University of Cincinnati

Date: 3/16/2021

I, Abigail Musial, hereby submit this original work as part of the requirements for the degree of Master of Science in Clinical and Translational Research.

It is entitled:

Increasing Time to Full Enteral Feeds in Hospitalized Children with Medical Complexity Experiencing Feeding Intolerance

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UNIVERSITY OF Cincinnati

38253

Increasing Time to Full Enteral Feeds in Hospitalized Children with Medical Complexity Experiencing Feeding Intolerance

A thesis submitted to the Graduate School of the University of Cincinnati in partial fulfillment of the requirements for the degree of:

Master of Science in Clinical and Translational Research

At the University of Cincinnati College of Medicine, Department of Environmental Health, Division of Epidemiology

Thesis submitted by Abigail M. Musial, March 16, 2021

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ABSTRACT

Background and Objectives: Children with medical complexity (CMC) have co-existing chronic conditions and resultant functional limitations that may lead to difficulty achieving adequate nutrition. Ineffective management of reeding intolerance, defined as the inability to achieve target enteral intake combined with symptoms consistent with gastrointestinal dysfunction, can exacerbate this issue. Our primary objective was to decrease median time from admission to goal feeds from 3.5 days to 2.5 days in CMC fed via gastrostomy and gastrojejunostomy tubes admitted for feeding intolerance.

Methods: A multi-disciplinary team of nurses, nurse practitioners, pediatric residents, hospitalist and gastroenterology physicians, parents, and a dietitian conducted this local quality improvement project. Key drivers included: standardized approach to managing feeding intolerance, shared understanding of parental goals for their child's feeds, timely delivery of formula to the bedside, and provider knowledge. Plan-do-study-act cycles included development of a standardized feeding algorithm, education of providers, correcting formula room misinformation, addressing physician ordering practices at admission, near-real time reminders and feedback. A run chart tracked the effect of interventions on median time to goal enteral feeds and median length of stay (LOS).

Results: Over the course of 6 months, median time to goal enteral feeds for CMC fed via gastrostomy or gastrojejunostomy tubes decreased from 3.5 days to 2 days, meeting special cause variation, and this decrease has been sustained for 1 year. This change coincided with implementation of a standardized feeding intolerance management algorithm. There was no change in LOS.

Conclusions:
There was a temporal association between implementation of a standardized algorithm for CMC hospitalized with Feeding intolerance and decreased time to goal enteral feeds; LOS did not change. Future work will include incorporating the algorithm into electronic health record order sets and spread of the algorithm to other service lines in our institution that frequently care for CMC.

ACKNOWLEDGEMENTS

I would like to acknowledge the quality improvement team, collaborators, and mentors who have all made significant contributions too this work:

Owen Densel, RD

Lacey Edwards MSN, APRN

Lori Herbst MD

Setenay Kara MS, PhD*

Jodi Kelley MSN, APRN

Conor Merritt MD

Marialena Mouzaki MD, MSc

Stephanie Olivera MD, CNSC

Jennifer Phillips, RD

James Rudloff MD

Amanda Schondelmeyer MD, MSc**

Angela Statile MD, MEd

Brittney Underwood

Jamie Swartzel

Tabitha L. Donner

Angela Younts MSN, APRN

* QI Analytic Collaborator
**Primary Research Mentor

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Introduction:

Children with medical complexity (CMC) have co-existing chronic conditions and resultant functional limitations that may lead to difficulty achieving adequate nutrition. Many CMC, particularly those with neurologic impairment, have associated oral motor dysfunction or gastrointestinal issues necessitating the use of enteral feeding tubes (e.g. gastrostomy tubes (GT) or gastrojejunostomy (GJ) tubes) to optimize nutrition while decreasing the risk for aspiration.[1-4] Even with a safe enteral feeding route, many CMC receive suboptimal nutrition. Undernutrition is especially prevalent among CMC with neurologic impairment, as >80% of this subpopulation does not receive sufficient nutrition to meet daily caloric requirements.[5]

One reason for suboptimal nutrition in CMC is feeding intolerance, defined as the inability to achieve target enteral intake combined with symptoms consistent with gastrointestinal dysfunction.[6] It is characterized by vomiting, retching, pain, agitation, and/or abdominal distension that occurs with administration of feeds and subsides with cessation of feeds.[7-10] Concern for dehydration in CMC with feeding intolerance can lead to admission to the hospital. We know that previous quality improvement initiatives in pediatric critical care populations have successfully and safely utilized standardized feeding protocols to improve time to full nutrition in hospitalized children.[11-16] However, a standardized approach to re-initiation of feeds in hospitalized children with medical complexity who experience feeding intolerance is lacking leading to provider reliance on personal experience or parental preference to guide decision making. At our institution, this reliance on anecdotal evidence and preference led to undesirable variation and non-evidence-based management strategies, including concern for delays in achieving full feeds and resultant increased length of stay (LOS).

