

# Hospital Readmission in Children With Complex Chronic Conditions Discharged From Subacute Care

## AUTHORS

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## KEY WORDS

children with medical complexity, complex chronic conditions, health care utilization, hospital readmission, subacute facility

## ABBREVIATION

CCC: complex chronic conditions

Dr Jurgens conceptualized and designed the study, collected data, and drafted the initial manuscript; Dr Spaeder conducted the initial analysis and reviewed and revised the manuscript; Dr Pavuluri refined the design of the study and reviewed and revised the manuscript; and Dr Waldman refined the design of the study, assisted with collection of data, and reviewed and revised the manuscript. All authors approved the final manuscript as submitted.

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## abstract

**OBJECTIVES:** Children with complex chronic conditions (CCC) are responsible for a disproportionate number of hospital readmissions. This study sought to determine 30-day hospital readmission rates in children with CCC discharged from a rehabilitation and transitional care hospital and to identify factors associated with increased risk of readmission.

**METHODS:** We conducted a retrospective cohort study identifying children with CCC discharged over an 18-month period from a subacute care facility staffed by hospitalists from a freestanding children's hospital. The primary outcome measure was readmission to the referring acute care hospital within 30 days of the subacute discharge.

**RESULTS:** Of the 272 discharged patients meeting inclusion criteria as children with at least 1 CCC, 19% had at least 1 readmission within 30 days of discharge. On univariate analysis, readmission was associated with the number of home medications ( $P = .001$ ), underlying chronic respiratory illness ( $P < .001$ ), home apnea or pulse oximetry monitor use ( $P = .02$ ), tracheostomy and/or ventilator dependence ( $P = .003$ ), length of stay ( $P = .04$ ), and number of follow-up appointments ( $P = .02$ ). On multivariate analysis, the number of discharge medications was associated with increased odds of readmission (odds ratio: 1.11 [95% confidence interval: 1.03–1.20];  $P = .01$ ). Receiver operating curve analysis identified a cutoff of 8 medications as most associated with readmission; in patients discharged with  $\geq 8$  medications, the hospital readmission rate was 29%.

**CONCLUSIONS:** This is the first known study that investigated hospital readmission rates in children with CCC discharged from a subacute facility and specifically identified the number of discharge medications as a significant risk factor for readmission.

Children with complex chronic conditions (CCC) are defined as children with  $\geq 1$  medical condition that can be reasonably expected to last at least 12 months and to involve either several organ systems or 1 organ system severely enough to require specialty pediatric care and probably some period of hospitalization in a tertiary care center.<sup>1</sup> Children with  $\geq 1$  CCC often have functional limitations and special health care needs, including neurologic impairment and technology dependence.<sup>2–5</sup> With advances in medical technology, the prevalence of CCC has increased over the past 15 years.<sup>4,6,7</sup> Not surprisingly, children with CCC disproportionately use inpatient health care resources, accounting for nearly 20% of hospital admissions and up to 50% of hospital days and charges.<sup>3–5,8–11</sup>

Children with CCC are also more likely than other children to be readmitted after an acute care hospitalization. Although the overall 30-day pediatric readmission rate is ~7%, 30-day hospital readmission rates in children with CCC vary from 13% to 40% based on the degree of medical complexity and technology dependence.<sup>3,12,13</sup> Because hospital readmission accounts for the largest share of subsequent costs after an index hospitalization,<sup>3,14–16</sup> payers are increasingly targeting hospital readmissions to reduce unnecessary health care expenditures.<sup>14,17,18</sup>

Children with CCC discharged from acute care often have complex care plans, including technology dependence, complicated medication regimens, and multispecialty care coordination. These issues can make acute care hospital discharge to home challenging and contribute to increased readmission rates.<sup>2,12,19,20</sup> Thus, some children with CCC are transitioned to subacute pediatric specialty hospitals for transitional medical care as well as focused discharge preparation and teaching. However, we are not aware of any studies to date specifically examining readmission rates or risk factors for patients discharged from subacute care facilities. Previous studies that focused on acute care hospitals found an increased hospital readmission rate in children with an increasing number of CCC, congenital heart disease, respiratory illness, neurologic illness, and dependence on medical technology, as well as demographic factors including female gender, non-Hispanic black race, and public insurance.<sup>3,6,9,10,17</sup>

We hypothesized that readmission risk factors would be similar for patients with CCC discharged from a subacute facility versus discharge from

acute care facilities but that the overall readmission rate would be lower due to the opportunity for more focused discharge preparation at the subacute facility. The objective of the present study was to describe the readmission rate for children with CCC discharged from a subacute facility and to identify associated risk factors.

