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Successfully Reducing Fat-modified Diet Duration for Treating Postoperative Chylothorax in Children

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ABSTRACT

BACKGROUND Medical management, primarily a fat-modified diet (FMD), is the mainstay of treatment for most patients with chylothorax. Duration of FMD is traditionally reported as 6 weeks, but no studies have demonstrated the shortest effective duration that prevents recurrence of chylothorax. The aim of this study was to decrease FMD duration to 2 weeks in children with postoperative chylothorax without a significant increase in recurrence.

METHODS This single-center study included pediatric (aged <18 years) patients in whom chylothorax developed within 30 days of cardiac surgery. Patients with cavopulmonary anastomoses were excluded. The preintervention cohort consisted of 19 patients with a diagnosis of chylothorax between February 2014 and June 2015, and the postintervention cohort comprised 98 patients from July 2015 to December 2019. FMD duration was decreased from 6 weeks to 4 weeks in May 2016 and to 2 weeks in June 2018. Recurrence was defined as a return of a chylous effusion requiring chest tube placement or hospital readmission within 30 days of resuming a regular diet.

RESULTS The median duration of FMD decreased from 42 days (interquartile range, 30, 43 days) in the preintervention cohort to 26 days (interquartile range, 14, 29 days) in the postintervention cohort, with no recurrence of chylothorax in any group. Compliance with the FMD duration instruction in the 6-week, 4-week, and 2-week groups was 100%, 84%, and 67% respectively. Compared with the first 6 months, compliance with the 2-week FMD instruction during the final 12 months increased from 40% (6/15) to 79% (26/33).

CONCLUSIONS At the study center, FMD duration decreased from 6 weeks to 2 weeks without any recurrence of chylothorax.

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Chylothorax occurs in 2.8% to 9% of children after cardiothoracic surgery and is associated with increased mortality, morbidity, and cost.[1-3] The disease process results from an accumulation of chyle in the pleural cavity that likely occurs as a result of disruption of the thoracic duct either through direct injury or alteration in cardiovascular physiology leading to lymphatic overload.[4]

Medical management is the mainstay of treatment for chylothorax, primarily including a fat-modified diet (FMD) (ie, medium-chain triglyceride [MCT] formulas, defatted human milk, and low-fat diets) and periods of nothing by mouth. MCT feedings are directly absorbed into the bloodstream from the gut, unlike long-chain triglyceride feedings, which are absorbed by the lymphatic system.[5] Therefore, MCT feedings, similar to low-fat diets, are believed to reduce the flow of chyle

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through the lymphatic system and allow for spontaneous healing of the thoracic duct.[4,6]

Despite the widespread use of FMDs, randomized controlled trials proving efficacy do not exist. FMDs are considered an appropriate temporary option to provide nutrition and facilitate growth while restricting dietary long-chain triglycerides.[6] However, the unintended consequences of FMDs include suboptimal nutrition, poor growth, appetite suppression, decreased fat deposition, and diarrhea.[7-9] Defatted breast milk is equally effective as MCT formula in treating chylothorax, but the benefits of immune factors and protein in breast milk are lost in the defatting process.[7,10-12] Restrictions associated with FMD may also be harmful because infant brain development is dependent on a balanced fatty acid supply.[13] The effect of FMD duration on growth metrics has not been directly studied. However, compared with long-chain triglycerides, MCT feedings are known to have lower caloricity and result in increased energy expenditure leading to reduced body mass, which may negatively affect growth patterns with longer durations of FMD.[8] These unintended consequences are compounded by parental dissatisfaction related to the high cost, the poorly available FMD options, and an inability to breastfeed.

Evidence is lacking to guide the duration of FMD that is required both to treat chylothorax and to prevent recurrence after resolution. In published protocols, FMD is the prescribed initial medical management when patients have achieved low chest tube output, often defined as <10 to 20 mL/kg/d.[14-16] The prescribed duration of FMD varies widely, with a 6-week total duration being the most common.[16-21] The shortest reported duration is 17 days in a single-center cohort of 17 infants (n = 17).[6] Examples such as this, along with the known dissatisfiers of using FMDs, led to our interest in studying the efficacy of a staged decrease of FMD duration.