The aim of our quality improvement project was to decrease median time to goal enteral feeds from a baseline median of 3.5 days to 2.5 days in children with medical complexity who are GT or GJ dependent admitted to the Hospital Medicine (HM) service over 1 year.

Methods:

Setting/Context

This was a quality improvement study based in the Model for Improvement [17] conducted on the HM service at Cincinnati Children's Hospital Medical Center (CCHMC), a large, quaternary care pediatric health system with >700 hospital beds. Collectively, the CCHMC HM service cares for > 8000 patients per year, including >500 children who have neurologic impairment and/or require medical technology assistance. At its main location, the HM service has 5 clinical teams, including a dedicated, interdisciplinary, inpatient complex care team. The inpatient complex care team is staffed by an attending physician and/or HM fellow, 4 residents, 1-2 nurse practitioners, a social worker, a dietitian, a care manager, and a pharmacist. The inpatient complex care team is capped at 10 patients. Thus, medically complex patients are also frequently cared for on the general HM teams as well.

Prior to our work, when patients were admitted to the HM service with feeding intolerance, they would typically be started on intravenous (IV) fluids and enteral feeds would be held. Once the decision was made to transition to enteral feeds, a low-calorie enteral electrolyte solution (e.g., Pedialyte) was typically initially administered at a low volume and rate. After reintroduction of enteral feeds, management varied greatly, including how providers defined and evaluated for "tolerance" of feeds and decisions to start, stop, or alter feeding plans based on perceived tolerance or intolerance, even in patients with similar presentations and underlying conditions (Figure 1). At discharge, homegoing feeding regimens of patients who experienced

feeding intolerance during admission also varied greatly with some patients discharged on their full volume and frequency of feeds, while other patients were discharged with instructions to continue titration of feeds at home.

Interventions:

We assembled a multidisciplinary team in June 2019 to improve the care of CMC dependent on enteral nutrition who experience feeding intolerance during hospitalization. Team members included two nurse practitioners, a bedside nurse, two resident physicians, an HM fellow, three HM attending physicians, five parents, and a registered dietitian with experience caring for CMC. We also engaged key stakeholders in consultant roles for this project including two gastroenterology physicians who care for children with intestinal failure, formula room technicians, additional bedside nurses, and an intensive care unit dietitian.

The team chose a goal of 2.5 days because we thought a 30% decrease in time to full feeds was an achievable objective. Additionally, parents in the team voiced the importance of more time spent at home and less time spent in the hospital. Thus, we felt that if a decrease in time to achievement of goal feeds was related to earlier discharge and decreased length of stay that this would be meaningful to families.

Because children with feeding intolerance may have acute, underlying, treatable causes of feeding intolerance prompting admission to the hospital[18], our team conducted a retrospective chart review of the 64 children with feeding intolerance admitted to the HM service in the 6 months prior to the onset of interventions to determine the most commonly documented reasons for feeding intolerance. A Pareto chart (Figure 2) was constructed to analyze the frequency of

these underlying conditions to determine their cumulative impact on children admitted with feeding intolerance.[19]

Based on chart review, process observation, input from key stakeholders, and through a modified failure modes and effects analysis [20], our improvement team also identified key drivers of decreasing time to goal enteral feeds (Figure 3). Key drivers included a standardized approach to managing feeding intolerance, shared understanding of parental goals, timely delivery of formula to the bedside, and provider knowledge. Key drivers were then utilized to guide the development and testing of interventions, (outlined below) which were tested and refined through sequential Plan-Do-Study-Act (PDSA) cycles.[19]

Development of a Standardized Feeding Algorithm

Engaging expert stakeholders and leveraging feeding protocols in the published literature for critical care populations, we formulated a management algorithm for CMC admitted with feeding intolerance.[11-16] The algorithm indicated guidance for how to evaluate for the most common underlying, treatable causes of feeding intolerance, when GI consultation was recommended, cautions on which patients should not be fed (e.g., patients with bilious emesis or tube output), and a framework for how and when to titrate feeds. In addition to providing a framework for feed titration, the algorithm also de-emphasized low calorie electrolyte solutions, based on existing evidence[21-25], and also given that we found that this method of titrating feeds caused significant delays in getting to goal feeds. The algorithm included several opportunities to partner with families to formulate a patient-specific feeding plan, including preference on how to titrate feeds based upon past experience, and volume goals to be met in the hospital before discharge, noting that these goals may differ from baseline home feeding regimen.

The algorithm was then presented to broader stakeholder groups, including residents, hospitalists, and the inpatient complex care team for feedback and then tested initially on individual patients. Based on qualitative feedback from parents and providers after each use of the algorithm, iterative changes were made. Five versions of the algorithm were trialed prior to wide distribution of the final algorithm (Figure 4). The algorithm was also posted on the resident resource website within our institution's intranet for easy access.

