Original Article

Unplanned Readmissions in Children with Medical Complexity in Saudi Arabia: A Large Multicenter Study

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Abstract

Background: Children with medical complexity (CMC) account for a substantial proportion of healthcare spending, and one-third of their expenditures are due to readmissions. However, knowledge regarding the healthcare-resource utilization and characteristics of CMC in Saudi Arabia is limited.

Objectives: To describe hospitalization patterns and characteristics of Saudi CMC with an unplanned 30-day readmission.

Methodology: This retrospective study included Saudi CMC (aged 0–14 years) who had an unplanned 30-day readmission at six tertiary centers in Riyadh, Jeddah, Dammam, Alahsa, and Almadina between January 2016 and December 2020. Hospital-based inclusion criteria focused on CMC with multiple complex chronic conditions (CCCs) and technology assistance (TA) device use. CMC were compared across demographics, clinical characteristics, and hospital-resource utilization.

Results: A total of 9139 pediatric patients had unplanned 30-day readmission during the study period, of which 680 (7.4%) met the inclusion criteria. Genetic conditions were the most predominant primary pathology (66.3%), with one-third of cases (33.7%) involving the neuromuscular system. During the index admission, pneumonia was the most common diagnosis (33.1%). Approximately 35.1% of the readmissions were after 2 weeks. Pneumonia accounted for 32.5% of the readmissions. After readmission, 16.9% of patients were diagnosed with another CCC or received a new TA device, and the in-hospital mortality rate was 6.6%.

Conclusion: The rate of unplanned 30-day readmissions in children with medical complexity in Saudi Arabia is 7.4%, which is lower than those reported from developed countries. Saudi children with CCCs and TA devices were readmitted approximately within similar post-discharge time and showed distinct hospitalization patterns associated with specific diagnoses. To effectively reduce the risk of 30-day readmissions, targeted measures must be introduced both during the hospitalization period and after discharge.

Keywords: Child, children with medical complexity, chronic illness, complex chronic conditions, mortality, patient readmission, pneumonia, technology assistance, Saudi Arabia

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INTRODUCTION

Recent advances in pediatric care have increased the survival of children with medical complexity (CMC).[1] CMC are children with one or more complex chronic conditions (CCCs), each involving an organ system and lasting >1 year. These children depend on one or more technology assistance (TA) devices for life-sustaining functions such as ventilation and feeding. Thus, they are fragile and require frequent hospital admissions and multiple follow-ups, which result in high healthcare expenditure, as found in international and local studies.[1-4]

Despite constituting a small portion of the pediatric population, they incur a disproportionate amount of healthcare costs, accounting for one-third of all pediatric healthcare expenditures, and one-third of this expenditure is attributed to readmissions.[2,5,6] There is a growing global interest in understanding the patterns and factors contributing to CMC readmissions to reduce their rates and associated costs. In fact, readmission rates serve as a healthcare quality performance indicator utilized by the majority of children's hospitals, as readmission may indicate suboptimal discharge care.[7]

According to previous studies from developed countries, CMC are at risk of readmissions due to multiple factors including the degree of medical complexity, as reflected by the number of CCCs, use of TA devices, and polypharmacy (defined as the use of ≥5 medications), and fragmentation of care.[5,8,9] Therefore, optimizing the quality of care provided to CMC may help reduce their readmission.

CMC remain understudied and their unplanned readmissions have not been investigated previously in Saudi Arabia. We hypothesize that the proportion of readmitted CMC in Saudi Arabia is higher than the international rate because of both medical and non-medical factors. This hypothesis is attributed to the socially acceptable parental consanguinity, which plays a role in certain genetic diseases that lead to medical complexity and fragility, such as congenital heart diseases, neurometabolic disorders, and hemoglobinopathies.[10] The prevalence of congenital and acquired neurological disorders, followed by hematological and respiratory diseases, are other contributing factors among Saudi children.[11] In centers with established complex care programs, >70% of the enrolled CMC have chronic neurological disorders.[12] In addition, sickle cell disease, which causes pediatric morbidity and mortality, is prevalent in Saudi Arabia.[13] In the United States, sickle cell disease readmissions have been identified as the highest among condition-specific readmissions for the same index admission diagnosis.[14] Further, the larger family size in Saudi Arabia than the average Western families[15] may impose an additional burden on families with CMC, contributing to high readmission rates.

Thus, this study aimed to examine Saudi CMC as a subgroup of all unplanned pediatric 30-day readmission, their demographics, clinical features, and analyze their hospitalization patterns and outcomes. The findings will aid in the development of more effective condition-specific inpatient management strategies and tailored post-discharge plans to reduce readmission rates and healthcare costs and improve the overall quality of care provided to CMC.

METHODOLOGY

Study design, setting, and patients

This multicenter retrospective study included Saudi CMC (age: 0–14 years) who had an unplanned 30-day readmission at six tertiary centers of the Ministry of National Guard Health Affairs (MNGHA) between January 01, 2016, and December 31, 2020. The tertiary centers, with a combined capacity of >700 pediatric beds, were as follows: King Abdullah Specialist Children's Hospital (KASCH) and King Fahad Hospital from the Central region; Imam Abdulrahman Al Faisal Hospital, Dammam, and King Abdulaziz Hospital, Alahsa, from the Eastern Province; and Prince Mohammed Bin Abdulaziz Hospital, Almadina, and King Khalid Hospital, Jeddah, from the Western region. Readmissions through both emergency department (ED) or outpatient clinics were included.

The ethical approval for this study included all MNGHA centers and was obtained from the Institutional Review Board at King Abdullah International Medical Research Center, Riyadh, Saudi Arabia.

Inclusion and exclusion criteria

The age cutoff was based on the MNGHA eligibility criteria for pediatric admission. Older patients, those admitted >30 days after discharge, or those who had a planned or elective admission, such as admission for a scheduled procedure, were excluded.

The following two types of CMC were included: CMC with ≥4 CCCs with or without TA devices and CMC with 3 CCCs and TA devices. For example, CMC with neurological, cardiovascular, and gastrointestinal CCCs with feeding TA devices were included. Meanwhile, CMC with <3 CCCs or with 3 CCCs but not dependent on TA device were excluded.

