Cardiology in the Young

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The final hospital need in children discharged from a cardiology acute care unit: a single-centre survey study

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Original Article

Cite this article: Ware AL, Reiter L, Winder M, Kelly D, Marietta J, Ohsiek S, Ou Z, Presson A, and Bailly DK (2023) The final hospital need in children discharged from a cardiology acute care unit: a single-centre survey study. *Cardiology in the Young* **33**: 1967–1974. doi: 10.1017/S1047951122003596

Received: 21 June 2022
Revised: 24 October 2022
Accepted: 25 October 2022
First published online: 28 November 2022

Keywords:
CHD; paediatric; cardiac acute care; survey; length of stay

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Abstract

Objective: Children with heart disease may require inpatient care for many reasons, but ultimately have a final reason for hospitalisation prior to discharge. Factors influencing length of stay in paediatric cardiac acute care units have been described but the last reason for hospitalisation has not been studied. Our aim was to describe Final Hospital Need as a novel measure, determine Final Hospital Need in our patients, and describe factors associated with this Need. *Methods:* Single-centre survey design. Discharging providers selected a Final Hospital Need from the following categories: cardiovascular, respiratory, feeding/fluid, haematology/ID, pain/sedation, systems issues, and other/wound issues. Univariable and multivariable analyses were performed separately for outcomes "cardiovascular" and "feeding/fluid." *Measurements and Results:* Survey response rate was 99% (624 encounters). The most frequent Final Hospital Needs were cardiovascular (36%), feeding/fluid (24%) and systems issues (13%). Probability of Final Hospital Need "cardiovascular" decreased as length of stay increased. Multivariate analysis showed Final Hospital Need "cardiovascular" was negatively associated with aortic arch repair, Norwood procedure, and Final ICU Need "respiratory" and "other." Final Hospital Need "feeding/fluid" was negatively associated with left-sided valve procedure, but positively associated with final ICU need "respiratory," and tube feeding at discharge. *Conclusions:* Final Hospital Need is a novel measure that can be predicted by clinical factors including age, Final ICU Need, and type of surgery. Final Hospital Need may be utilised to track changes in clinical care over time and as a target for improvement work.

Introduction

The hospital experience of children with CHD may consist of multiple segments of care including the operating room, the cardiac ICU, and the cardiac acute care unit. Each segment of care may impact subsequent segments and overall patient length of stay.[1–3] During each segment, multiple problems may be addressed, but ultimately, each segment requires resolution of a final clinical need prior to transitioning to the next segment.

A recent study at our institution evaluated the final reason a patient required care in the cardiac ICU.[4] The Final ICU Need was associated with benchmark operation and length of ICU stay. These data have led to improvement efforts to reduce practice variation and improve clinical processes in that segment of care.[5] However, there is a gap in our knowledge in the final segment of hospital-based care for paediatric CHD patients or the Final Hospital Need. We defined the Final Hospital Need as the primary reason a patient required inpatient care in the 24 hours preceding their discharge. We hypothesised that identifying the Final Hospital Need for patients on our cardiac acute care unit would enable us to better understand our current care environment, identify opportunities for system improvement, and provide a balance measure for future process changes.

As an initial step in understanding the Final Hospital Need, we aimed to (1) describe the Final Hospital Need as a novel measure, (2) determine the Final Hospital Need in children hospitalised for medical and/or surgical care related to CHD, and (3) describe patient factors associated with the declared Final Hospital Need. For this project, we hypothesised that factors such as the Final ICU Need, complications, length of stay, and discharging provider would be associated with the Final Hospital Need.

Materials and methods

Study population and setting

We conducted a single-centre cross-sectional survey study from a tertiary-care paediatric cardiac acute care unit. Study approval was obtained by the University of Utah Institutional Review Board and Primary Children's Hospital Privacy Board.

We included all patients cared for by the acute care cardiology teams at Primary Children's Hospital (i.e., post-operative patients, inter-stage single ventricle patients, and heart failure/transplant patients). The care teams at our institution include attending cardiologists, paediatric cardiology fellows, paediatric residents, and a dedicated team of cardiac advanced practice providers. The discharge of acute care patients is managed by the cardiac advanced practice providers. We excluded all patients >18 years, those requiring ≤48 hours of care in the cardiac acute care unit, and patients who died during their post-operative course.