Provider Education

To address the driver of provider knowledge, multiple presentations were given throughout this improvement initiative to detail the rationale for the project and interventions. Group presentations included resident educational conferences, HM division provider meetings, and inpatient nutrition support meetings attended by gastroenterologists and registered dietitians. Further education has occurred with monthly email provider reminders, and the algorithm has become a permanent part of resident education at their monthly hospital medicine orientation sessions.

Correcting Feeding Room Misinformation

To address the driver of timely delivery of formula to the bedside, the process of how formula is ordered and delivered to the bedside was explored. Our team discovered a misperception among staff, resulting from when the formula room was under construction, that formula could only be ordered at certain times. Outdated information was posted on the on the nursing units reinforcing this confusion. Our team subsequently facilitated dissemination of up-to-date information through nursing leadership, and bedside nurses began calling for formula on-demand again.

Addressing Physician Ordering Practices at Admission

Our team noted through chart review that patients admitted in the evening or overnight with feeding intolerance were often placed on intravenous fluids without attempting to reinitiate feeds. Residents shared that they could not order certain formulas after the formula room closed in the evening. Formula room staff confirmed that a courier with access to the formula room was available to retrieve formulas after hours, and that residents could call and request formula to be prepared for patients being admitted but who had not arrived to the inpatient unit. This information, including the number for the overnight courier, was shared with residents and nurses and added to the feeding algorithm.

Near-real Time Reminders and Feedback

At the launch of improvement efforts, QI team members reviewed patients admitted for feeding intolerance and sent emails to attendings requesting them to consider use of the feeding algorithm if appropriate, which provided real-time reminders of this new tool. Through chart review, team members also identified patients who may have been eligible for the feeding algorithm but were managed in an alternate manner. QI team members then reached out to the medical team for these patients to elicit the reasons why the feeding algorithm had not been utilized. This served as a form of audit and feedback,[26] and allowed our team to collect information on barriers to use of the feeding algorithm.

Studying the Interventions

Measures

We retrospectively collected baseline time to goal enteral feeds and LOS for hospitalized children with GT or GJ tubes who experienced feeding intolerance and were admitted to a HM service from February 1, 2019 to September 1, 2019 from the electronic health record. After baseline measurement, data from the electronic health record (EHR) was retrieved on a bi-weekly basis throughout the intervention period to understand the impact of our improvement interventions and allow for rapid-cycle learning.

Given that there is no reliable, standardized billing code for feeding intolerance, patients of interest were identified through manual chart review of children with gastrostomy or GJ tubes admitted to HM. We included patients who, based on review of provider documentation, were unable to achieve sufficient enteral intake combined with symptoms consistent with gastrointestinal dysfunction characterized by vomiting, retching, pain, agitation, and/or abdominal distension that occurred with administration of feeds and subsided with cessation of feeds.[6] We excluded patients who received TPN at baseline or who received a surgical consult during admission, as these patients' feeds were often managed by the surgical team rather than the HM service, due to an underlying condition where the management of the patient required nil per os (NPO) status (e.g., obstruction, pneumatosis intestinalis).

LOS was calculated as time in days from admission to the inpatient unit until discharge, and 7- and 30-day readmissions were counted. We excluded previously scheduled admissions (i.e., sleep studies). Given that feeding orders changed frequently throughout admissions and timestamps were not always representative of when patients achieved goal feeds, time to goal enteral feeds was determined through manual chart review of progress notes and counted in days. For example, if progress note documentation on Day 4 of hospitalization indicated that a patient had tolerated full home feeds, we determined that it took 4 days for the patient to achieve goal

enteral feeds. Some parents preferred to continue titration of feeds after discharge. If a child was discharged prior to achieving home, baseline feeds, we counted the day of discharge as the day goal enteral feeds were achieved. For example, if a patient who received bolus feeds at baseline is hospitalized for 5 days and is discharged on continuous feeds, we determined it took 5 days for the patient to achieve goal enteral feeds. Our primary measure of median time to goal enteral feeds and secondary measure of median LOS were measured in increments of 5 patients, given the unpredictable patient volumes of children with feeding intolerance on the HM service from week to week.

Analysis

We examined cohort demographic and clinical characteristics using descriptive statistics. A run chart tracked the effect of interventions on median time to goal enteral feeds and median LOS, and we used established run chart rules for special cause for analysis.[27] Age of the baseline group, and intervention and sustain group were compared using a two sample t-test. Gender, route of enteral feeds (gastrostomy tube vs. gastrojejunostomy tube), and readmission rates (7- and 30-day) were compared by using a X^2 test. Underlying reasons for feeding intolerance were compared using Fisher's exact test.