Optimal management of chylothorax would include the shortest duration of FMD without increasing recurrence rates. Therefore, we implemented Plan-Do-Study-Act cycles within an existing chylothorax management protocol to decrease FMD duration. Our aim was to decrease FMD duration to 2 weeks in children with postoperative chylothorax with at least 80% compliance over 1 year and without a significant increase in recurrence.

PATIENTS AND METHODS

This quality improvement intervention was undertaken at Primary Children's Hospital, a tertiary care children's hospital in Salt Lake City, Utah, where approximately 450 heart operations are performed annually. Postoperative care is managed by a pediatric multidisciplinary team consisting of cardiac intensivists, cardiologists, cardiothoracic surgeons, nurse practitioners, pharmacists, nutritionists, fellows, nurses, and respiratory therapists. During the course of this protocol intervention, our cardiothoracic surgeon group consisted of 4 different surgeons with overlapping time periods. The study was approved by the University of Utah Institutional Review Board (IRB_00091635) and the Primary Children's Hospital Privacy Board and was granted a waiver of requirement for informed consent.

SUBJECTS AND DATA COLLECTION. Patients were included if they were <18 years old and had a diagnosis of chylothorax within 30 days after cardiac surgery at our institution. Patients were excluded if chylothorax was diagnosed preoperatively. Patients were also excluded if they underwent a superior cavopulmonary anastomosis or Glenn or Fontan operation because these operations result in physiologic changes that predispose these patients to late-presenting, recurrent, or protracted chylothorax that may require longer treatment. Finally, we excluded patients if the chylothorax was diagnosed and primarily managed in the newborn intensive care unit (ICU) because postoperative cardiac care is exclusively provided in our cardiac ICU. Transfer to the newborn ICU occurs for medical management of prematurity in the late postoperative period, with chylothorax subsequently managed with the newborn ICU's congenital chylothorax standards of care. The preintervention cohort consisted of children with a diagnosis of postoperative chylothorax between February 2014 and June 2015, during which no standard treatment guidelines were in place for chylothorax. The postintervention period was from July 2015 to December 2019.

Data collection included patient demographics, preoperative cardiac diagnosis, surgical intervention, the Society of Thoracic Surgeons-European Association for Cardio-Thoracic Surgery (STAT) score, cardiopulmonary bypass time, unplanned reoperation, pleural fluid testing results, daily chest tube output, net daily fluid balance, use of milrinone, and venous ultrasound results. Outcome measures collected included duration of FMD, recurrence of chylothorax, date of chylothorax diagnosis, chest tube duration, days of nothing by mouth, use of octreotide, additional invasive interventions for chylothorax, mechanical ventilation duration, cardiac ICU and hospital lengths of stay, readmission dates and diagnosis, and in-hospital mortality.

OUTCOMES AND BALANCE MEASURES. The primary outcome was FMD duration. Balance measures included chylothorax recurrence as demonstrated by chest tube reinsertion or hospital readmission related to

chylothorax. Secondary outcomes included protocol compliance, postoperative chest tube duration, postoperative days to chylothorax diagnosis, days of nothing by mouth, secondary interventions, ICU and hospital lengths of stay, mechanical ventilation days, and mortality.

DEFINITIONS. *Chylothorax* was defined as pleural fluid with triglycerides >110 mg/dL, lymphocytes >80%, or pleural triglycerides higher than serum triglycerides. *FMD* was defined as a diet consisting of an MCT formula, defatted human milk with MCT formula fortification, or a low-fat diet (<10 g/d). Diets used are described in Supplemental Table 1. The first day of *FMD duration* was defined as the day FMD was initiated after any days of nothing by mouth (if applicable), and the last FMD day was defined as the day a regular diet was resumed. Therefore, the FMD duration in most cases included some days before chylothorax resolution. *Chylothorax resolution* referred to chest tube output <10 mL/kg/d without a subsequent increase. *Milrinone use* was defined as the use of milrinone at any dose and on any day or days during the encounter. *Chylothorax recurrence* was defined as a return of a chylous effusion requiring chest tube placement or hospital readmission within 30 days of resuming a regular diet. To assess the need for chest tube replacement, a chest roentgenogram and clinical evaluation were performed 2 to 3 days after resumption of a regular diet, including patients already discharged from the hospital. *Compliance* was defined as adhering to an instruction within 48 hours or less of the protocol-directed timing for the 5 primary instructions: (1) FMD duration, (2) duration of nothing by mouth status, (3) high-output designation, (4) ultrasound completed, and (5) timing of secondary intervention. We opted for 48 hours to determine compliance, to allow for delays in inpatient formula preparation and outpatient constraints such as scheduling clinic visits around weekends, ability to obtain chest roentgenograms, and directives to modify patient diets within 2 to 3 days of clinic visits. Compliance with the treatment bundle was considered compliance with 4 of the 5 categories.