The inclusion criteria were adopted from the complex care program criteria at KASCH. This structured clinical program, launched in February 2021, is the first of its kind in the region and caters to CMC from different backgrounds, including trauma and high-risk surgeries such as conjoined twin separation. It offers comprehensive care through specialized inpatient, outpatient, and consultation services. The criteria were based on the number of CCCs, use of life-sustaining TA device, fragility defined by two admissions in a 12-month period, and the need for high care coordination. We hypothesize that the degree of complexity, as reflected by the number of CCCs, is the main driver of other domains. Although some international clinical programs may include patients with one CCC with and without TA device, our criteria provide a closer look at the most vulnerable CMC at risk of hospitalization.[5]

Data collection

Data collection was a four-step process. First, the electronic MNGHA data warehouse was searched for the preliminary identification of study patients. In the second step, three research assistants manually searched the included files to apply the inclusion criteria. In the third step, three senior reviewers independently reviewed the included files for validation. Finally, in the event of any disagreement, cases were referred to a physician from the complex care program to verify the inclusion criteria. A standardized form was used to collect all variables.

Definitions

The International Classification of Diseases, Tenth Edition codes (ICD-10), was used for admission diagnoses and CCC categorization. Diagnoses were categorized into homogenous groups. For example, viral pneumonia and aspiration pneumonia were counted as pneumonia. Conversely, conditions that differ in severity, such as fever secondary to viral illness and febrile neutropenia, were counted separately. Fever presumed to be related to a viral illness with a negative rapid respiratory virus multiplex polymerase chain reaction test and no signs of serious bacterial infections such as meningitis, pneumonia, and urinary tract infection (UTI) were counted as nonspecific febrile illness.

Patients' demographics and clinical characteristics were examined within the context of the index admission diagnoses and other relevant clinical characteristics. Primary pathology was defined as a genetic condition, trauma, or prematurity as a root cause of complexity affecting one or more systems. In addition, CMC were assessed in terms of main system involvement, i.e., the dominant CCC system driving their complexity irrespective of index admission. For example, in a child with cerebral palsy and frequent aspirations leading to chronic lung disease, the neurological system would be considered the main system involved. Meanwhile, in CMC with lung hypoplasia and oxygen dependence, the respiratory system, or respiratory CCC, would be the main system involved.

Moreover, CMC were evaluated in terms of the number of CCCs, type of TA devices used at baseline, regardless of index admission, and home healthcare (HHC) involvement, defined by the enrollment to any HHC service at the time of index admission.

Variables

The primary outcome was unplanned 30-day readmission. This metric was chosen because it is the most commonly used time window.[16,17] Index admission variables included hospital length of stay (LOS, in days), need for pediatric intensive care unit (PICU) admission, and medical subspecialty involvement, excluding allied health specialties, such as clinical nutritional service and occupational therapy, as they are part of the inpatient multidisciplinary care. Discharge variables included the number of scheduled discharge medications, time interval between discharge and follow-up appointments, and number of ED visits after discharge. A discharge follow-up appointment was defined as any office-based medical appointment with the admitting physician booked at discharge.

Readmission diagnosis was analyzed considering its relevance to the initial index admission. Clinical status upon readmission was compared with that upon previous discharge. Patients with a new onset of fever, vital instability, and needing more supplemental oxygen than at baseline were considered to have worsened conditions. By contrast, patients with stable status who required the same home oxygen were considered the same at discharge. Readmission complications included hospital-acquired infections, such as pneumonia or UTI, with the onset of symptoms 48 hours after admission.

The study outcomes were assessed based on three categories: discharge without additional complexity, discharge with additional complexity indicated by the acquisition of another CCC or introduction of a new TA device, and mortality.

Statistical analysis

Data analyses were performed using STATA 16 for PC. The *P*-value cutoff for statistical significance was set at <0.05. Data obtained from the electronic hospital records were collected using Microsoft Excel. Descriptive statistics are presented as frequencies, and categorical variables (age, sex, and primary pathology) as percentages.

RESULTS

A total of 9139 pediatric patients had a 30-day unplanned readmission during the study period, of which 692 met the inclusion criteria. The inter-rater agreement was 95.8%; 4.2% ($n = 29$) of the patients were reviewed by the complex care physician for confirmation, and 1.7% ($n = 12$) were excluded. Therefore, 680 CMC were included (7.4%) in the analysis [Figure 1]. Boys represented 53.2% of the sample. About 45% of the patients were 1–5 years old, and 25% were <1 year old. Most patients were from the Central region (64.7%), followed by the Western (28.2%) and Eastern (7.1%) regions.

Two-thirds of CMC (66.3%) had genetic or congenital conditions as their primary pathology. The systems most commonly affected in CMC were the neurological or neuromuscular system (33.7%), followed by hematology and immunology (13.8%) and cardiology (12.7%) [Table 1]. Figure 2 shows the percentages of main system involved per region.

Complex chronic conditions

Patients were divided into two groups based on the number of CCCs: 79.4% had four or more CCCs, and 20.6% had three CCCs. Patients with three CCCs had a higher chance of malignancy as a primary pathology than those with four or more CCCs (15.0% vs. 4.4%, respectively; $P < 0.001$). Feeding technology was the most commonly utilized TA (26.8%), followed by central line (13.5%). In total, 91.3% of the patients had no HHC involvement, with no significant correlation with the number of CCCs. Further, no significant correlation was found between the number of CCCs and index admission diagnoses. Interestingly, a positive correlation was found between the pneumonia readmission rate and the number of CCCs ($P = 0.005$) [Table 1].

Index admission

The demographics and clinical characteristics of the CMC cohort were analyzed in relation to the five most common index admission diagnoses: pneumonia ($n = 225$; 33.1%), gastroenteritis (GE) (67; 9.9%), nonspecific febrile illness (58; 8.5%), UTI (35; 5.1%), and bronchial asthma (BA) (29; 4.3%) [Table 2]. CMC admitted for these top five diagnoses accounted for 60.8% ($n = 414$) of all readmitted CMC. Neurological or neuromuscular system was the predominant system among the five diagnoses (36.2%). In addition, a significant correlation was found between the respiratory system and BA (48.3%; $P < 0.001$). Although over 40% of the patients did not require TA devices, more than one-third of patients with pneumonia relied on feeding technology (36.4%), and approximately one-quarter of patients with nonspecific febrile illness had a central line (24.1%) ($P < 0.001$).