Results

Of 160 encounters during the study period (February 2019 through January 2021), there were a total of 110 unique patients. We identified 64 patients with feeding intolerance during the baseline period (Feb 1, 2019 through September 1, 2019) and 96 patients during the intervention and sustain period (September 1, 2019 through Jan 28, 2021). During the baseline period,

patients were 59% male, mean patient age was 7.9 years, and 29.6% of patients were fed jejunely. During the intervention and sustain period, patients were 60% male, and mean patient age was 7.8 years, and 26% of patients were fed jejunely. Approximately 85% of children were discharged on full volume and frequency of feeds in both the pre- and post-intervention time periods. The most common underlying causes of feeding intolerance throughout the study period were viral gastroenteritis, viral respiratory infections, ileus, constipation, and urinary tract infection (Table 1).

Baseline median time to goal enteral feeds for children with gastrostomy or GJ tubes who experienced feeding intolerance during hospitalization demonstrated substantial variability (Figure 5) at 3.5 days. We tested and adopted several interventions including development and implementation of a standardized feeding algorithm, initial education of providers, correction of feeding room misinformation, addressment of physician ordering practices on admission, and near real time feedback of providers. We documented special cause within 6 months of improvement interventions, which was temporally associated with implementation and wide distribution of the standardized feeding intolerance management algorithm, at which time there was a decrease in median time it took to achieve goal enteral feeds in this population to 2 days. We did not document any further improvement with subsequent interventions, which included continued education at monthly resident orientation sessions, monthly email provider reminders, subsequent provider reminders, and feedback. This reduction has been sustained even during the COVID-19 pandemic, when there were lower inpatient volumes and fewer members of the interdisciplinary team physically present due to infection precautions.

For the duration of the intervention period, median LOS remained unchanged at 5 days. We did not see a statistically significant change in 7- or 30-day readmission rates (Table 1).

Discussion

Summary

Using improvement science methods, we successfully decreased median time to goal enteral feeds from 3.5 days to 2 days in children with medical complexity who are GT/GJ dependent admitted to the HM service over 1 year. Our key interventions involved implementing a standardized feeding intolerance management algorithm, provider education, correction of formula room misinformation, optimized ordering practices of physicians, reminders to ordering providers, and near-real time feedback. Special cause was temporally associated with introduction of a standardized feeding algorithm suggesting this may have been a particularly impactful intervention.

Interpretation

Previous studies have shown that standardized management of other acute, common pediatric diagnoses (e.g. pneumonia, urinary tract infections) in otherwise healthy children improves quality of care.[28-30] Additionally, there is a well-established and growing body of evidence within the neonatal and pediatric intensive care unit populations, who like CMC are at high risk of malnutrition and feeding intolerance, that supports utilizing standardized enteral feeding protocols to improve outcomes, particularly time to full enteral feeds.[11-14] Utilizing a standardized feeding guideline to guide enteral feeding advancement in pre-term infants, Chu et al improved time to full feeds with an average reduction of 5 days to full feeds from baseline and a reduction in central line days per hospital days by 35%, without a rise in complications.[16] In the PICU, Ziemba et al utilized an early enteral nutrition feeding protocol to successfully and safely

increase the percentage of critically ill children who reached goal enteral feeds in the first 48 hours of admission by 20%. Our study has expanded upon this aforementioned work, by focusing on CMC, a population of children frequently excluded from research and quality improvement[31], highlighting the feasibility of implementing a standardized management protocol to treat a common issue in a complex, heterogenous group of patients.

The feeding algorithm also promoted families and providers to partner together in order to more intentionally collaborate on feeding plans. Promoting parental engagement in decision-making for hospitalized children is accepted as a key component of family-centered care and is endorsed by the American Academy of Pediatrics Committee on Hospital Care.[32] Further, previous studies have shown that effective provider-family communication can lead to safer care.[33,34] Khan et al conducted a prospective, multi-center study utilizing a structured, standardized mode of communication with families on rounds and achieved a significant decrease in harmful errors and non-preventable adverse events, and an increase in family experience scores.[33] Families of CMC bring experience with their child's previous illnesses, knowledge of their child's particular disease, medications, and medical technologies. If engagement of families can improve the safety of care, then certainly standardized engagement of families of CMC might improve quality of care for common conditions, like feeding intolerance, faced by CMC. Our experience using the feeding algorithm suggests caregivers of CMC bring valuable viewpoints and expertise on the care of their child and should be productively and actively engaged during hospitalization.

During our project, we found that some delays in formula order and delivery for patients, were not due to inefficient processes, but simply lack of knowledge of existing processes. Through discovery of misinformation about formula room policies (e.g., on demand delivery and

the overnight courier), our study also emphasized that sharing and sustaining important clinical process knowledge in a large, complex healthcare system is challenging.