INTERVENTIONS. In July 2015, we implemented a postoperative chylothorax management protocol developed using existing literature and local consensus, as previously described.[15] For this project, Plan-Do-Study-Act cycles were focused on efforts to reduce unnecessary exposure to the deleterious effects of FMD, without increasing recurrence of chylothorax. Interventions were presented and reinforced through education provided at heart center clinical review meetings, emails and newsletters sent to the multidisciplinary care team, and display of the protocol at workstations. Data were reviewed at least quarterly.

STUDY OF THE INTERVENTIONS. Decreasing Fat-modified Diet Duration. Initially, our protocol used an FMD duration of 6 weeks after chylothorax resolution. Lack of consensus on FMD duration and the diet's potentially deleterious effects led us to systematically shorten the duration of FMD by 2-week increments to 2 weeks. With each decrease, success was a priori defined as no recurrence of chylothorax for at least 20 patients. The decrease from 6 weeks to 4 weeks included 37 patients and occurred between May 2016 and June 2018. Given no recurrence in the 4-week duration group, we further decreased the FMD duration to 2 weeks (June 2018 to December 2019 for the purpose of analysis, with the intervention ongoing at present) for 48 patients.

Other Interventions. Other interventions that were implemented with the chylothorax management protocol, but that are outside of the scope of this analysis, include the following: a trigger to test for chylothorax when chest tube output is >15 mL/kg/d regardless of feeding status or fluid appearance, head and neck ultrasound examinations to assess for thrombi when chest tube output is >20 mL/kg/d, and duration of nothing by mouth on the basis of chest tube output volume rather than a set number of days. The protocol suggests that chest tubes may be removed when output is <3 mL/kg/12 h and feeding volume is at least 40 mL/kg/d. Figure 1 displays our current chylothorax management protocol.

STATISTICAL ANALYSIS. Categoric variables were summarized with counts and percentages, and continuous variables were summarized with median and first and third quartiles. The Fisher exact test was used to compare categoric variables in the preintervention vs postintervention cohorts. The Wilcoxon rank-sum test was used for continuous variables. All reported *P* values are based on 2-sided alternatives and are considered statistically significant if less than .05. Analyses were performed using SAS software version 9.4 (SAS Institute).

RESULTS

A total of 117 patients were analyzed, with 19 preintervention and 98 postintervention patients. We excluded 16 Glenn patients (1 preintervention and 15 postintervention), 4 postintervention Fontan patients, 2 postintervention patients with preoperative chylothorax, and 2 postintervention patients with chylothorax managed completely in the newborn ICU. FMD duration data were excluded for 4 postintervention patients who died before completion of the prescribed duration of FMD. Of the postintervention patients, there were 13 in