## METHODS

### Study Setting and Design

We performed a retrospective cohort study of patients discharged to home from a 100-bed, urban, subacute care pediatric facility that provides rehabilitation and transitional care for children with special health care needs. The facility is staffed by hospitalists from its primary referral site, a 303-bed, urban, academic, freestanding children's hospital. Eighty-five percent of patients in the subacute facility come from the primary referral site.

### Study Population

Administrative data were used to identify all children aged <18 years discharged to home from the subacute care facility between December 2009 (when our current electronic medical record was instituted) and August 2011. We reviewed the subacute facility medical records by using the framework of Feudtner et al<sup>1</sup> to identify all children with at least 1 CCC. Specifically, a CCC was defined as any medical condition that can be reasonably expected to last at least 12 months and to involve either several organ systems or 1 organ system severely enough to require specialty pediatric care and probably some period of hospitalization in a tertiary care center. The framework includes a list of possible conditions based on *International Classification of Diseases, Ninth Revision*, codes, categorized

according to organ system (Table 1). We then reviewed the electronic medical record from the referring acute care institution to identify patients readmitted  $\geq 1$  time to the acute care hospital within 30 days of subacute discharge. We excluded patients emergently transferred to an acute care facility, discharged to an outside residential facility rather than home, and patients with planned readmissions.

### Data Collection

Using the medical record and clinical and administrative databases, demographic information and discharge characteristics were identified, including number of and type of chronic medical conditions based on the framework of Feudtner et al,<sup>1</sup> technology dependence, number of discharge medications, number of scheduled follow-up appointments, and home nursing arrangements. The primary outcome was hospital readmission within 30 days of discharge.

### Statistical Analysis

Wilcoxon rank sum testing was used to compare continuous variables;  $\chi^2$  or Fisher's exact tests were used (as appropriate) to compare categorical variables; and multivariate logistic regression analyses were used to adjust for potential confounders. Age was considered an a priori confounder. Demographic or discharge characteristics with  $P$  values <.05 in the univariate analysis were included in the logistic regression analysis. We used receiver operating characteristic curve analysis to determine if specific values of count variables could better predict readmission and determined cutoff values based on optimal sensitivity and specificity. Optimal sensitivity and specificity were defined<sup>21</sup>

**TABLE 1** Categories of CCCs and Corresponding 4-Digit ICD-9 Codes

Category	Subcategory	ICD-9 Code
Neuromuscular	Brain and spinal cord malformations	740.0–742.9
	Mental retardation	318.0–318.2
	Central nervous system degeneration and disease	330.0–330.9, 334.0–334.2, 335.0–335.9
	Infantile cerebral palsy	343.0–343.9
	Muscular dystrophies and myopathies	359.0–359.3
Cardiovascular	Heart and great vessel malformations	745.0–747.4
	Cardiomyopathies	425.0–425.4, 429.1
	Conduction disorders	426.0–427.4
	Dysrhythmias	427.6–427.9
Respiratory	Respiratory malformations	748.0–748.9
	Chronic respiratory disease	770.7
	Cystic fibrosis	277.0
Renal	Congenital anomalies	753.0–753.9
	Chronic renal failure	585
Gastrointestinal	Congenital anomalies	750.3, 751.1–751.3, 751.6–751.9
	Chronic liver disease and cirrhosis	571.4–571.9
	Inflammatory bowel disease	555.0–556.9
Hematologic or immunologic	Sickle cell disease	282.5–282.6
	Hereditary anemias	282.0–282.4
	Hereditary immunodeficiency	279.00–279.9, 288.1–288.2, 446.1
	Acquired immunodeficiency	0420–0421
Metabolic	Amino acid metabolism	270.0–270.9
	Carbohydrate metabolism	271.0–271.9
	Lipid metabolism	272.0–272.9
	Storage disorders	277.3, 277.5
	Other metabolic disorders	275.0–275.3, 277.2, 277.4, 277.6, 277.8–277.9
Other congenital or genetic defect	Chromosomal anomalies	758.0–758.9
	Bone and joint anomalies	259.4, 737.3, 756.0–756.5
	Diaphragm and abdominal wall	553.3, 756.6–756.7
	Other congenital anomalies	759.7–759.9
Malignancy	Malignant neoplasms	140.0–208.9, 235.0–239.9