Although patients were able to achieve goal feeds more quickly, there was no change in LOS. We hypothesize this is due to the complicated and multifaceted nature of medical readiness for discharge in CMC,[35] and that CMC may experience multiple reasons for hospitalization simultaneously (i.e., bacterial pneumonia leading to an increased in oxygen requirement in conjunction with feeding intolerance).[36]An overall improvement of time to full enteral feeds is valuable, even without change in LOS. By decreasing time to full enteral feeds, we are able to better supply full nutrition to an acutely ill cohort of children who are at high risk of undernutrition, growth failure, micronutrient deficiencies, and osteopenia at baseline.[18,37,38]

Lastly, the COVID-19 pandemic provided additional challenges to our improvement effort. During this period of time, the hospital restricted which personnel were physically present in the hospital and which personnel (i.e dietitians) worked from home, and hospital admissions also declined substantially. If staff had infrequent encounters with patients experiencing feeding intolerance during this time, it may have proved difficult to remember the interventions our team put in place. These findings demonstrate the importance of high reliability interventions such as system level changes and electronic health record automation, because while low reliability interventions and interventions reliant on people can lead to early improvement, it is often not sustained.

Limitations

This study occurred at a single center at an institution with a dedicated, highly resourced complex care team on its HM service, thus generalizability of results may be limited. However,

this algorithm was also widely utilized on our general HM teams, thus, the feeding intolerance management algorithm can likely be applied to other institutions who care for a large number of medically complex children. We did not track patient characteristics such as co-morbid conditions or socioeconomic status that could have contributed to ability to obtain goal feeds or readiness for discharge from the hospital. Our team plans to do a secondary retrospective analysis of these variables as they may provide helpful targets for future, ongoing improvement efforts. Because of institutional and EHR constraints on data retrieval, and no standardized, unifying code for feeding intolerance, manual chart review for our primary measure was required. Manual chart review and reliance on physician documentation both have inherent limitations, (for example, reliability of accurate documentation of feeds in the progress note). While utilizing formula order timestamps may have eliminated the need for manual chart review, our team realized that these timestamps seldom reflected when the patient actually achieved full feeds, and often underestimated time to goal enteral feeds. Conversely, we believe measuring time to goal enteral feeds in days once achievement of goal feeds was documented in the progress note likely overestimated the time to goal feeds. Lastly, given that many of our interventions were people dependent, our project will benefit from continued implementation of high reliability interventions (i.e. integrating principles of the feeding algorithm into ordering functions in the EHR).

Conclusion:

Through education, correction of misinformation, partnership on care plans with families, and a standardized approach to feeding intolerance, we decreased time to full enteral feeds for CMC fed via gastrostomy tube or GJ tube on an HM Service. Ongoing efforts are focused on

sustainability, including integration of elements of the feeding intolerance management algorithm into EHR order sets, and spread to other service lines within our institution that frequently care for CMC. Our project has also identified the need for further clinical research into management variation of feeding intolerance as it relates to hospital and nutritional outcomes. Accurate data in this arena may help inform clinical outcomes research for the management of feeding intolerance.

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Table 1. Characteristics of Children with Medical Complexity Hospitalized with Feeding Intolerance

Characteristics	Pre-Intervention (*n* = 64)	Post-intervention (*n* = 96)	*p* value
Average age at presentation (mean, standard deviation)	7.9 ± 6.6	7.8 ± 6.4	0.07
Male Gender, *n* (%)	38 (59)	58 (60)	0.89
Jejunely Fed, *n* (%)	19 (29.6)	25 (26.0)	0.61
7-day readmission rate, *n* (%)	3 (4.7)	9 (9.4)	0.27
30-day readmission rate, *n* (%)	23 (35.9)	29 (30.2)	0.45
Underlying cause of feeding intolerance, n (%)			
Viral Respiratory Infection	6 (9)	18 (18.8)	0.12
Acute Gastroenteritis	16 (25)	14 (14.6)	0.10
Urinary Tract Infection	3 (4.7)	15 (15.6)	**0.04**
Constipation	6 (9)	16 (16.7)	0.24
Ileus	8 (12.5)	10 (10.4)	0.79
Feeding Tube Malfunction	5 (8)	3 (3)	0.27
Bacterial Pneumonia	3 (4.7)	4 (4)	1.00
Electrolyte Derangement	2 (3)	8 (8.3)	0.32
Medication Change	2 (3)	4 (4)	1.00
Pancreatitis	3 (4.7)	2 (2.1)	0.38
Formula type or volume issue	2 (3)	3 (3)	1.00
Agitation	1	2 (2.1)	1.00
Gastritis	NA	3 (3)	0.28
Other	3	2	0.39

Figure 1. The hospital course of two patients of the same age and gender with similar underlying conditions admitted for feeding intolerance on the hospital medicine service pre-intervention.