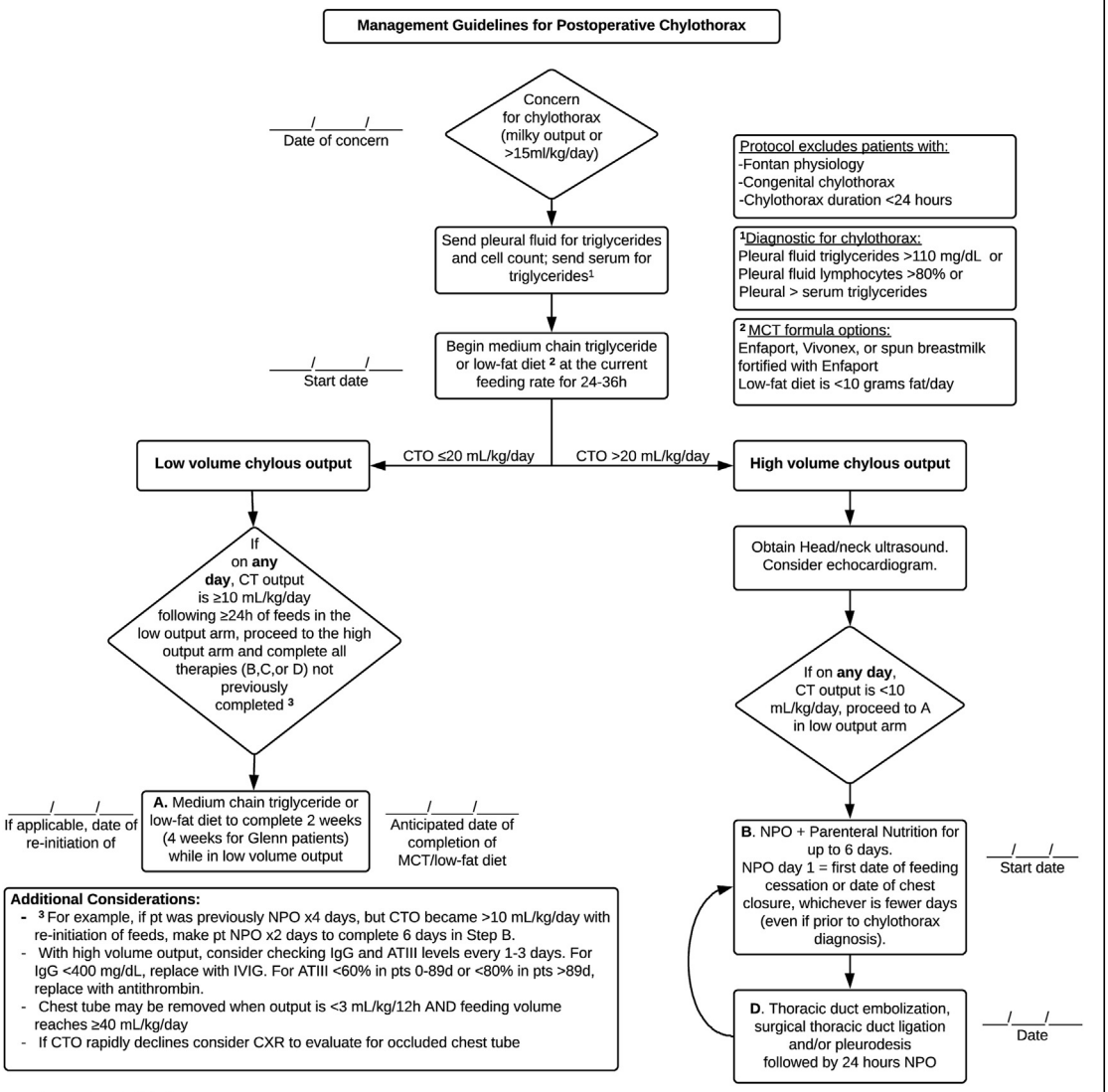

FIGURE 1 Chylothorax management guidelines currently used at Primary Children's Hospital, Salt Lake City, Utah. Figure is courtesy of the Primary Children's Hospital, Salt Lake City, UT. (ATIII, antithrombin III; CT, chest tube; CXR, chest roentgenogram; IgG, immunoglobulin G; IVIG, intravenous immunoglobulin; MCT, medium-chain triglyceride; NPO, nothing by mouth.)

the 6-week group, 37 in the 4-week group, and 48 in the 2-week group.

PATIENT CHARACTERISTICS. Patient demographic, surgical, and chylothorax characteristics across groups are shown in Table 1. The postintervention group consisted of more patients with STAT 4 to 5 operations and fewer patients with STAT 1 to 3 operations than the preintervention group ($P = .010$). All other demographic and surgical characteristics were similar across groups.

Compared with the preintervention cohort, the postintervention cohort had higher pleural lymphocytes (Table 1). We saw no significant differences in potential drivers of chylothorax development and duration, such as net fluid balance, thrombi, or therapies to mitigate venous hypertension such as milrinone. There were no other differences between the groups in clinical characteristics related to chylothorax.