Data were collected utilising local electronic health records and included: age (neonate: <29 days; paediatric: 30 days to 18 years), gender, presence of a genetic condition (defined as any patient with a genetic syndrome, chromosomal abnormality, or significant congenital non-cardiac abnormality according to the Pediatric Cardiac Critical Care Consortium reporting dictionary[6]), benchmark cardiac operation (categorised according to the Society of Thoracic Surgeons classification system[7]), hospital complications (necrotising enterocolitis, ventricular assist device, extra-corporeal membrane oxygenation, or cardiac arrest), zip code of home address, and discharge needs (feeding route, oxygen, and narcotic or sedation wean). The Pediatric Cardiac Critical Care Consortium registry shares common terminology and definitions from the International Pediatric and Congenital Cardiac Code, the Society of Thoracic Surgeons Congenital Heart Surgery Database, and American College of Cardiology Improving Pediatric and Adult Congenital Treatment Registry.[6–8]

Survey rationale and development

The Final Hospital Need survey, created in REDCap (Research Electronic Data Capture), is included (Supplemental Figure 1). Final Hospital Need categories were defined based on previous reports of aetiologies for hospital readmissions in patients with CHD and according to the authors' discretion.[3,4,9–11] In addition to the Final Hospital Need category, providers can select from a list of common modifiable factors associated with the Final Hospital Need designation (Supplemental Figure 1). Final Hospital Need categories included the following:

Cardiovascular: Discharge was pending resolution or treatment of hypotension/hypertension, impaired perfusion, monitoring or treatment for pulmonary hypertension, dysrhythmia, management of fluid balance, or concern for cardiovascular instability.

Feeding/Fluid: Discharge was pending resolution or treatment of feeding issues including dependence on intravenous nutrition or fluid delivery; management of tube or oral feeds; weight loss or inadequate gain; treatment for constipation, nausea, vomiting or abnormal electrolytes; or pending consults or studies related to feeding.

Haematology/ID: Discharge was pending management of anticoagulation, anaemia, or delivery of intravenous antibiotics.

Other/Wound Issues: Free-text response regarding any Final Hospital Need which did not fit in any other categories, including those related to post-operative wound care.

Pain/*Sedation*: Patient had symptoms consistent with withdrawal requiring multiple breakthrough medications or regression on planned sedation/narcotic wean plans.

Respiratory: Patient required increased amount of oxygen to maintain saturations, management of pleural effusions or pneumothorax, and/or observation for work of breathing, tachypnoea, or airway obstruction.

Systems Issues: Patient was clinically ready for discharge but remained in the hospital due to infrastructural insufficiencies including awaiting discharge teaching, rooming-in (if applicable), study results, equipment or prescription delivery, or delays related to an accepting care facility (if applicable).

Education related to the survey and Final Hospital Need definitions was completed by all cardiac advanced practice providers one month prior to implementation. The advanced practice provider on service at the time of hospital discharge was instructed to select a single Final Hospital Need according to clinical judgement. The survey was part of the discharge paperwork and completed by the discharging advanced practice provider at the time of hospital discharge. This survey has not been formally validated. Impact of respondents was evaluated by comparing responses from providers in univariable and multivariable analysis. Inter- and intra-rater reliability has not been conducted.

Statistical analysis

Continuous clinical characteristics were summarised using medians and interquartile ranges (IQRs) at the encounter level due to distribution skew. For categorical variables, counts and percentages were reported.

Primary analyses focused on patients with a Final Hospital Need designation of "cardiovascular" or "feeding/fluid," due to limited number of encounters for the remaining Final Hospital Need categories. Univariable and multivariable logistic regression models were fitted to the binary outcome variables "cardiovascular" and "feeding/fluid," with generalised estimating equation method to account for correlation of outcomes within subjects. The models include the following clinical variables of interest: final ICU need ("cardiovascular," "respiratory" or "other"),[5] benchmark operation, age, cardiac ICU and acute care unit length of stay, presence of genetic syndrome, post-operative complications (such as necrotising enterocolitis, extra-corporeal membrane oxygenation, ventricular assist device, or cardiac arrest), and discharge needs (provider, season, distance to home, and feeding/oxygen/narcotic weans). We used the generalised variance inflation factor to assess multicollinearity among covariates in our multivariable model settings. Multicollinearity was considered tolerable if the generalised variance inflation factor was <2.24, which is equivalent to variance inflation factor <5.[12]

Interaction effects between age group and acute care unit length of stay were examined on Final Hospital Need "cardiovascular" because we *a priori* hypothesised that the effect of length of stay on final ICU need differed by age group. A logistic model included age group, cardiac acute care unit length of stay, and their interaction was fitted. Length of stay was centred at its mean value to provide meaningful interpretation.