In the index admission, >80% of patients with BA had LOS of 1–5 days. Meanwhile, 40% of the patients with UTI had LOS of 6–10 days ($P = 0.011$). One-fifth of the patients with pneumonia required PICU admission. In addition, over half of the patients with all diagnoses required medical subspecialty involvement (59.4%), which was in contrast to patients with BA, where nearly two-thirds (62.1%) did not require subspecialty involvement. Over 40% of the patients had follow-up appointments more than 2 weeks after the index admission discharge, and 43.9% of all patients were readmitted before their appointment. However, this varied

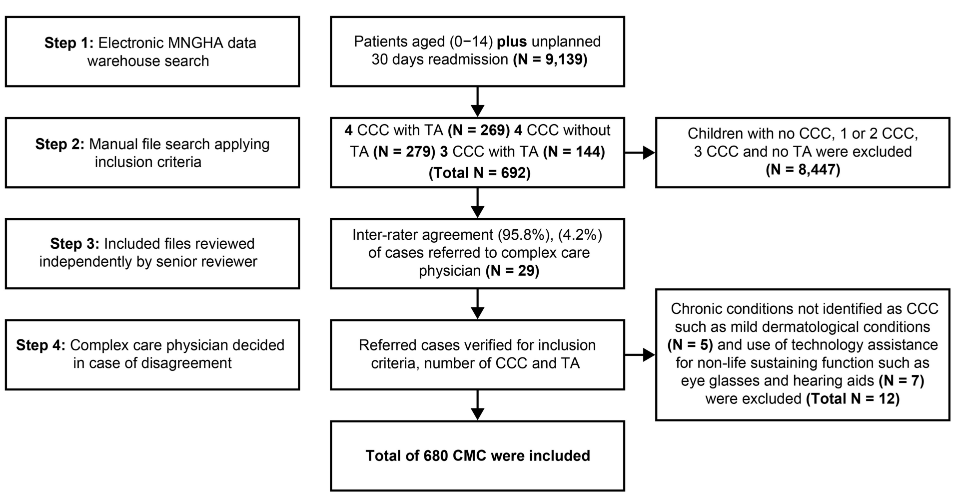

Figure 1: Flowchart of patient screening process

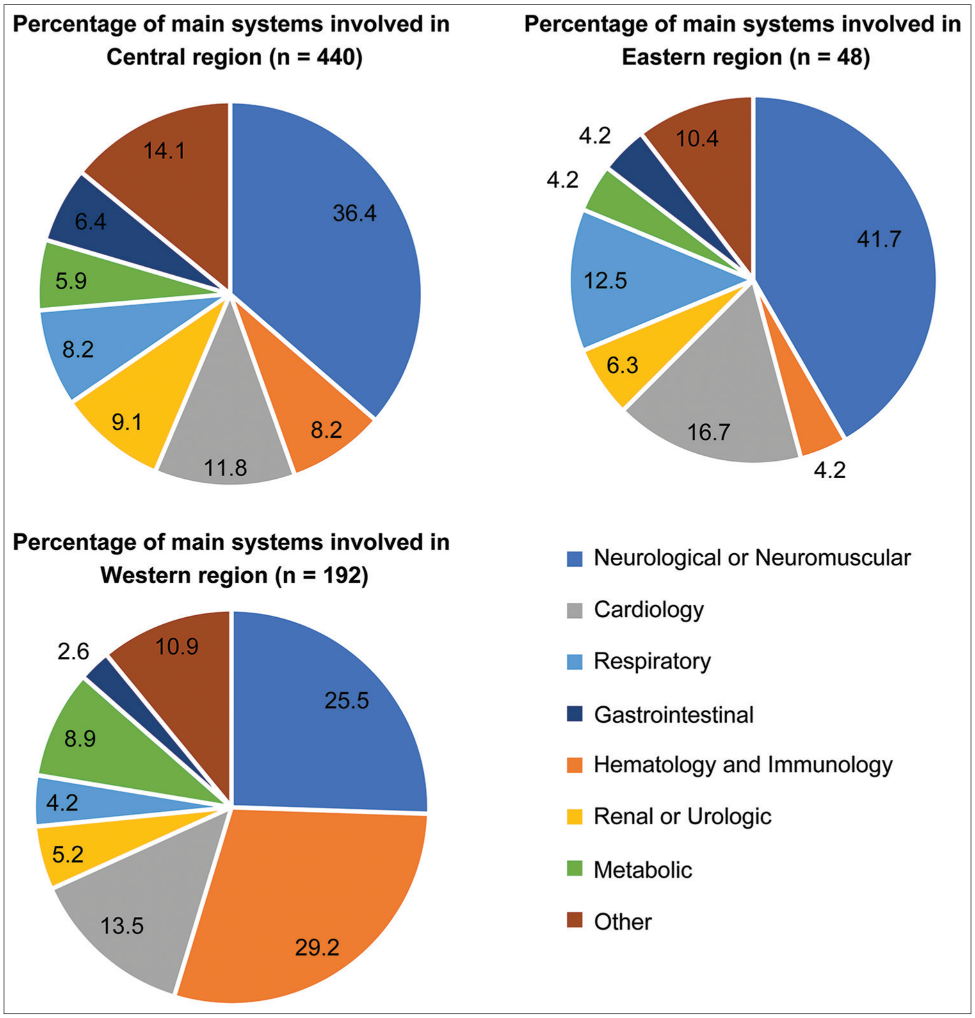

Figure 2: Percentages of main system involved per region

significantly between diagnoses. Over half of the patients with BA had their appointments in that period compared with only one-fifth of the patients with nonspecific febrile illness (55.2% vs. 20.7%, respectively; $P = 0.007$). Nearly one-third of the patients (28%) had >5 discharge medications. [Table 2].

Readmission

Table 3 lists the clinical characteristics of the CMC and resource utilization across readmission diagnoses. The most common readmission diagnoses were pneumonia (32.5%, $n = 221$), nonspecific febrile illness (13.4%, $n = 91$), GE (9.3%, $n = 63$), UTI (6.8%, $n = 46$), and BA (3.8%, $n = 26$). This subsample accounted for 65.7% ($n = 447$) of all readmitted CMC. Less than half of the patients with GE were initially admitted with the same diagnosis, whereas most readmitted patients with nonspecific febrile illness and BA had the same admission diagnosis (47.6% vs. 81.3% and 84.6%, respectively; $P < 0.001$). One-third of the BA readmissions occurred within 3 days of discharge, while more than one-fourth (26.9%) were readmitted within 4 to 7 days. The remaining 42.3% of BA readmissions occurred more than 1 week after discharge.

Among the readmitted patients, 15.4% were admitted to the PICU, with the rate increasing to one-fifth for patients with pneumonia and decreasing to one-twentieth for those with GE (21.7% vs. 6.3%, respectively; $P = 0.046$). Although the majority of patients did not require TA device, 13.2% of the patients readmitted for nonspecific febrile illness were started on feeding technology.