PRIMARY OUTCOME. The median duration of FMD decreased from 42 days (interquartile range [IQR],: 30, 43 days) to 26 days (IQR, 14, 29 days; $P < .001$) (Table 2). Figure 2 is a run chart illustrating FMD duration per patient sequentially throughout the interventions. Compared with the original protocol, our intervention resulted in a total decrease in FMD duration from a projected 3948 days if 6 weeks had been maintained

TABLE 1 Demographic and Clinical Characteristics of Children With a Diagnosis of Chylothorax

Variable, n (%) or Median (IQR)	Preintervention, n = 19	Postintervention, n = 98	*P* Value
Demographics			
Age at surgery, d	12 (7, 71)	17 (6, 158)	.62
Weight at surgery, kg	3.3 (3, 4.6)	3.7 (3, 5.7)	.39
Male sex	12 (63)	55 (56)	.62
Race, White	16 (84)	83 (85)	1.00
Genetic abnormality present	7 (37)	34 (35)	1.00
Surgical characteristics			
STAT mortality category			.01
1-3	14 (74)	40 (41)	
4-5	5 (26)	58 (59%	
Cardiopulmonary bypass time, min	131 (98, 148)	130 (101, 160)	.89
Unplanned reoperation	3 (16)	18 (18)	1.00
Chylothorax characteristics			
Pleural triglyceride levels, mg/dL	245 (144, 349)	176 (113, 255)	.12
Pleural lymphocytes, %	67 (45, 76)	86 (6, 93)	.02
Average daily CTO, mL/kg/d	16.5 (11.8, 23.3)	11.9 (7, 19.5)	.09
Average net daily fluid balance, mL/kg/d	11.7 (-0.2, 40.3)	7.9 (-3.7, 18.6)	.37
High CTO, >20 mL/kg/d	10 (53)	39 (40)	.32
Milrinone used	18 (95)	96 (98)	.42
Ultrasound completed	7 (37)	55 (56)	.14
Thrombus identified	6 (32)	36 (37)	.80
Anticoagulated	5 (26)	34 (35)	.60

CTO, chest tube output; IQR, interquartile range; STAT, Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery.

TABLE 2 Outcome Measures in Patients Treated for Chylothorax

Variable, n (%) or Median (IQR)	Preintervention, n = 19	Postintervention, n = 98	*P* Value
Primary outcome measures			
FMD duration, d	42 (30, 43)	26 (14, 29)	<.001
Recurrence of chylothorax	0 (0)	0 (0%)	…
Secondary outcome measures			
Postoperative day at diagnosis	5 (4, 9)	5 (3, 7)	.35
Total chest tube use, d	10 (8, 18)	9.5 (6, 13)	.26
Nothing by mouth			
Treated with nothing by mouth	12 (63)	53 (54)	.62
Duration of nothing by mouth, d	3 (1, 5.5)	4 (2, 7)	.26
Treated with octreotide	0 (0)	4 (4)	1.00
Additional interventions	2 (11)	23 (24)	.36
Thoracic duct ligation	0 (0)	8 (8)	.35
Cath lab intervention	2 (11)	18 (18)	.52
Pleurodesis	0 (0)	3 (3)	1.00
Thoracic duct embolization	0 (0)	4 (4)	1.00
Hospitalization characteristics			
Mechanical ventilation, d	8 (5, 15)	7 (3, 14)	.71
Hospital length of stay, d	21 (14, 43)	24.5 (15, 38)	.87
CICU length of stay, d	10 (8, 15)	11.5 (7, 22)	.52
In-hospital mortality	2 (11)	10 (10)	1.00

Cath lab, catheterization laboratory; CICU, cardiac intensive care unit; FMD, fat-modified diet; IQR, interquartile range.