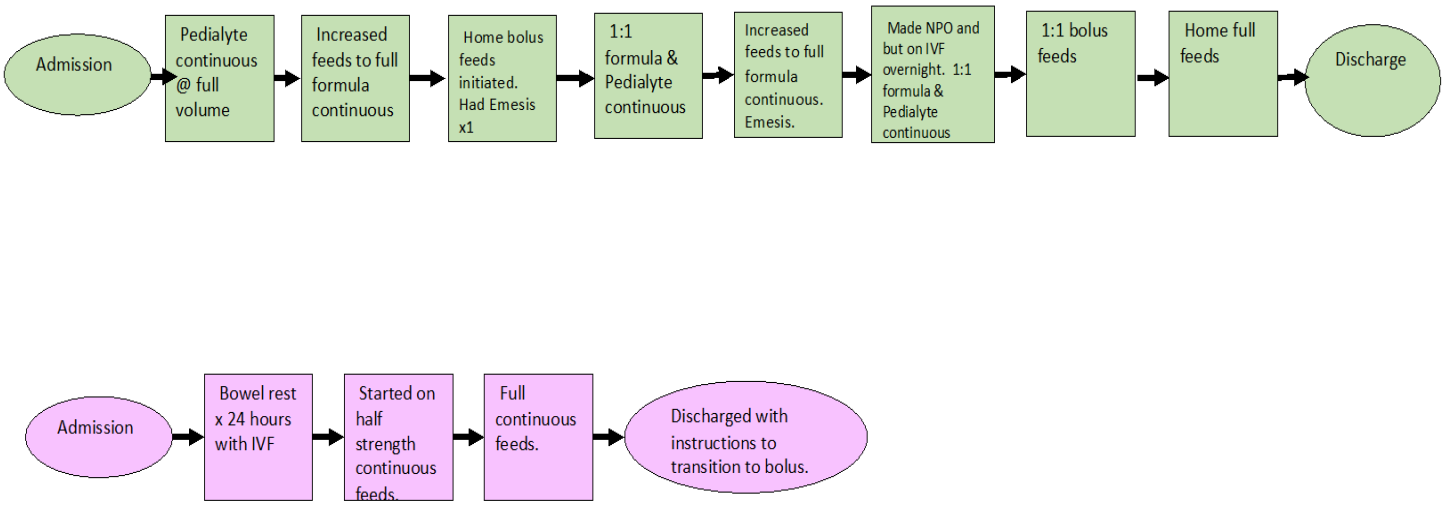

Figure 2. Preprocess Pareto chart of the underlying conditions among children admitted with feeding intolerance.