Readmission outcomes

Table 4 presents the readmission outcomes based on age, diagnosis, LOS, and PICU involvement. The majority of the cases (76.5%) were discharged home with no additional complexity. However, 16.9% of the patients acquired another complexity as another CCC diagnosis or the introduction of a new TA device, which added

Table 1: Demographics and clinical characteristics of children with medical complexity according to complex chronic conditions

Characteristics	Overall (*n*=680) *n* (%)	Three CCC (*n*=140) *n* (%)	Four or more CCC (*n*=540) *n* (%)	*P*
Age group (years)				
<1	170 (25.0)	31 (22.1)	139 (25.7)	0.555
1–5	306 (45.0)	67 (47.9)	239 (44.3)	
6–10	126 (18.5)	29 (20.7)	97 (18.0)	
>10	78 (11.5)	13 (9.3)	65 (12.0)	
Gender				
Male	362 (53.2)	71 (50.7)	291 (53.9)	0.502
Female	318 (46.8)	69 (49.3)	249 (46.1)	
Region				
Central	440 (64.7)	86 (61.4)	354 (65.6)	0.589
Eastern	48 (7.1)	12 (8.6)	36 (6.7)	
Western	192 (28.2)	42 (30.0)	150 (27.8)	
Primary pathology				
Genetic or congenital	451 (66.3)	83 (59.3)	368 (68.1)	<0.001
Prematurity	75 (11.0)	12 (8.6)	63 (11.7)	
Malignancy	45 (6.6)	21 (15.0)	24 (4.4)	
Cerebral palsy	31 (4.6)	5 (3.6)	26 (4.8)	
Other	78 (11.5)	19 (13.6)	59 (10.9)	
Main system involved				
Neurological or neuromuscular	229 (33.7)	50 (35.7)	179 (33.2)	0.012
Hematology and immunology	94 (13.8)	31 (22.1)	63 (11.7)	
Cardiology	86 (12.7)	13 (9.3)	73 (13.5)	
Renal or urologic	53 (7.8)	8 (5.7)	45 (8.3)	
Other	218 (32.1)	38 (27.1)	180 (33.3)	
Technology assistance device				
None	274 (40.3)	0	274 (50.7)	<0.001
Feeding technology	182 (26.8)	46 (32.9)	136 (25.2)	
Central line	92 (13.5)	39 (27.9)	53 (9.8)	
VP shunt	47 (6.9)	18 (12.9)	29 (5.4)	
Tracheostomy				
Tube	46 (6.8)	17 (12.1)	29 (5.4)	
Other	39 (5.7)	20 (14.3)	19 (3.5)	
HHC involvement				
Yes	59 (8.7)	15 (10.7)	44 (8.1)	0.336
No	621 (91.3)	125 (89.3)	496 (91.9)	
Most common index admission diagnoses				
Pneumonia	225 (33.1)	44 (31.4)	181 (33.5)	0.201
GE	67 (9.9)	21 (15.0)	46 (8.5)	
Nonspecific febrile illness	58 (8.5)	10 (7.1)	48 (8.9)	
UTI	35 (5.1)	8 (5.7)	27 (5.0)	
BA	29 (4.3)	3 (2.1)	26 (4.8)	
Other	266 (39.1)	54 (38.6)	212 (39.3)	
Most common readmission diagnoses				
Pneumonia	221 (32.5)	34 (24.3)	187 (34.6)	0.005
Nonspecific febrile illness	91 (13.4)	15 (10.7)	76 (14.1)	
GE	63 (9.3)	24 (17.1)	39 (7.2)	
UTI	46 (6.8)	10 (7.1)	36 (6.7)	
BA	26 (3.8)	6 (4.3)	20 (3.7)	
Other	233 (34.3)	51 (36.4)	182 (33.7)	

CCC – complex chronic conditions; VP shunt – Ventriculoperitoneal shunt; GE – Gastroenteritis, BA – Bronchial asthma; UTI – Urinary tract infection; HHC – Home healthcare

to their morbidity. The mortality rate was 6.6%, and 37.8% of the deceased patients were diagnosed with pneumonia.

Mortality was more common in the group aged <1 year, while the most common age group for additional complexity was 1–5 years (53.3% and 39.1%, respectively; $P < 0.001$). Patients discharged with additional complexity had a higher median LOS than those discharged with no additional complexity and expired patients (13 vs. 5 and 10 days, respectively; $P < 0.001$). Expectedly, expired patients were more likely to have PICU involvement than patients discharged with additional complexity (64.4% and 30.4%, respectively; $P < 0.001$).

DISCUSSION

Our study closely examined readmitted CMC with multiple CCCs and TA devices and analyzed their clinical characteristics and resource utilization starting from the

Table 2: Demographics, clinical characteristics, resource utilization, and discharge factors of the patients with the most common index admission diagnosis