An interaction plot visually shows the degree of changes from acute care unit length of stay on the likelihood of Final Hospital Need "cardiovascular" for each age group. Alluvial plots use coloured streams to show changes in encounter size between age, acute care unit length of stay, and Final Hospital Need.

https://doi.org/10.1017/S1047951122003596 Published online by Cambridge University Press

Table 1. Patient characteristics by final hospital need.

		Final Hospital Need						
	All encounters n = 624 (%)	Cardiovascular n = 222 (36)	Feeding/ fluid n = 149 (24)	Systems issues n = 81 (13)	Respiratory n = 67 (11)	Haematology/ ID n = 52 (8)	Pain/sedation n = 33 (5)	Other/ wound issues n = 20 (3)
Age group Neonate	217 (35)	47 (22)	81 (37)	40 (18)	13 (6)	8 (4)	16 (7)	12 (6)
Paediatric	407 (65)	175 (43)	68 (17)	41 (10)	54 (13)	44 (11)	17 (4)	8 (2)
ACU LOS (hr) Median (IQR)	118.0 (72.0, 196.3)	73.2 (66.6, 116.7)	142.7 (93.7, 216.9)	167.5 (119.1, 15.5)	113.7 (79.7, 143.2)	138.9 (101.1, 208.4)	192.8 (143.7, 290.6)	182.9 (116.7, 295.5)
Syndrome Flag	157 (25)	54 (34)	29 (18)	21 (14)	22 (14)	13 (8)	15 (10)	3 (2)
Non-surgical Medical, Cath, Transplant	129 (21)	42 (33)	24 (19)	15 (12)	26 (20)	17 (13)	1 (1)	4 (3)
Benchmark operation Aortic arch	80 (13)	15 (6.8)	36 (24.2)	13 (16)	3 (4.5)	3 (5.8)	6 (18.2)	4 (20)
ASD/VSD	44 (7)	25 (57)	8 (18)	3 (7)	5 (11)	1 (2)	2 (5)	0 (0)
ASO	32 (5)	7 (22)	12 (38)	7 (22)	1 (2)	0 (0)	2 (6)	3 (9)
AVC	34 (5)	18 (53)	7 (21)	1 (3)	3 (9)	2 (6)	3 (9)	0 (0)
Fontan	20 (3)	12 (60)	0 (0)	1 (5)	7 (35)	0 (0)	0 (0)	0 (0)
Glenn	48 (8)	23 (48)	7 (15)	8 (17)	6 (13)	2 (4)	2 (4)	0 (0)
Left-side valve	48 (8)	18 (38)	2 (4)	5 (10)	3 (6)	18 (38)	2 (4)	0 (0)
Norwood	46 (7)	5 (11)	19 (41)	10 (22)	4 (9)	2 (4)	4 (9)	2 (4)
Other/ Truncus/ Vascular ring	80 (13)	21 (26)	21 (26)	12 (15)	7 (9)	6 (8)	6 (8)	7 (9)
PVR/Conduit	24 (4)	14 (58)	4 (17)	3 (13)	1 (4)	0 (0)	2 (8)	0 (0)
TOF	39 (6)	22 (56)	9 (23)	3 (8)	1 (3)	1 (3)	3 (8)	0 (0)
Post-op. complications NEC, Cardiac arrest, MCS	24 (4)	3 (13)	7 (29)	5 (21)	4 (17)	1 (4)	3 (13)	1 (4)
Discharge planning Nasal Cannula O_2	262 (42)	87 (33)	62 (24)	36 (14)	39 (15)	15 (6)	19 (7)	4 (2)
Narcotic Wean	17 (3)	2 (12)	5 (29)	3 (18)	1 (6)	1 (6)	4 (24)	1 (6)
Home Zip code to PCH in miles: Median (IQR)	35.1 (21.5, 188.9)	32.1 (21.6, 203.7)	36.4 (20.8, 167.6)	37.4 (22.9, 203.7)	26.7 (20.8, 188.9)	44.2 (24.3, 183.8)	33.2 (26.7, 174.3)	59.4 (22.9, 194.0)
Feeds At Discharge: GT	11 (2)	2 (18)	2 (18)	2 (18)	3 (27)	2 (18)	0 (0)	0 (0)
NG + NJ	219 (35)	49 (22)	76 (35)	42 (19)	12 (5)	12 (5)	17 (8)	11 (5)
PO	394 (63)	171 (43)	71 (18)	37 (9)	52 (13)	38 (10)	16 (4)	9 (3)
Final ICU need Cardiovascular	392 (65)	178 (45)	85 (22)	49 (13)	35 (9)	31 (8)	11 (3)	3 (1)