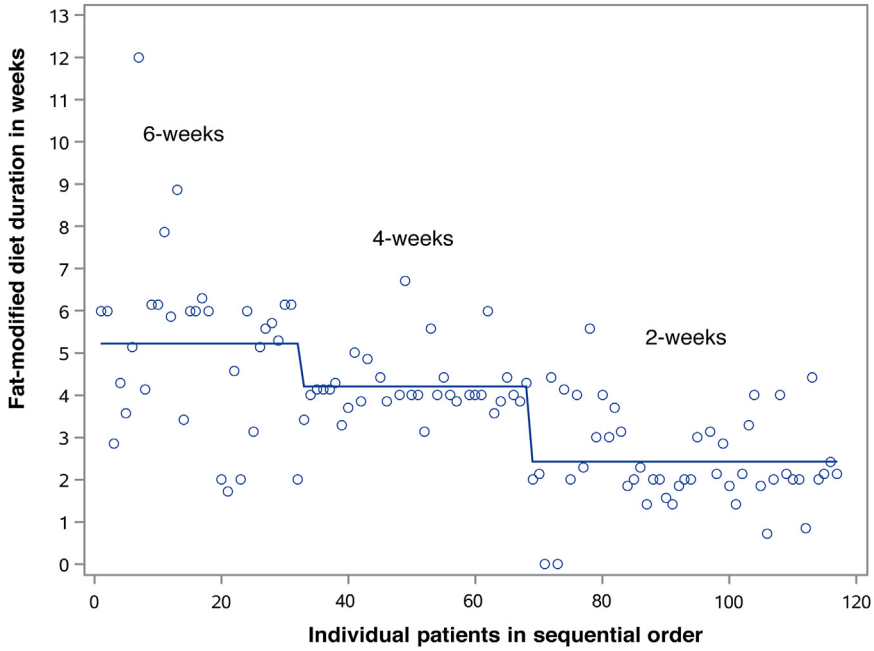

FIGURE 2 Run chart illustrating fat-modified diet duration in each patient over time. The mean line reflects the average fat-modified diet duration for each intervention group: 6-week duration, 4-week duration, and 2-week duration.

down to 2175 days (55% decrease) across the 98 post-intervention patients.

BALANCE MEASURES. There was no recurrence of chylothorax or hospital readmission for chylothorax or pleural effusions in the 6-week, 4-week, and 2-week groups.

SECONDARY OUTCOMES. Additional chylothorax treatment strategies were not significantly different between groups (Table 2). When resuming FMD after days of nothing by mouth, no patients had an increase in chest tube output necessitating return to nothing by mouth status as directed by the protocol. Days to diagnosis, total days of chest tube use, mechanical ventilation days, ICU and hospital lengths of stay, and in-hospital mortality were unchanged. Median chest tube output on the day before removal was 4.3 mL/kg/d in the preintervention cohort vs 2.2 mL/kg/d in the postintervention cohort.

Table 3 represents patient characteristics, primary and secondary outcomes, balance measures, and compliance for patients with chylothorax across FMD duration groups. Characteristics and outcomes were similar for the 6-week, 4-week, and 2-week groups.

COMPLIANCE. Compliance with the chylothorax treatment bundle during the study period was 90% (Supplemental Table 2). Compliance with the bundle for STAT 4 to 5 patients was 88% compared with 90% in the STAT 1 to 3 patients. Compliance with the FMD duration instruction in the 6-week, 4-week, and 2-week groups was 100%, 76%, and 67% respectively (Table 3).

Compared with the first 6 months, compliance with the 2-week FMD instruction during the final 12 months increased from 40% (6/15) to 79% (26/33). These early deviations were mostly related to inadequate education regarding the decrease in FMD duration, as evidenced by multiple clinical notes erroneously stating "patient will receive 4 weeks of medium-chain triglyceride feeds per chylothorax protocol." Since January 2019, when deviations were no longer related to inadequate education, the 7 noncompliant patients had a median chest tube duration of 17 days (IQR, 7, 54 days) and a median FMD duration of 23 days (IQR, 21, 28 days), and 6 of these patients had STAT 4 to 5 surgical procedures. In 4 of these 7 patients, surgeon or attending physician preference dictated the protracted duration.