Characteristics	Overall (*n*=414) *n* (%)	Pneumonia (*n*=225) *n* (%)	GE (*n*=67) *n* (%)	Nonspecific febrile illness (*n*=58) *n* (%)	UTI (*n*=35) *n* (%)	BA (*n*=29) *n* (%)	*P*
Age group (years)							
<1	100 (4.2)	67 (29.8)	17 (25.4)	7 (12.1)	8 (22.9)	1 (3.4)	0.002
1–5	199 (48.1)	114 (50.7)	23 (34.3)	31 (53.4)	13 (37.1)	18 (62.1)	
6–10	73 (17.6)	30 (13.3)	16 (23.9)	11 (19.0)	9 (25.7)	7 (24.1)	
>10	42 (10.1)	14 (6.2)	11 (16.4)	9 (15.5)	5 (14.3)	3 (10.3)	
Gender							
Male	212 (51.2)	116 (51.6)	38 (56.7)	27 (46.6)	12 (34.3)	19 (65.5)	0.103
Female	202 (48.8)	109 (48.4)	29 (43.3)	31 (53.4)	23 (65.7)	10 (34.5)	
Main system involved							
Neurological or neuromuscular	150 (36.2)	95 (42.2)	19 (28.4)	15 (25.9)	12 (34.3)	9 (31.0)	<0.001
Cardiology	58 (14.0)	40 (17.8)	9 (13.4)	5 (8.6)	2 (5.7)	2 (6.9)	
Hematology and immunology	47 (11.4)	6 (2.7)	17 (25.4)	22 (37.9)	1 (2.9)	1 (3.4)	
Respiratory	41 (9.9)	24 (10.7)	1 (1.5)	1 (1.7)	1 (2.9)	14 (48.3)	
Other	118 (28.5)	60 (26.7)	21 (31.3)	15 (25.9)	19 (54.3)	3 (10.3)	
Technology assistance device							
None	167 (40.3)	80 (35.6)	25 (37.3)	29 (50.0)	13 (37.1)	20 (69.0)	<0.001
Feeding technology	121 (29.2)	82 (36.4)	16 (23.9)	9 (15.5)	8 (22.9)	6 (20.7)	
Central line	41 (9.9)	13 (5.8)	14 (20.9)	14 (24.1)	0	0	
VP shunt	29 (7.0)	12 (5.3)	9 (13.4)	2 (3.4)	6 (17.1)	0	
Tracheostomy tube	28 (6.8)	22 (9.8)	2 (3.0)	3 (5.2)	0	1 (3.4)	
Other	28 (6.8)	16 (7.1)	1 (1.5)	1 (1.7)	8 (22.9)	2 (6.9)	
LOS (days)							
1–5	214 (51.7)	110 (48.9)	34 (50.7)	31 (53.4)	15 (42.9)	24 (82.8)	0.011
6–10	92 (22.2)	53 (23.6)	13 (19.4)	8 (13.8)	14 (40.0)	4 (13.8)	
11–15	36 (8.7)	18 (8.0)	6 (9.0)	9 (15.5)	2 (5.7)	1 (3.4)	
>15	72 (17.4)	44 (19.6)	14 (20.9)	10 (17.2)	4 (11.4)	0	
PICU admission							
Admitted	73 (17.6)	49 (21.8)	9 (13.4)	7 (12.1)	6 (17.1)	2 (6.9)	0.088
Involved through consultation	13 (3.1)	11 (4.9)	1 (1.5)	0	0	1 (3.4)	
Not admitted	328 (79.2)	165 (73.3)	57 (85.1)	51 (87.9)	29 (82.9)	26 (89.7)	
Medical specialty involvement							
Yes	246 (59.4)	139 (61.8)	45 (67.2)	30 (51.7)	21 (60.0)	11 (37.9)	0.057
No	168 (40.6)	86 (38.2)	22 (32.8)	28 (48.3)	14 (40.0)	18 (62.1)	
Discharge medication							
<3 medications	135 (32.6)	71 (31.6)	22 (32.8)	23 (39.7)	12 (34.3)	7 (24.1)	0.710
3–5 medications	163 (39.4)	92 (40.9)	26 (38.8)	23 (39.7)	10 (28.6)	12 (41.4)	
>5 medications	116 (28.0)	62 (27.6)	19 (28.4)	12 (20.7)	13 (37.1)	10 (34.5)	
Time of follow-up appointment (days)							
≤3	31 (7.5)	15 (6.7)	8 (11.9)	5 (8.6)	1 (2.9)	2 (6.9)	0.007
4–7	51 (12.3)	23 (10.2)	8 (11.9)	14 (24.1)	6 (17.1)	0	
8–14	69 (16.7)	29 (12.9)	15 (22.4)	12 (20.7)	6 (17.1)	7 (24.1)	
≥15	168 (40.6)	105 (46.7)	19 (28.4)	12 (20.7)	16 (45.7)	16 (55.2)	
No follow-up	95 (22.9)	53 (23.6)	17 (25.4)	15 (25.9)	6 (17.1)	4 (13.8)	
Number of ED visits							
None	5 (1.2)	3 (1.3)	0	2 (3.4)	0	0	0.521
1 visit	359 (86.7)	190 (84.4)	61 (91.0)	52 (89.7)	31 (88.6)	25 (86.2)	
≥2 visits	50 (12.1)	32 (14.2)	6 (9.0)	4 (6.9)	4 (11.4)	4 (13.8)	

VP shunt – Ventriculoperitoneal shunt; GE – Gastroenteritis; BA – Bronchial asthma; UTI – Urinary tract infection; ED – Emergency department; LOS – Length of stay; PICU – Pediatric intensive care unit

index admission. The proportion of unplanned 30-day pediatric readmissions in CMC in Saudi Arabia was 7.4%, which is lower than the international rates of 12.4% and 16.8% for CMC with three and four CCCs, respectively.[14] A possible explanation for this difference is that some CMC may reside in either governmental or private long-term care facility centers in Saudi Arabia, where they receive comprehensive care, eliminating the need for transfer to tertiary care hospitals. Furthermore, patients can be treated in daycare or walk-in clinics without readmission. Another potential explanation is that some patients may be readmitted to non-MNGHA hospitals, which were not included in our sample. Nonetheless, our mortality rate was consistent with a prior report.[5]

Pneumonia was the most common cause of readmissions in our study and positively correlated with the number of CCCs. Furthermore, our finding of PICU readmission mainly due to respiratory conditions among CMC was similar to that reported by a previous study.[18] Although the etiology of pneumonia was not accounted for in our

Table 3: Clinical characteristics and resource utilization of patients with the most common readmission diagnosis