(*Continued*)

https://doi.org/10.1017/S1047951122003596 Published online by Cambridge University Press

Table 1. (*Continued*)

	Final Hospital Need							
	All encounters n = 624 (%)	Cardiovascular n = 222 (36)	Feeding/ fluid n = 149 (24)	Systems issues n = 81 (13)	Respiratory n = 67 (11)	Haematology/ ID n = 52 (8)	Pain/sedation n = 33 (5)	Other/ wound issues n = 20 (3)
Other FIN	65 (11)	10 (15)	12 (18)	12 (18)	6 (9)	11 (17)	5 (8)	9 (14)
Respiratory	144 (24)	28 (19)	50 (35)	20 (14)	18 (13)	7 (5)	17 (12)	4 (3)

Column percentage reported for "All Encounters." Row percentage reported for all others.
Abbreviations: ACU = acute care unit; ASD = atrial septal defect; ASO = arterial switch operation; AVC = atrioventricular canal; FIN = Final ICU Need; GT = gastrostomy tube; LOS = length of stay; MCS = mechanical circulatory support; NEC = necrotising enterocolitis; NG = nasogastric; NJ = nasojejunal; PO = by mouth; Post-op = post-operative; PVR = pulmonary valve replacement; TOF = tetralogy of Fallot; VSD = ventricular septal defect

All logistic model results are reported as odds ratios (OR) and their 95% confidence intervals (CI). Statistical analyses were implemented using R v.3.4.4 (15). Statistical significance was assessed at the 0.05 level, and all tests were two-sided.

Results

Between April 2016 and July 2018, a total of 624 encounters from 513 unique patients were eligible for analysis after excluding 175 encounters for cardiac acute care unit length of stay ≤48 hours. Survey response rate was 99% (799/807) from a total of seven respondents. Of the 624 encounters, 79% (495/624) were surgical encounters. The median cardiac acute care unit length of stay was 4 days (IQR: 3, 8.2). Patient demographics and clinical characteristics summarised across Final Hospital Need category are shown in Table 1.

Overall, the most frequent Final Hospital Needs were "cardiovascular" (36%, 222/624), followed by "feeding/fluid" (24%, 149/624) and "systems issues" (13%, 81/624) (Table 1). In non-surgical encounters, the most frequent Final Hospital Needs were "cardiovascular" (33%, 42/129) and "respiratory" (20%, 26/129), and in surgical encounters, the most frequent were "cardiovascular" (36%, 180/495) and "feeding/fluid" (25%, 125/495) (Table 1). "Cardiovascular" made up 43% (175/407) of Final Hospital Needs in children, compared to 22% (47/217) in neonates. The most frequent Final Hospital Need for neonates was "feeding/fluid" (37%, 81/217) which only accounted for 17% (68/407) of Final Hospital Needs in children.

The interaction model showed that the predicted probability of Final Hospital Need being "cardiovascular" decreased as cardiac acute care unit length of stay increased in both paediatric and neonatal encounters; however, the rate of decrease was faster among neonates than children (Fig 1). Compared to children, the neonates had a 1% decrease in likelihood of Final Hospital Need "cardiovascular" for each additional hospital day (OR: 1.009, 95%CI: 1.006, 1.013, p-value <0.001).

An alluvial plot demonstrating the relationships between age (neonate vs. paediatric), cardiac acute care unit length of stay (≤75th percentile vs. >75th percentile), and Final Hospital Need is shown in Figure 2. The plots show that a larger portion of children with short lengths of stay trends towards Final Hospital Need "cardiovascular," compared to neonates with short lengths of stay. For lengths of stay >75th percentile, the number of patients with a Final Hospital Need "cardiovascular" was similar between neonates and children. When comparing those with shorter acute care unit lengths of stay, Final Hospital Need "respiratory" was more common in children than in neonates.

Figure 3 shows that the final need shifts categories as patients transition from ICU discharge to hospital discharge. For example, a "respiratory" Final ICU Need rarely led to a "respiratory" Final Hospital Need. The variety of final discharge categories was much greater at time of hospital discharge compared to ICU discharge.