ICD-9, *International Classification of Diseases, Ninth Revision*.

as those yielding minimal value for  $(1 - \text{sensitivity})^2 + (1 - \text{specificity})^2$ . The type I error was set at 0.05. All calculations were performed by using Stata/IC version 10.1 (Stata Corp, College Station, TX).

### Human Subjects Protection

The protocol for the conduct of this study was reviewed and approved by the institutional review boards at Children's National Medical Center and the research committee at HSC Pediatric Center.

## RESULTS

Of the 429 subacute care facility discharges during the study period, 272 met inclusion criteria as children

with CCC. Of these 272 discharges, 52 (19%) had at least 1 acute care facility readmission within 30 days of discharge, with 44 (85%) readmitted once and 8 (15%) readmitted twice. Patients who did not meet inclusion criteria were admitted to the facility for a variety of other reasons, including a prolonged course of intravenous antibiotics, rehabilitation after an orthopedic procedure, or for brief respite care.

Table 2 describes patient characteristics. Readmitted patients tended to be younger (median age: 11 months [interquartile range: 6–132]) than non-readmitted patients (median age: 22 months [interquartile range: 5–23]), although this difference did not reach

statistical significance ( $P = .06$ ). There were no significant differences in readmission rate according to gender, race/ethnicity, or primary insurance.

Univariate analysis showed increased readmission rates among patients with chronic respiratory conditions ( $P < .001$ ), patients discharged with an apnea or pulse oximetry monitor ( $P = .002$ ), and patients with a tracheostomy, with or without ventilator dependence ( $P = .003$ ). Readmission was also associated with increased length of stay ( $P = .04$ ), number of follow-up appointments ( $P = .02$ ), and number of home medications ( $P < .001$ ).

For the multivariate analysis, a logistic regression model was constructed incorporating significant variables from the univariate analysis and confounding variables (Table 3). Both age and number of medications were significant variables in the multivariate analysis. Controlling for chronic respiratory condition, use of apnea or pulse oximetry monitoring, presence of a tracheostomy and/or ventilator, length of stay, number of medications, and number of follow-up appointments, the logistic regression analysis demonstrated that age was associated with decreased odds of readmission (odds ratio: 0.99 [95% confidence interval: 0.99–1.00];  $P = .034$ ). Specifically, for each additional month of age, the odds of readmission decreased by 1%. Controlling for age, chronic respiratory condition, use of apnea or pulse oximetry monitoring, presence of a tracheostomy and/or ventilator, length of stay, and number of follow-up appointments, logistic regression analysis demonstrated that the number of medications with which a patient was discharged from the hospital was associated with increased odds of readmission (odds ratio: 1.11