Characteristics	Overall (*n*=447) *n* (%)	Pneumonia (*n*=221) *n* (%)	Nonspecific febrile illness (*n*=91) *n* (%)	GE (*n*=63) *n* (%)	UTI (*n*=46) *n* (%)	BA (*n*=26) *n* (%)	*P*
Related to index admission							
No	138 (30.9)	64 (29.0)	17 (18.7)	33 (52.4)	20 (43.5)	4 (15.4)	<0.001
Yes	309 (69.1)	157 (71.0)	74 (81.3)	30 (47.6)	26 (56.5)	22 (84.6)	
Time of readmission (days)							
≤3	91 (20.4)	39 (17.6)	24 (26.4)	16 (25.4)	4 (8.7)	8 (30.8)	0.301
4–7	89 (19.9)	44 (19.9)	16 (17.6)	14 (22.2)	8 (17.4)	7 (26.9)	
8–14	110 (24.6)	59 (26.7)	19 (20.9)	13 (20.6)	13 (28.3)	6 (23.1)	
15–30	157 (35.1)	79 (35.7)	32 (35.2)	20 (31.7)	21 (45.7)	5 (19.2)	
Clinical status compared with at discharge							
Worse	394 (88.1)	196 (88.7)	90 (98.9)	45 (71.4)	40 (87.0)	23 (88.5)	<0.001
Same	53 (11.9)	25 (11.3)	1 (1.1)	18 (28.6)	6 (13.0)	3 (11.5)	
PICU admission							
Admitted	69 (15.4)	48 (21.7)	9 (9.9)	4 (6.3)	6 (13.0)	2 (7.7)	0.046
Involved through consultation	19 (4.3)	11 (5.0)	3 (3.3)	3 (4.8)	1 (2.2)	1 (3.8)	
Not admitted	359 (80.3)	162 (73.3)	79 (86.8)	56 (88.9)	39 (84.8)	23 (88.5)	
New medical subspecialty involvement							
Yes	209 (46.8)	102 (46.2)	47 (51.6)	28 (44.4)	26 (56.5)	6 (23.1)	0.070
No	238 (53.2)	119 (53.8)	44 (48.4)	35 (55.6)	20 (43.5)	20 (76.9)	
Introduction of new technology							
None	399 (89.3)	214 (96.8)	68 (74.7)	55 (87.3)	36 (78.3)	26 (100.0)	<0.001
Feeding technology	18 (4.0)	1 (0.5)	12 (13.2)	3 (4.8)	2 (4.3)	0	
Central line	15 (3.4)	4 (1.8)	6 (6.6)	1 (1.6)	4 (8.7)	0	
CPAP or BIPAP	7 (1.6)	1 (0.5)	1 (1.1)	1 (1.6)	4 (8.7)	0	
Other	8 (1.8)	1 (0.5)	4 (4.4)	3 (4.8)	0	0	
LOS (days)							
1–5	224 (50.1)	99 (44.8)	46 (50.5)	38 (60.3)	24 (52.2)	17 (65.4)	0.053
6–10	105 (23.5)	51 (23.1)	20 (22.0)	18 (28.6)	11 (23.9)	5 (19.2)	
11–15	41 (9.2)	27 (12.2)	4 (4.4)	3 (4.8)	6 (13.0)	1 (3.8)	
>15	77 (17.2)	44 (19.9)	21 (23.1)	4 (6.3)	5 (10.9)	3 (11.5)	
Complications							
No complication	374 (83.7)	187 (84.6)	71 (78.0)	57 (90.5)	36 (78.3)	23 (88.5)	0.268
Pneumonia	24 (5.4)	13 (5.9)	6 (6.6)	0	2 (4.3)	3 (11.5)	
Sepsis	15 (3.4)	7 (3.2)	3 (3.3)	2 (3.2)	3 (6.5)	0	
Other	34 (7.6)	14 (6.3)	11 (12.1)	4 (6.3)	5 (10.9)	0	

CPAP – Continuous positive airway pressure; BIPAP – Bilevel positive airway pressure; GE – Gastroenteritis; BA – Bronchial asthma; UTI – Urinary tract infection; PICU – Pediatric intensive care unit; LOS – Length of stay

Table 4: Readmission outcome by age, diagnosis, length of stay, and pediatric intensive care unit involvement

Characteristics	Overall (*n*=680) *n* (%)	Discharged home with no additional complexity (*n*=520) *n* (%)	Discharged home with additional complexity (*n*=115) *n* (%)	Expired (*n*=45)	*P*
Readmission diagnosis					
Pneumonia	221 (32.5)	171 (32.9)	33 (28.7)	17 (37.8)	0.053
Nonspecific febrile illness	91 (13.4)	74 (14.2)	13 (11.3)	4 (8.9)	
GE	63 (9.3)	56 (10.8)	7 (6.1)	0	
UTI	46 (6.8)	36 (6.9)	7 (6.1)	3 (6.7)	
BA	26 (3.8)	22 (4.2)	4 (3.5)	0	
Other	233 (34.3)	161 (31.0)	51 (44.3)	21 (46.7)	
Age (years)					
<1	170 (25.0)	113 (21.7)	33 (28.7)	24 (53.3)	<0.001
1–5	306 (45.0)	249 (47.9)	45 (39.1)	12 (26.7)	
6–10	126 (18.5)	101 (19.4)	21 (18.3)	4 (8.9)	
>10	78 (11.5)	57 (11.0)	16 (13.9)	5 (11.1)	
LOS (days)					
1–5	331 (48.7)	285 (54.8)	30 (26.1)	16 (35.6)	<0.001
6–10	159 (23.4)	128 (24.6)	24 (20.9)	7 (15.6)	
11–15	55 (8.1)	38 (7.3)	14 (12.2)	3 (6.7)	
>15	135 (19.9)	69 (13.3)	47 (40.9)	19 (42.2)	
Median LOS (IQR)	6 (3–12)	5 (3–9)	13 (5–30)	10 (2–39)	<0.001
PICU admission					
Admitted	136 (20.0)	72 (13.8)	35 (30.4)	29 (64.4)	<0.001
Involved through consultation	28 (4.1)	21 (4.0)	7 (6.1)	0	
No involvement	516 (75.9)	427 (82.1)	73 (63.5)	16 (35.6)	

LOS – Length of stay; PICU – Pediatric intensive care unit; GE – Gastroenteritis; BA – Bronchial asthma; UTI – Urinary tract infection; IQR – Interquartile range cohort, Thomson *et al*. observed a similar pattern of prevalent neurological system involvement, multiple CCCs, feeding technology dependence, and high rates of PICU admission in children with aspiration pneumonia compared with non-aspiration pneumonia.[19] However, overdiagnosis of pneumonia in the context of upper respiratory tract infections must be considered, considering the increased risk of aspiration due to sialorrhea and poor cough reflex in CMC.[20]

In our cohort, genetic conditions were the most prevalent primary pathology; however, the heritability of these conditions is yet to be determined, considering the local cultural practice of consanguinity.[10] Recent advancements in precision medicine and genomics offer rapid and cost-effective tools for early diagnosis, which may inform the goals of care and healthcare-resource utilization discussions in CMC;[21] however, the applicability of such measures is yet to be evaluated. The dominance of neurological system involvement, as opposed to the cardiac system observed in a previous study,[14] is consistent with the findings of Al Salloum *et al*. ranking neurological conditions as the most common chronic conditions among Saudi children.[11]

Overall predominance of feeding technology and polypharmacy in our study is consistent with previous findings.[8] Nonetheless, distinct characteristics of Saudi CMC were observed across different diagnoses. The nonspecific febrile illness subgroup had hematology and immunology conditions and used central lines, a known risk factor for central line-associated bloodstream infections.[22] Among CMC cases readmitted for UTI, one-third had neurological or neuromuscular system involvement, raising the suspicion of the neurogenic bladder as a predisposing condition for recurrent UTIs.[23]