By multivariate analysis, compared to all other Final Hospital Needs, Final Hospital Need "cardiovascular" was independently associated with aortic arch repair (aOR: 0.21; 95% CI: 0.06, 0.7; p = 0.011), Norwood procedure (aOR: 0.14, 95% CI 0.03, 0.64; p = 0.011), Final ICU Need "respiratory" (aOR 0.42, 95% CI 0.25, 0.71; p = 0.001), and Final ICU Need "other" (aOR: 0.31; 95% CI: 0.14, 0.68; p = 0.003) (Table 2). Final Hospital Need "feeding/fluid" was independently associated with left-sided valve replacement/repair (aOR 0.13, 95% CI 0.02, 0.78; p = 0.026), requirement of tube feeds at discharge (aOR: 2.00, 95% CI 1.12, 3.56; p = 0.019), and Final ICU Need "respiratory" (aOR 1.93, 95% CI 1.08, 3.47; 0.027) (Table 2). Individual respondents were mostly insignificant with only one provider demonstrating significant association with Final Hospital Need "cardiovascular" in multivariable analysis compared to the reference provider (OR 0.49 95% CI 0.24, 0.98; p = 0.043). There was no association between providers in univariable analysis for Final Hospital Need "cardiovascular" or in univariable or multivariable analysis for Final Hospital Need "feeding/fluid." Multicollinearity was not detected in the above models (generalised variance inflation factors <2.24).

Discussion

Our single-centre, survey study is the first to describe Final Hospital Need for children discharged from a cardiac acute care unit. As a novel measure, Final Hospital Need can identify the most important clinical need of patient populations in the last 24 hours of their inpatient care. The Final Hospital Need measure has low utility for individual patients but provides valuable data to understand systems and patient populations. Additionally, this knowledge enables providers to longitudinally evaluate the clinical environment and assess the impact of process changes within the hospital system.

The wide distribution of Final Hospital Needs reported across neonatal and children admitted for cardiac disease highlights the need for multidisciplinary care if we are to optimise the final portion of the patient's experience. It may be assumed that a "cardiovascular" Final Hospital Need designation would predominate in our studied population, and this was true of the Final ICU Need study,[4] but a "cardiovascular" Final Hospital Need accounted for only 36% of all encounters, and for neonates, "feeding/fluid" issues

https://doi.org/10.1017/S1047951122003596 Published online by Cambridge University Press

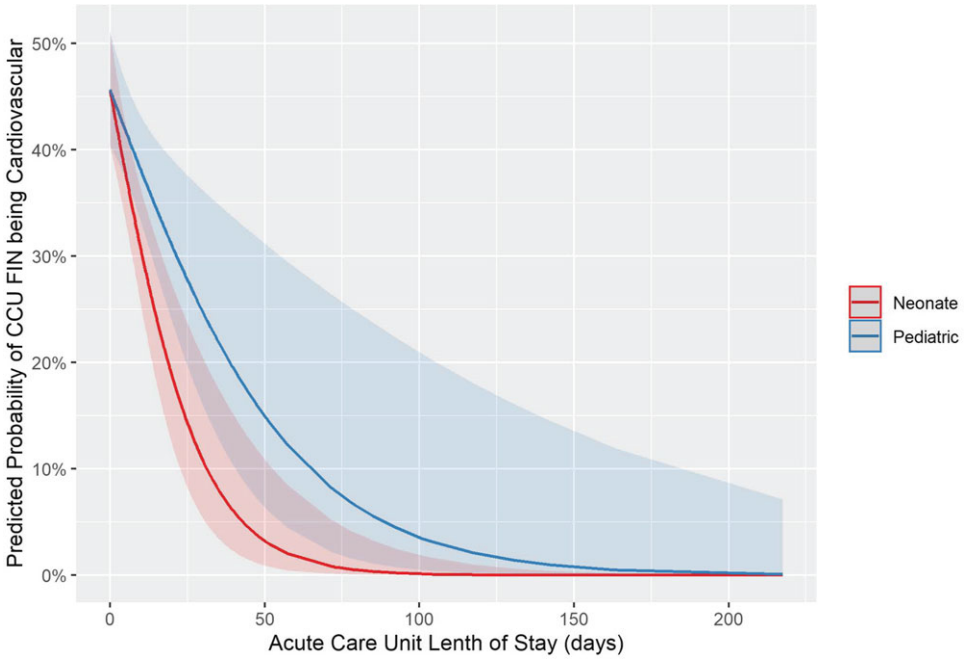

Figure 1. Interaction plot comparing likelihood of Final Hospital Need 'cardiovascular' to acute care unit length of stay by patient age.