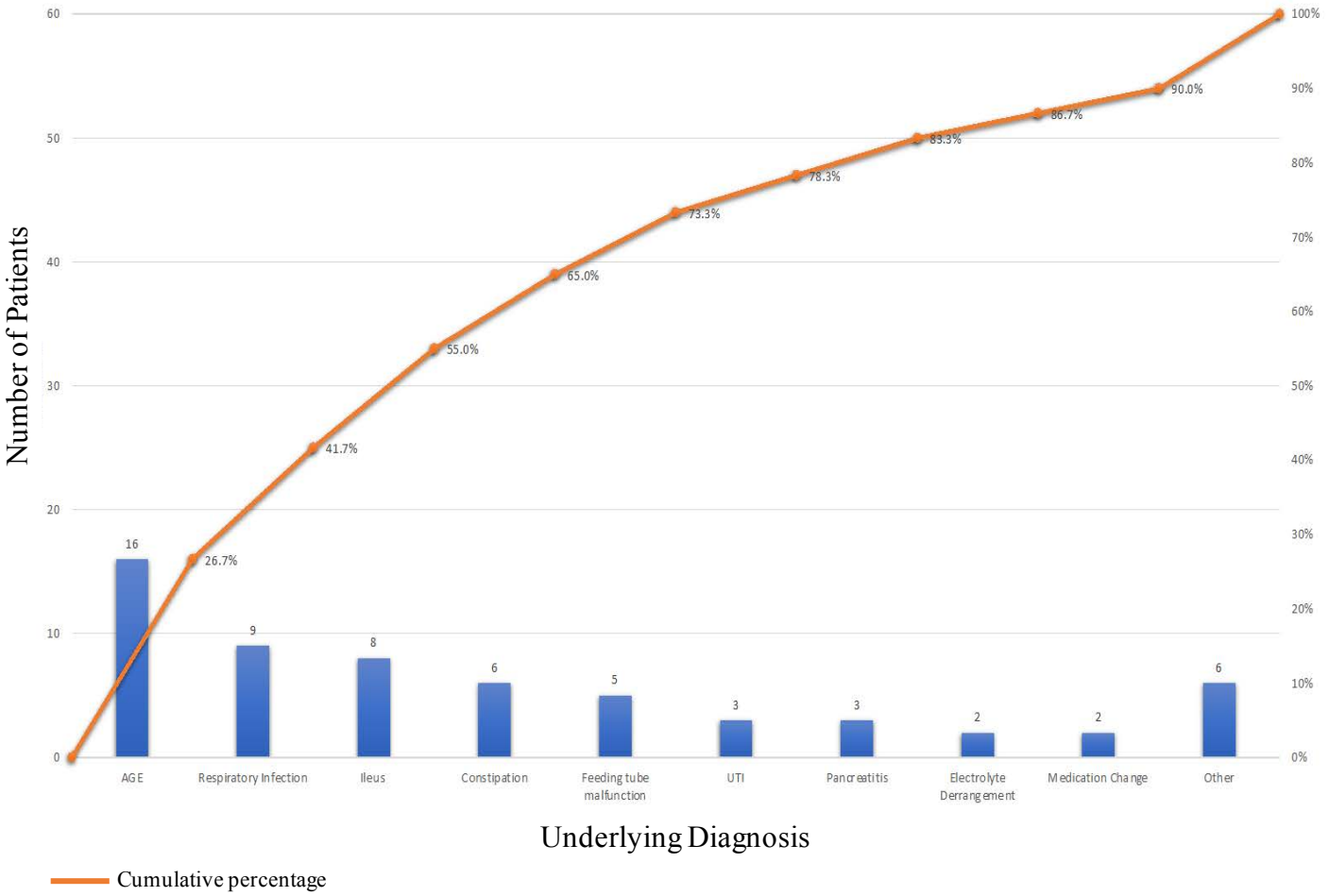

Figure 3. Key drive diagram which describes the drivers of decreased time to full enteral feeds for CMC experiencing feeding intolerance in the hospital and how the project interventions addressed these drivers.

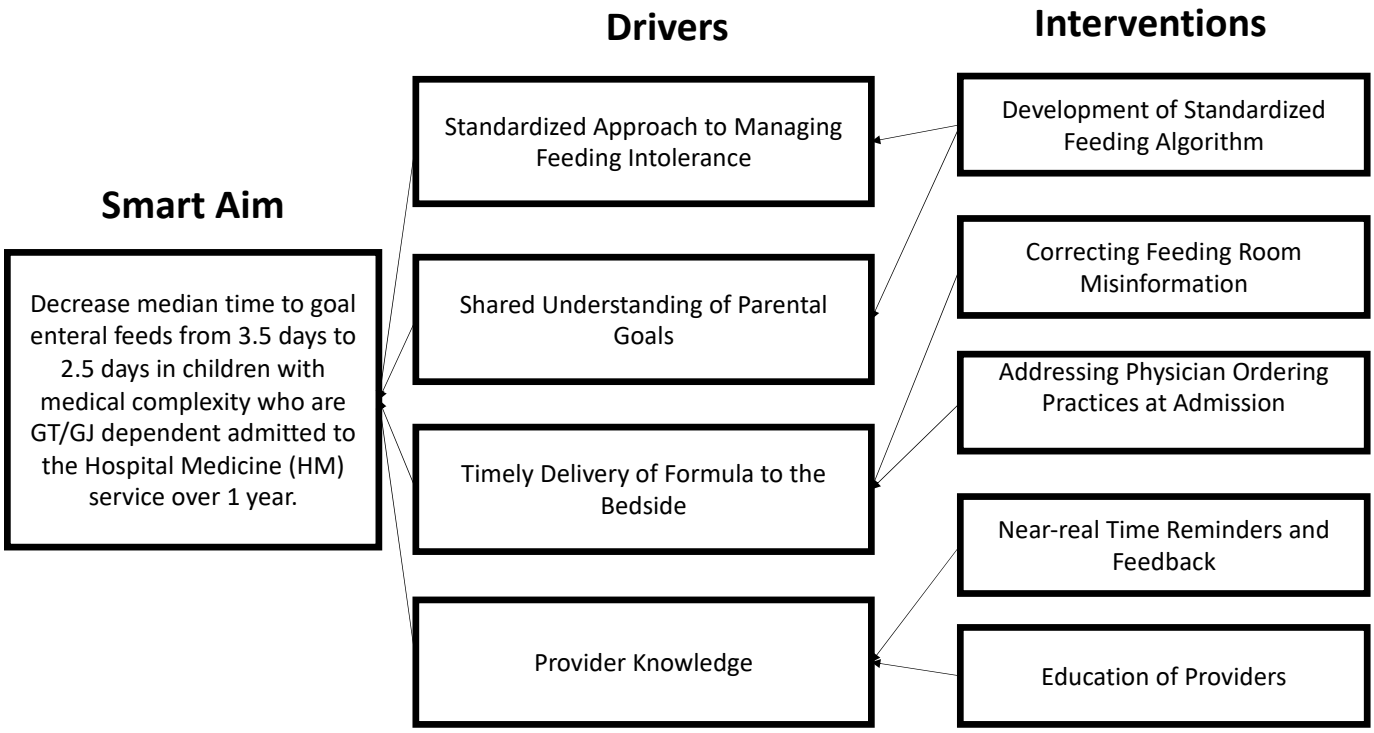

Figure 4. Hospital Medicine Feeding Intolerance Algorithm.