Recognizing these specific characteristics allows for targeted interventions during hospitalization to decrease the risk of readmission. For example, salivary botulinum toxin injection for sialorrhea, chest physiotherapy, and tracheostomy care education decrease the risk of pneumonia.[24-27] Similarly, clean intermittent catheterization for neurogenic bladder can help reduce the risk of UTIs.[28] Furthermore, ensuring appropriate inhaler techniques and providing action plans for bronchial asthma can prevent hospitalizations.[29]

In CMC, multifaceted postdischarge care, including parental coaching, home health nursing care, medication reconciliation, and follow-up appointments, reduces readmissions.[30-32] Although previous studies have demonstrated a reduced risk of readmission with late postdischarge follow-up (4–29 days after discharge),[33] most of our patients were readmitted before their late postdischarge appointments. This may be attributed to the higher complexity of our cohort than previous studies or to other unmeasured factors. More studies are needed to evaluate the efficacy of early postdischarge appointments, considering that most readmission diagnoses, except for nonspecific febrile illness, are ambulatory care-sensitive conditions that can potentially be managed in the outpatient setting, reducing the need for hospitalization.[34] Moreover, a comprehensive patient-centered medical home for a child with medical complexity ensures continuity of outpatient care and provides a targeted approach to mitigate the risk of preventable admissions.[35]

Limitations

This study has several limitations. First, this study represents a closed healthcare system comprising six hospitals under the MNGHA healthcare, excluding admissions to non-MNGHA and transfers from long-term care facilities, which may limit the generalizability of the findings to the entire Saudi population. Furthermore, HHC services were limited to Riyadh and Alahsa with a catchment area of 50 km^2 excluding many eligible patients.

Second, despite implementing multiple steps and involving senior reviewers, ensuring consistent categorization remained challenging, and there could be an element of subjectivity. Globally, the overarching standardization of classifying CMC remains challenging, and there are ongoing efforts to modify ICD-10 codes and establish a pediatric medical complexity algorithm for clinical, administrative, and research purposes.[36] Furthermore, although clear definitions were used to differentiate the primary pathologies and main systems involved, the etiologies and manifestations of chronic conditions can overlap. Third, it is important to acknowledge that the study period coincided with the first year of the COVID-19 pandemic, which may impact access to medical care, potentially leading to reduced readmission rates and delayed follow-up appointments. However, the specific effects of the pandemic on readmissions and appointment scheduling were not assessed.

Fourth, the study did not explore the specific reasons for readmission, such as disease recurrence or persistence due to medication non-adherence. In addition, a detailed analysis of pneumonia readmissions, including the differentiation of bacterial or viral etiology based on radiographic findings, was not conducted. Exploring these aspects could serve as the basis for quality improvement initiatives to optimize infection control measures, given that most readmissions were related to infectious conditions. Moreover, the study did not examine the goals of care status, such as comfort or palliative care goals, which may have impacted the mortality rate. Fifth, this study only focused on the first readmission within 30 days after discharge, and subsequent readmissions were not included in our analysis. Lastly, given the retrospective nature of the study, psychosocial factors associated with readmissions, such as family size and the caregiver's level of education, were not evaluated.

Despite these limitations, this study provides valuable insights into the timing of readmissions and specific characteristics of CMC across common diagnoses. This study highlights areas for future research and quality improvement projects, focusing on implementing condition-specific measures during the index admission period and assessing the applicability and efficacy of these interventions in reducing readmission rates.

CONCLUSION

This study revealed that the rate of unplanned 30-day pediatric readmissions in CMC in Saudi Arabia was lower than those in developed countries. However, CMC with three or more CCCs and TA device use remain at significant risk of readmission, often for the same conditions as in the index admission. Despite this similarity, variations were observed in their clinical characteristics and resource utilization, depending on their specific diagnosis. To effectively reduce the risk of 30-day readmissions, targeted measures must be introduced both during the hospitalization period and after discharge. These measures should focus on the specific medical conditions of CMC and be tailored to address the factors contributing to unplanned readmissions. Future studies should prioritize the development and implementation of such interventions, as they may substantially reduce readmission rates and improve the overall healthcare outcomes for Saudi CMC.

Ethical considerations

The study was approved by the Institutional Review Board at King Abdullah International Medical Research Center, Riyadh, Saudi Arabia (Ref. no.: IRBC/0609/21; date: March 17, 2021). The requirement for patient consent was waived owing to the study design. The study adhered to the principles of the Declaration of Helsinki, 2013.

Peer review

This article was peer-reviewed by three independent and anonymous reviewers.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author contributions

Conceptualization: H.A., S.A., and F.A.; Methodology: H.A., S.A., and F.A.; Data collection; H.S. and H.M; Data analysis: S.A. and A.U.; Writing–original draft preparation: F.A.; Writing – review and editing: H.A. and S.A.; Supervision: H.A. and S.A.

All authors have read and agreed to the published version of the manuscript.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Cohen E, Kuo DZ, Agrawal R, Berry JG, Bhagat SK, Simon TD, *et al.* Children with medical complexity: An emerging population for clinical and research initiatives. Pediatrics 2011;127:529-38.
2. Berry JG, Hall M, Neff J, Goodman D, Cohen E, Agrawal R, *et al.* Children with medical complexity and Medicaid: Spending and cost savings. Health Aff (Millwood) 2014;33:2199-206.
3. Temsah MH, Abouammoh N, Al Eyadhy A, AlRuthia Y, Hassounah M, Alsohime F, *et al.* Predictors and direct cost estimation of long stays in pediatric intensive care units in Saudi Arabia: A mixed methods study. Risk Manag Healthc Policy 2021;14:2625-36.
4. AlKhalaf H, AlHamdan W, Kinani S, AlZighaibi R, Fallata S, Al Mutrafy A, *et al.* Identifying the prevalence and causes of 30-day hospital readmission in children: A case study from a tertiary pediatric hospital. Glob J Qual Saf Healthc 2023;6:101-10.
5. Cohen E, Berry JG, Camacho X, Anderson G, Wodchis W, Guttmann A. Patterns and costs of health care use of children with medical complexity. Pediatrics 2012;130:e1463-70.
6. Berry JG, Agrawal R, Kuo DZ, Cohen E, Risko W, Hall M, *et al.* Characteristics of hospitalizations for patients who use a structured clinical care program for children with medical complexity. J Pediatr 2011;159:284-90.
7. Srivastava R, Keren R. Pediatric readmissions as a hospital quality measure. JAMA 2013;309:396-8.
8. Auger KA, Shah SS, Huang B, Brady PW, Weinberg SH, Reamer E, *et al.* Discharge medical complexity, change in medical complexity and pediatric 30-day readmission. J Hosp Med 2019;14:474-81.
9. Jurgens V, Spaeder MC, Pavuluri P, Waldman Z. Hospital readmission in children with complex chronic conditions discharged from subacute care. Hosp Pediatr 2014;4:153-8.
10. El Mouzan MI, Al Salloum AA, Al Herbish AS, Qurachi MM, Al Omar AA. Consanguinity and major genetic disorders in Saudi children: A community-based cross-sectional study. Ann Saudi Med 2008;28:169-73.
11. Al Salloum AA, El Mouzan MI, Al Omar AA, Al Herbish AS, Qurashi MM. The prevalence of neurological disorders in Saudi