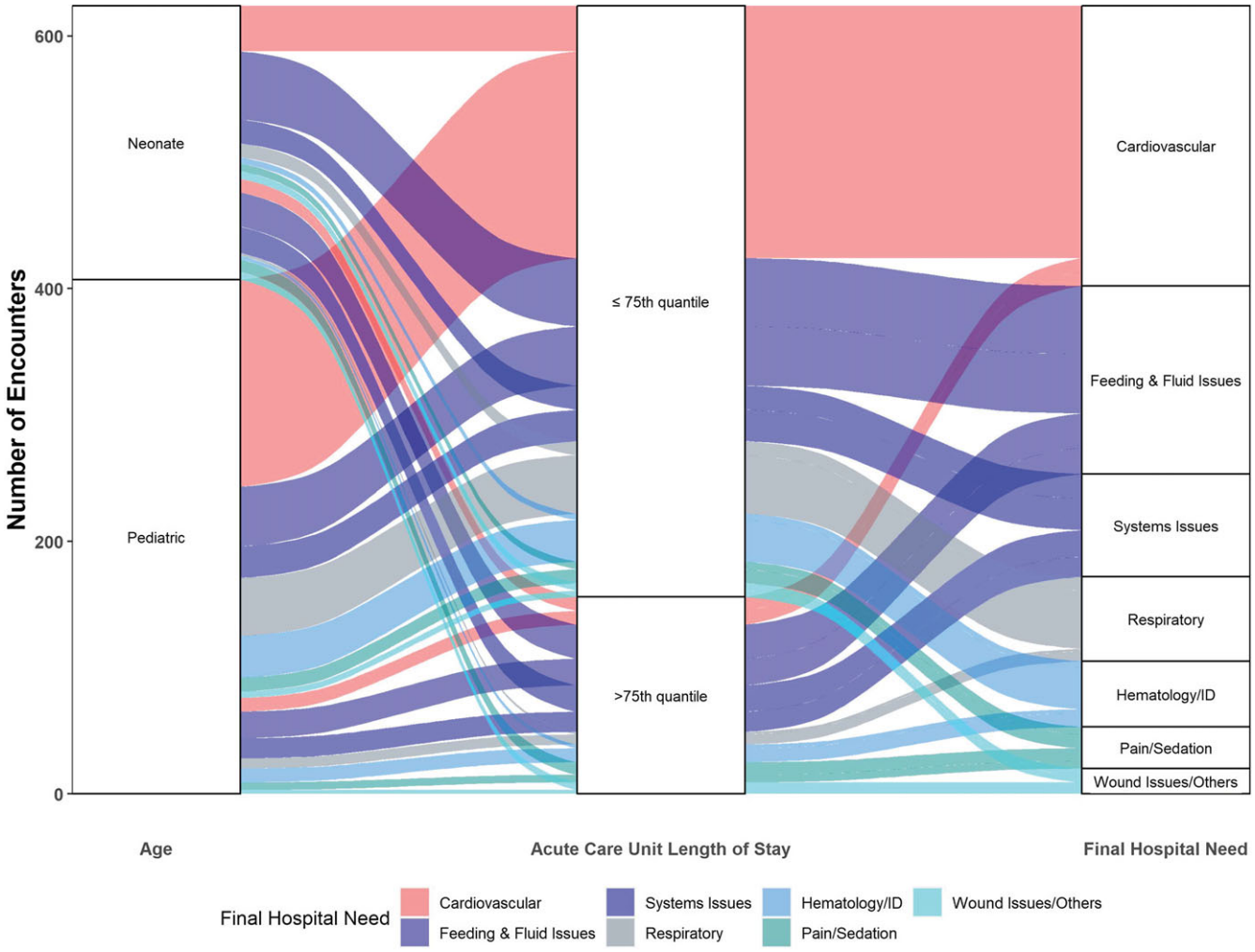

Figure 2. Alluvial plot correlating age with acute care unit length of stay and Final Hospital Need. Relationships between categories are demonstrated by connecting lines with height of categories and width of lines determined by number of observations.