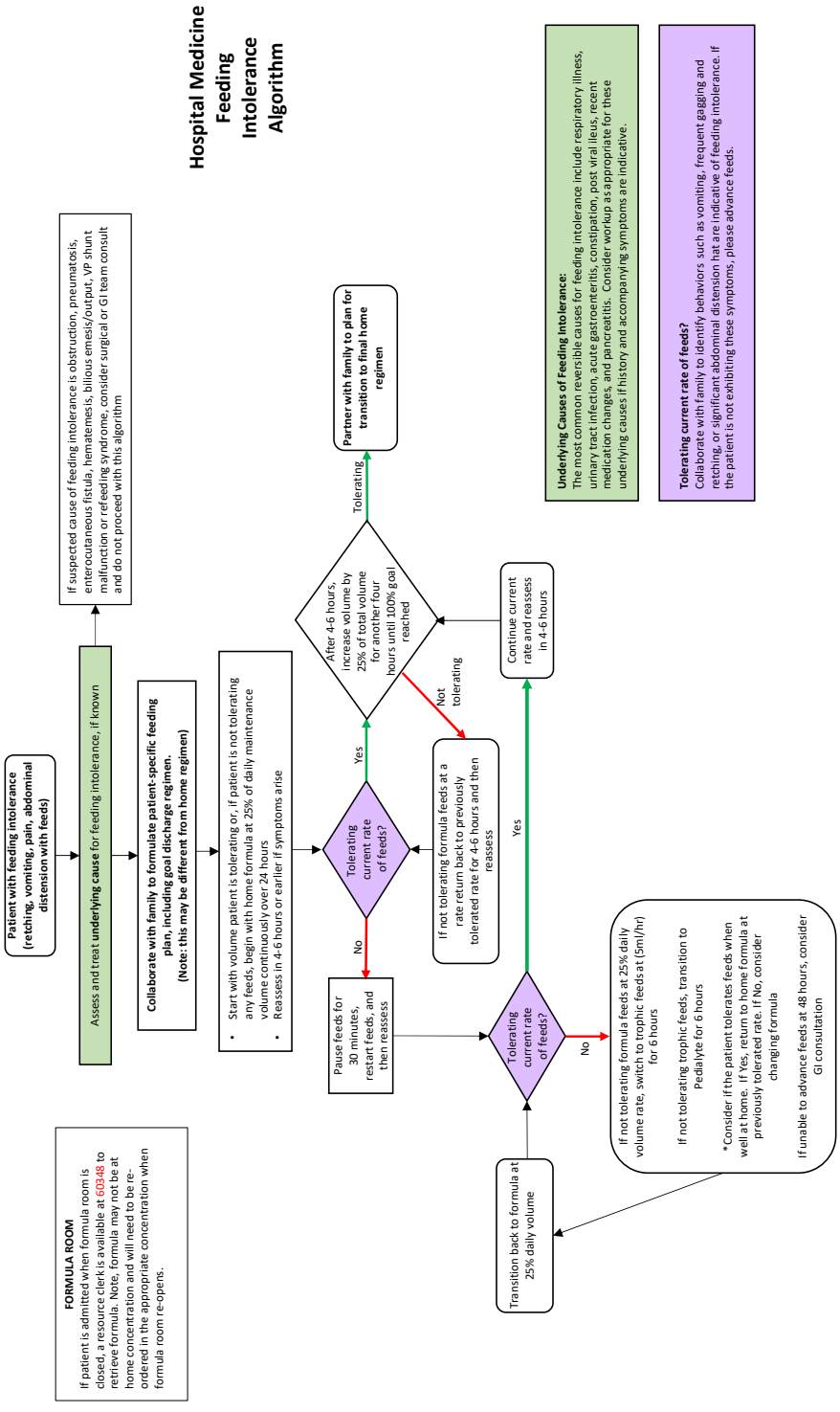

Figure 5. Run chart displaying the median number of days taken to achieve feeds for every 5 patients who experienced feeding intolerance. The y axis shows the days of hospitalization it took for the patient to achieve full feeds. The x axis is groups of 5 patients.