children: A community-based study. J Child Neurol 2011;26:21-4.
12. Murphy NA, Alvey J, Valentine KJ, Mann K, Wilkes J, Clark EB. Children with medical complexity: The 10-year experience of a single center. Hosp Pediatr 2020;10:702-8.
13. Al Qurashi MM, El Mouzan MI, Al Herbish AS, Al Salloum AA, Al Omar AA. The prevalence of sickle cell disease in Saudi children and adolescents. A community-based survey. Saudi Med J 2008;29:1480-3.
14. Berry JG, Toomey SL, Zaslavsky AM, Jha AK, Nakamura MM, Klein DJ, *et al.* Pediatric readmission prevalence and variability across hospitals. JAMA 2013;309:372-80.
15. Abdul Salam A, Elsegaey I, Khraif R, Al-Mutairi A. Population distribution and household conditions in Saudi Arabia: Reflections from the 2010 Census. Springerplus 2014;3:530.
16. Leary JC, Price LL, Scott CE, Kent D, Wong JB, Freund KM. Developing prediction models for 30-day unplanned readmission among children with medical complexity. Hosp Pediatr 2019;9:201-8.
17. Bucholz EM, Gay JC, Hall M, Harris M, Berry JG. Timing and causes of common pediatric readmissions. J Pediatr 2018;200:240-8.e1.
18. Ding M, Yang C, Li Y. Risk factors of readmission to pediatric intensive care unit within 1 year: A case-control study. Front Pediatr 2022;10:887885.
19. Thomson J, Hall M, Ambroggio L, Stone B, Srivastava R, Shah SS, *et al.* Aspiration and non-aspiration Pneumonia in hospitalized children with neurologic impairment. Pediatrics 2016;137:e20151612.
20. Seddon PC, Khan Y. Respiratory problems in children with neurological impairment. Arch Dis Child 2003;88:75-8.
21. Monies D, Goljan E, Rapid Exome Consortium, Assoum M, Albreacan M, Binhumaid F, *et al*. The clinical utility of rapid exome sequencing in a consanguineous population. Genome Med 2023;15:44.
22. Moon HM, Kim S, Yun KW, Kim HY, Jung SE, Choi EH, *et al.* Clinical characteristics and risk factors of long-term central venous catheter-associated bloodstream infections in children. Pediatr Infect Dis J 2018;37:401-6.
23. Bross S, Honeck P, Kwon ST, Badawi JK, Trojan L, Alken P. Correlation between motor function and lower urinary tract dysfunction in patients with infantile cerebral palsy. Neurourol Urodyn 2007;26:222-7.
24. Faria J, Harb J, Hilton A, Yacobucci D, Pizzuto M. Salivary botulinum toxin injection may reduce aspiration pneumonia in neurologically impaired children. Int J Pediatr Otorhinolaryngol 2015;79:2124-8.
25. Fitzgerald K, Dugre J, Pagala S, Homel P, Marcus M, Kazachkov M. High-frequency chest wall compression therapy in neurologically impaired children. Respir Care 2014;59:107-12.
26. van den Oudenrijn LV, Veldhoen E. The Use of Cough Assist in Children with Neuromuscular Diseases in a Pediatric Hospital with Neuromuscular and Chronic Ventilation Clinic. European Respiratory Society; 2017. Available from: https://erj.ersjournals.com/content/50/suppl_61/OA3414.article-info. [Last accessed on 2022 Dec 26].
27. Morrison JM, Hassan A, Kysh L, Dudas RA, Russell CJ. Diagnosis, management, and outcomes of pediatric tracheostomy-associated infections: A scoping review. Pediatr Pulmonol 2022;57:1145-56.
28. Verpoorten C, Buyse GM. The neurogenic bladder: Medical treatment. Pediatr Nephrol 2008;23:717-25.
29. Zipkin R, Schrager SM, Nguyen E, Mamey MR, Banuelos I, Wu S. Association between pediatric home management plan of care compliance and asthma readmission. J Asthma 2017;54:761-7.
30. Zemaitis CT, Morris G, Cabie M, Abdelghany O, Lee L. Reducing readmission at an academic medical center: Results of a pharmacy-facilitated discharge counseling and medication reconciliation program. Hosp Pharm 2016;51:468-73.
31. Coller RJ, Klitzner TS, Lerner CF, Nelson BB, Thompson LR, Zhao Q, *et al.* Complex care hospital use and postdischarge coaching: A randomized controlled trial. Pediatrics 2018;142:e20174278.
32. Gay JC, Thurm CW, Hall M, Fassino MJ, Fowler L, Palusci JV, *et al.* Home health nursing care and hospital use for medically complex children. Pediatrics 2016;138:e20160530.
33. Brittan MS, Sills MR, Fox D, Campagna EJ, Shmueli D, Feinstein JA, *et al.* Outpatient follow-up visits and readmission in medically complex children enrolled in Medicaid. J Pediatr 2015;166:998-1005.e1.
34. Coller RJ, Kelly MM, Ehlenbach ML, Goyette E, Warner G, Chung PJ. Hospitalizations for ambulatory care-sensitive conditions among children with chronic and complex diseases. J Pediatr 2018;194:218-24.
35. Mosquera RA, Avritscher EB, Samuels CL, Harris TS, Pedroza C, Evans P, *et al.* Effect of an enhanced medical home on serious illness and cost of care among high-risk children with chronic illness: A randomized clinical trial. JAMA 2014;312:2640-8.
36. Simon TD, Haaland W, Hawley K, Lambka K, Mangione Smith R. Development and validation of the Pediatric Medical Complexity Algorithm (PMCA) version 3.0. Acad Pediatr 2018;18:577-80.