**TABLE 2** Univariate Analysis

Characteristic	Overall	Readmission Status		P
		No Readmission	Readmission	
		N (%) (n = 220)	N (%) (n = 52)	
<b>Demographic</b>				
Age, mo	15 (IQR: 5–9)	22 (IQR: 6–132)	11 (IQR: 5–23)	.06
Male gender	58%	131 (60%)	28 (54%)	.45
Public insurance	76%	167 (76%)	40 (77%)	.88
<b>Race/ethnicity</b>				
Black	60%	131 (60%)	31 (59%)	.29
Hispanic	11%	41 (19%)	10 (19%)	
White	19%	27 (12%)	3 (7%)	
Other	10%	21 (9%)	8 (15%)	
<b>Discharge characteristics</b>				
No. of CCC		6 (IQR: 5–8)	7 (IQR: 6–8)	.05
Cardiac		49 (22%)	16 (31%)	.20
Gastrointestinal		142 (65%)	40 (77%)	.09
Neurologic		137 (62%)	28 (54%)	.26
Prematurity		74 (34%)	23 (44%)	.15
Respiratory		106 (48%)	39 (75%)	<.001
No. of medications		6 (IQR: 4–8)	8.5 (IQR: 5–12)	<.001
<b>Technologies</b>				
<b>Gastrointestinal</b>				
Gastrostomy and/or jejunostomy tube		72 (33%)	23 (44%)	.12
Nasogastric tube		50 (23%)	11 (21%)	.81
Ostomy		3 (1%)	0 (0%)	1.0
<b>Neurologic</b>				
Baclofen pump		1 (0.5%)	0 (0%)	1.0
Halo		1 (0.5%)	0 (0%)	1.0
Ventricular shunt		12 (5%)	4 (8%)	.52
<b>Respiratory</b>				
Apnea or pulse oximetry		69 (31%)	28 (54%)	.002
BiPap/CPAP		4 (2%)	0 (0%)	1.00
Nasal cannula		27 (12%)	9 (17%)	.34
Tracheostomy and/or ventilator		33 (15%)	17 (33%)	.003
<b>Other</b>				
Insulin pump		1 (0.5%)	0 (0%)	1.0
Urinary catheter		5 (2%)	1 (2%)	1.0
Vascular access		10 (5%)	4 (8%)	.36
Wound vacuum		0	1 (2%)	.19
PCP identified		121 (55%)	34 (52%)	.11
No. of appointments		5 (IQR: 3–6)	6 (IQR: 4–7)	.02
Home nursing		88 (40%)	25 (48%)	.29
Length of stay, d (range)		24 (13–44)	35 (15–89)	.04

BiPap, bilevel positive airway pressure; CPAP, continuous positive airway pressure; IQR, interquartile range; PCP, primary care physician.

[95% confidence interval: 1.03–1.20]; *P* = .01). Specifically, for each additional medication prescribed at the time of discharge, the odds of readmission increased by 11%.

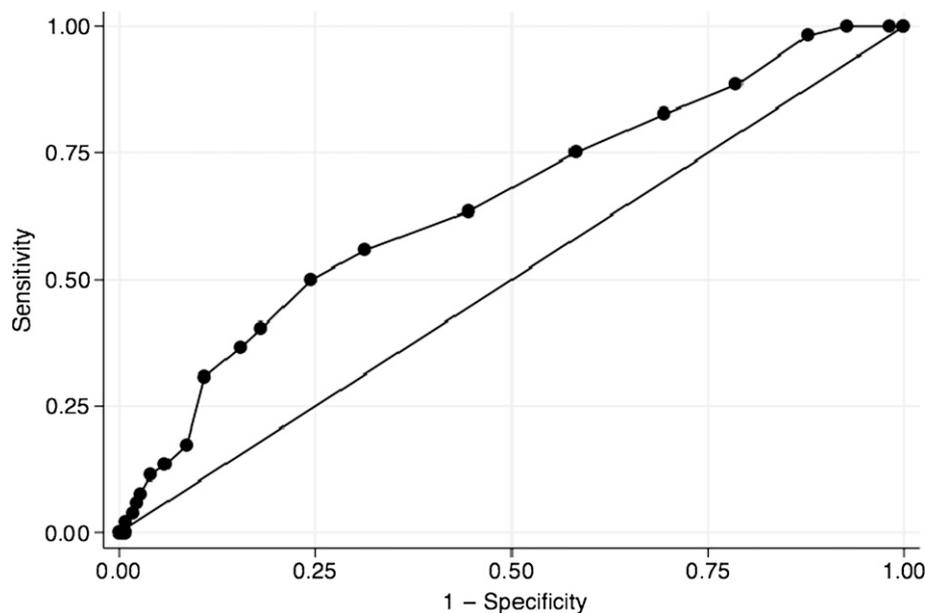
Receiver operating characteristic curve analysis demonstrated that a cutoff of 8 medications best predicted readmission, optimizing sensitivity (56%) and specificity (69%) (Fig 1). The area under the curve was 0.65

(*P* = .04). A cutoff of ≥8 discharge medications yielded a positive likelihood ratio of 1.78 and posttest probability of

readmission of 29%. Thus, in patients discharged with ≥8 medications, the probability of hospital readmission