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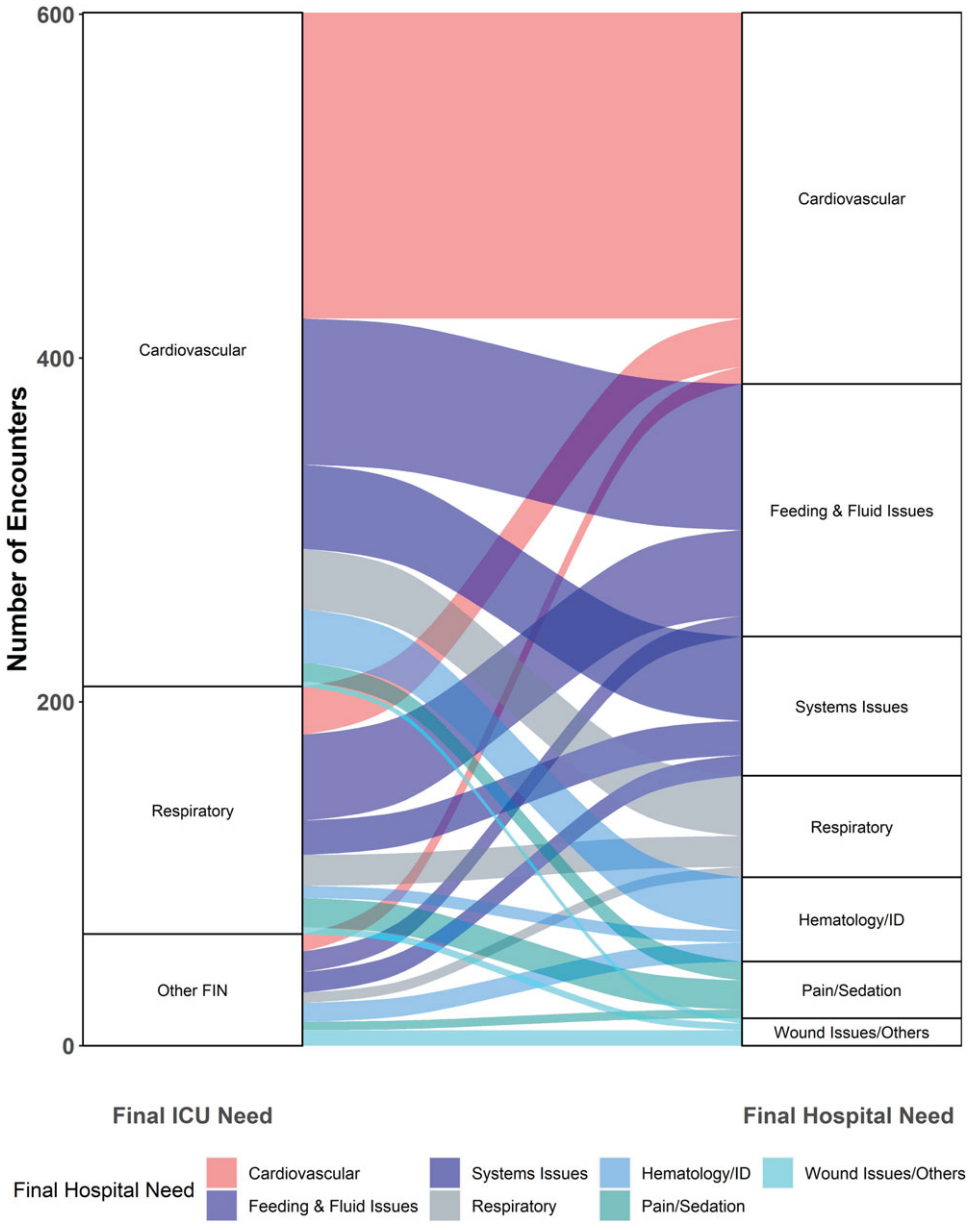

Figure 3. Alluvial plot correlating Final ICU Need with Final Hospital Need. Relationships between categories are demonstrated by connecting lines with height of categories and width of lines determined by number of observations.

were more frequent. The decline in Final Hospital Need "cardiovascular" frequency was further augmented as acute care unit length of stay increased (Figs 1 and 2). Even major complications such as cardiac arrest or mechanical circulatory support did not demonstrate an independent association with a "cardiovascular" Final Hospital Need designation. This relationship suggests that work to improve the final hospital days may need to target non-cardiac issues such as feeding, respiratory status, or improved preparation for discharge (systems issues).[9,13–18]

Interestingly, the only operations independently associated with Final Hospital Need "cardiovascular" were aortic arch repair and Norwood, both of which *decreased* the odds, despite having very disparate levels of complexity. Hence, we suggest that providers prepare families to expect a multidisciplinary recovery experience (i.e., feeding, haematology, respiratory issues), irrespective of surgical complexity.

Feeding/fluid issues constitute a growing area of focus for optimal recovery of patients with CHD.[19] In our cohort, we did not find an independent association with age, need for nasal cannula at time of discharge, narcotic wean, or perioperative necrotising enterocolitis with Final Hospital Need "feeding/fluid." We did find an increased odds of Final Hospital Need "feeding/fluid" at time of discharge from the acute care unit in encounters whose Final ICU Need was "respiratory." Prior studies also demonstrate an association between prolonged mechanical ventilation or need for non-invasive positive pressure ventilation in the cardiac ICU and decreased feeding skills and use of nasogastric supplementation.[1,13,14,19,20] Left-sided valve lesions were associated with decreased odds of Final Hospital Need "feeding/fluid" but this was likely due to the need for anticoagulation (Final Hospital Need haematology) in this group.

