient has nursing in the home, regardless of the type. Similar findings were attributed to home therapies. Readmission risk was more associated to the presence of any type of therapy, and risk did not increase with more than one therapy present in the home. This resulted in simplification from screening for individual therapies to screening for presence of any type of therapy (Tables 1 & 2).

#### Limitations

Some limitations were identified with this study. Due to electronic system limitations, the data collected were dependent upon selections made by a licensed Nurse Case Manager. Quality improvement methods

**Table 4**  
Odds ratio for low, moderate, and high risk groups on HARRPS tool.

Risk group	Odds ratio	p-Value	95% confidence interval		Predicted prob.	95% confidence interval	
			Lower	Upper		Lower	Upper
Low (score: 0–2)	0.409	<0.0001	0.351	0.477	17.6%	16.4%	18.9%
Moderate (score: 3–6)	ref-	-	-	-	34.3%	31.5%	37.2%
High (score: ≥7)	2.378	<0.0001	1.939	2.916	55.4%	51.5%	59.4%

**Table 5**  
HARRPS tool.

Category	Response	Score attribute
Admitting diagnosis (single select; max value = 1)	No high-risk admitting diagnosis	0
	Patient has one or more of the following admission diagnoses: Anemia/Neutropenia, Appendectomy, Asthma, Bronchiolitis, Gastroenteritis, Pneumonia, Seizure, Sickle Cell Crisis, Upper Respiratory Tract Infection, or Ventricular Surt	1
Chronic condition indicator <sup>a</sup> (single select; max value = 3)	0	0
	1	0
	2	1
	3	2
	4+	3
Readmission history (single select; max value = 2)	No history of readmission within last 6 months	0
	History of readmission within last 30 days	2
	History of readmission within last 6 months	1
Acuity of admission (single select; Max value = 1)	No acuity identified at admission	0
Insurance type (multi-select; max value = 1)	ICN/PICU Admission	1
	Commercial/Private	0
Number of home equipment/Supplies (single select; max value = 4)	Medicaid or Self Pay	1
	No equipment/medical supplies in home	0
	1	1
	2	2
	3	3
	4+	4
	Does patient have in-home therapy or nursing? (multi-select; max value = 2)	None
	Therapy (PT, OT, and/or Speech)	1
	Nursing (Skilled and/or Private Duty)	1
Total		— / 14

Low risk: 0–2; moderate risk: 3–6; high risk: 7–14.

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<sup>a</sup> Chronic Condition Indicator as defined by AHRQ: [https://www.hcup-us.ahrq.gov/toolssoftware/chronic\\_icd10/chronic\\_icd10.jsp](https://www.hcup-us.ahrq.gov/toolssoftware/chronic_icd10/chronic_icd10.jsp).

were utilized to increase reliability of the form's accuracy and completion rates, but a potential still exists for data points to unintentionally be documented incorrectly. Selections were made based on available documentation within the electronic health record. At the time of admission, all available patient information was not always readily available when completing the screen. Consideration was made for the patient encounter type of inpatient and observation as it relates to defining a readmission.

Due to the study being deemed as a non-human subjects project by the IRB, all samples were required to be masked prior to receiving the results. <1% of the samples obtained from the automated data pull had missing values. This resulted in each category assessed having different denominator values. Since the data was masked, it was impossible to go back into these charts to manually review the actual data point. Therefore, the data was excluded from final analysis. In addition to missing data points, the current report was only designed to look for 30-day readmissions where the index admission and studied admission were an inpatient or observation encounter type. The organization also has an encounter type of extended stay; however, due to reporting limitations, these patients had to also be excluded from the data. Patient demographics were not collected, therefore can not be reported as part of the study.

## Conclusions

The research demonstrated that readmission risk can be predicted utilizing the HARRPS Tool within a pediatric acute hospital setting. Implementation of the HARRPS Tool can help identify pediatric patients who would most greatly benefit from higher levels of intervention to ultimately reduce readmission rates.

## CRedit authorship contribution statement

**Sarah Bradshaw:** Conceptualization, Methodology, Software, Validation, Investigation, Writing - original draft, Visualization, Project administration. **Blair Buening:** Conceptualization, Methodology, Validation, Investigation, Writing - review & editing, Visualization. **Anita Powell:** Conceptualization, Methodology, Validation, Investigation, Writing - review & editing, Visualization, Funding acquisition. **Susan Teasley:** Validation, Writing - review & editing, Supervision. **Adrienne Olney:** Validation, Investigation, Resources, Data curation, Writing - review & editing. **Brian Lee:** Software, Validation, Formal analysis, Resources, Data curation, Writing - review & editing.

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