**TABLE 3** Multivariate Analysis

Variable	Odds Ratio	95% Confidence Interval	P
Age (mo)	0.99	0.99–1.00	.03
Chronic respiratory condition	1.74	0.76–3.94	.19
Apnea and/or pulse oximetry monitor	1.02	0.41–2.55	.97
Tracheostomy and/or ventilator	1.42	0.55–3.67	.47
Length of stay (d)	1.00	0.99–1.00	.28
No. of appointments	1.02	0.89–1.18	.75
No. of medications	1.11	1.03–1.20	.01



**FIGURE 1** Receiver operating characteristic curve analysis. Area under receiver operating characteristic curve: 0.6521.

increased from 19% to 29%. The selection of our cutoff at  $\geq 8$  discharge medications provided the single largest increase in relative probability of readmission (18%) compared with any other cutoff factor.

## DISCUSSION

We found that children with CCC discharged from a subacute facility were readmitted at rates similar to those discharged from acute care facilities. Specific risk factors identified by using univariate analysis included: presence of a chronic respiratory illness, home apnea or pulse oximetry monitor use, tracheostomy and/or ventilator dependence, length of stay, number of follow-up appointments, and number of discharge medications. The number of discharge medications and age both remained significant when controlling for other factors noted in univariate analysis.

The finding from our univariate analysis that children with chronic respiratory illness are at increased risk of

readmission is consistent with previous findings from acute care facilities.<sup>4,13</sup> Unlike these studies, however, we found no association with demographic factors (eg, female gender, older age, black race, public insurance) and neurologic conditions.<sup>20</sup> This outcome could be in part attributable to the relative homogeneity of our sample compared with the acute care populations previously studied.

We suspect that the positive correlation between the number of follow-up appointments and readmission risk may reflect an underlying relationship between patient complexity or fragility and the extent of follow-up required, although the study does not specifically examine this relationship. Follow-up appointments are also an important time for provider reassessments, medication adjustments, technology evaluation, and testing. Although it is reasonable to suspect that missed appointments may put patients at risk for readmission, we do not have data

regarding nonadherence with follow-up appointments. Nonetheless, interventions such as transportation assistance for outpatient appointments, increased home nursing support, ongoing case management, and enhanced communication with the outpatient medical team may warrant further study.

Our multivariate analysis identified a positive correlation between hospital readmission and number of discharge medications. Previous research that focused on medication reconciliation in admitted children with CCC found errors in 1 in 5 medications, affecting more than one-half of patients.<sup>22</sup> These errors included omissions as well as incorrect frequencies and doses. An additional study in the outpatient setting identified multiple prescriptions as a significant risk factor for adverse drug events.<sup>23</sup> Although difficulties with medication procurement, maintenance, education, administration, monitoring, or adverse drug events may increase the risk of hospital readmission, our study did not specifically examine whether readmissions were medication related. However, interventions to reduce medication-related readmission risk (eg, enhanced medication teaching, assistance with medication procurement) may be useful areas for future study.

Comparing readmission rates for children with CCC discharged from subacute versus acute care facilities is complicated by the fact that there may be unmeasured differences between the 2 hospital populations. For example, the clinical decision to discharge a patient to subacute care, rather than directly to home, may be related to the presence of psychosocial or socioeconomic risk factors such as

poor housing conditions, inadequate financial resources, and poor health literacy. Although subacute care discharge processes may mitigate these risk factors, many are likely to persist at discharge. These are difficult factors to identify, quantify, and study, and they comprise an important direction for further study.

Our study has several limitations. Although our sample was powered for the primary outcome, our sample size limited comparison among patients with different numbers of readmissions. This trial was also a single-center study focused on discharges from subacute rehabilitation and transitional care facility followed by admission to a single acute care facility. Although the acute care facility is the largest regional provider of inpatient pediatric care for CCC and the primary referral center for the subacute care facility, some patients may have been admitted to other institutions and not counted as readmissions in our study.

## CONCLUSIONS

To the best of our knowledge, this is the first study to identify readmission rates and risk factors for CCC discharged from a subacute pediatric facility. The readmission rate from this single subacute care institution was similar to readmission rates from acute care hospitals. The presence of at least 8 discharge medications was associated with increased readmission risk. Although future studies are needed to characterize any preventability of these readmissions, subacute hospitals may want to consider enhancing discharge-planning processes for patients with high number of discharge medications.

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