We anticipate that measuring the Final Hospital Need longitudinally will provide opportunities for quality improvement initiatives with outcome measures built into the survey. For example, we found that 13% (n = 81) of encounters were clinically ready for discharge but remained in the hospital due to "systems issues." After

https://doi.org/10.1017/S1047951122003596 Published online by Cambridge University Press

Table 2. Variables associated with Final Hospital Need "Cardiovascular" and "Feeding/Fluid" by multivariate logistic regression.

	Cardiovascular	
	OR (95% CI)	p-value
Benchmark operation		
Aortic Arch	0.21 (0.06, 0.7)	0.011
Norwood	0.14 (0.03, 0.64)	0.011
Final ICU need		
Other	0.31 (0.14, 0.68)	0.043
Respiratory	0.42 (0.25, 0.71)	0.001
	Feeding/Fluid	
	OR (95% CI)	p-value
Benchmark operation		
Left-sided valve	0.13 (0.02, 0.78)	0.026
Feeding route at discharge		
NG + NJ	2.00 (1.12, 3.56)	0.019
Final ICU need		
Respiratory	1.93 (1.08, 3.47)	0.027

Abbreviations: NG = nasogastric; NJ = nasojejunal.

designating the Final Hospital Need, our survey provides respondents the ability to mark the patient factors that contributed to that need (Supplemental Figure 1). While a formal analysis of subcategorisations within each Final Hospital Need category is beyond the scope of this work, the response options under the designation "systems issues" can easily be converted into a Pareto chart to identify the most common causes of delay (see Supplemental Figure 2 for an example). Additionally, the proportion of patients with a designation of "systems issue" can easily be graphed on a statistical process control chart to monitor for change once quality improvement efforts are initiated. Improvement efforts can target any aspect of the Final Hospital Need as a statistical process control chart and Pareto chart can be built for any of the categories.

In addition to utilising the Final Hospital Need as a primary outcome measure, tracking the Final Hospital Need on our unit may serve as a powerful balance measure. When combined with the Final ICU Need, the Final Hospital Need may help illuminate the impact of upstream process changes quickly and with real data. For example, altering pain or sedation protocols in the ICU may result in prolonged sedation weans on the floor and may protract the usual acute care unit length of stay. If the Final Hospital Need has been tracked as described above, a statistical process control chart may demonstrate special cause variation in the number of discharges with a Final Hospital Need "pain/sedation" after the implementation of the new ICU protocol. This example illustrates why we have integrated statistical process control charts for the Final Hospital Need categories into our cardiac acute care unit dashboard. Given the multidisciplinary care requirements for children with CHD, we anticipate that the Final Hospital Need will be beneficial to a wide range of providers including dieticians, speech and occupational therapists, pharmacists, respiratory therapists, cardiac intensivist, surgeons, and anaesthesiologists to measure the impact of their process changes.

Limitations of the study include the lack of validation for our survey tool. Inter-rater analysis demonstrates consistency between providers, but intra-rater reliability has not been tested. Recall bias may be present, but was limited by including the discharge survey in the standard discharge process. An analysis of subcategorisations within each Final Hospital Need is needed, but beyond the scope of this work.

Conclusion

The Final Hospital Need is a novel measure to identify the final reason a patient requires care within the hospital. In our patients, the most frequent Final Hospital Needs were "cardiovascular," "feeding/fluid," and "systems issues." Clinical factors including age, length of stay, Final ICU Need, surgery type, and feeding route at discharge are associated with the Final Hospital Need. The Final Hospital Need can be incorporated with high reliability into the discharge process. Longitudinal assessment of the Final Hospital Need may increase understanding of the clinical environment, provide targets for improvement, and aid in evaluation of the downstream impact of process changes in earlier segments of care.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/S1047951122003596

Acknowledgements. This investigation was supported by the University of Utah Study Design and Biostatistics Center, with funding in part from the National Center for Research Resources and the National Center for Advancing Translational Sciences, National Institutes of Health, through Grant UL1TR002538 (formerly 5UL1TR001067-05, 8UL1TR000105 and UL1RR025764).

Financial support. This research received no specific grant from any funding agency, commercial, or not-for-profit sectors.

Conflicts of interest. None.

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https://doi.org/10.1017/S1047951122003596 Published online by Cambridge University Press