In the 32 patients compliant with the 2-week FMD instruction, 69% underwent STAT 4 to 5 surgical procedures (n = 18), and median chest tube duration was 8 days (IQR, 5.5, 11 days). Two of the 4 patients who underwent secondary interventions in the 2-week FMD group were compliant; the 2 who were noncompliant received 3 to 4 weeks of FMD at the surgeon's request. Compliance with the 2-week FMD duration instruction was higher in those patients with shorter chest tube duration: 73% (19/26) with chest tube duration <10 days vs 59% (13/22) in those with a chest tube duration of ≥10

TABLE 3 Characteristics and Outcomes of Patients With Chylothorax by Fat-Modified Diet Duration

	Fat-Modified Diet Duration		
Variable, n (%) or Median (IQR)	**6-wk, n =13**	**4-wk, n = 37**	**2-wk, n = 48**
Patient characteristics			
Weight at surgery, kg	3.9 (2.9, 5.1)	3.3 (3, 5.4)	3.7 (3, 6)
Genetic abnormality present	6 (46)	12 (32)	16 (33)
STAT mortality category			
1-3	4 (31)	17 (46)	19 (40)
4-5	9 (69)	20 (54)	29 (60)
High CTO, >20 mL/kg/d	5 (38)	16 (43)	18 (38)
Primary outcome measures			
FMD duration, d	36 (14, 40)	28 (27, 30)	15 (14, 22)
Recurrence of chylothorax	0	0	0
Secondary outcome measures			
Postoperative day at diagnosis	5 (4, 9)	5 (4, 9)	4 (1, 6)
Total chest tube use, d	9 (5, 10)	11 (7, 16)	9 (6, 13)
Nothing by mouth			
Treated with nothing by mouth	4 (31)	14 (38)	18 (38)
Duration of nothing by mouth, d	3 (3, 4)	5 (2, 9)	4 (2, 7)
Additional interventions[a]	3 (23)	8 (22)	11 (23)
Hospitalization characteristics			
Mechanical ventilation, d	8 (2, 9)	8 (5, 15)	6, (3, 15)
Hospital length of stay, d	20 (17, 31)	26 (19, 39)	25 (12, 39)
CICU length of stay, d	11 (8, 20)	15 (8, 24)	10 (6, 16)
In-hospital mortality	0	4 (11)	7 (15)
Compliance			
FMD duration	13 (100)	28 (76)	32 (67)
Bundle compliance	13 (100)	35 (95)	40 (83)

[a]Additional interventions include cardiac catheterization, thoracic duct ligation, thoracic duct embolization, or pleurodesis. CICU, cardiac intensive care unit; CTO, chest tube output; FMD, fat-modified diet; IQR, interquartile range; STAT, Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery.

days. However, 2-week FMD instruction compliance improved over time in patients with chest tube duration ≥10 days, with 33% (2/6) in the first 6 months of the instruction and 69% (11/16) the last 12 months.

COMMENT

We report a single-center quality improvement project that effectively decreased FMD duration from 6 weeks to 2 weeks and sustained the 2-week FMD duration for more than 18 months. No patients treated with the 2-week FMD duration had a chylothorax recurrence. Our study shows that the duration of FMD can be reduced to 2 weeks without chylothorax recurrence irrespective of surgical complexity, duration of drainage, or need for interventions before initial resolution. Efforts to decrease FMD duration are vitally important to mitigate the negative health effects associated with FMDs, including suboptimal nutrition and poor growth.[7-9]

Higher surgical complexity increases the risk of chylothorax[22] *development,* but this may not translate to the need for a longer duration of FMD after resolution to reduce the risk of *recurrence*. Despite the lack of data showing the association between recurrence of chylothorax and surgical complexity, we found that compliance with the 2-week FMD instruction in the highest STAT categories was indeed lower. We postulate that higher surgical complexity may have initially contributed to a hesitancy to decrease FMD duration because these patients are viewed as more tenuous and therefore are managed more cautiously. However, as education and compliance improved, we found that surgical complexity was not associated with recurrence of chylothorax in patients with a 2-week FMD duration.

With regard to protracted chylothorax, a previous report by Biewer and colleagues[6] demonstrated that a reduced duration of FMD at approximately 2 weeks was achievable; however, the intervention was limited to 17 infants whose chylothorax resolved within 10 days of FMD and never required a secondary intervention.

We demonstrated that protracted chest tube duration is not associated with chylothorax recurrence, even in patients who receive only 2 weeks of FMD. As directed in the protocol, these patients have nothing by mouth for high or prolonged chest tube output, thus further subjecting them to the nutritional deficits related to periods of nothing by mouth. However, we also found that providers were initially less likely to shorten the

duration of FMD when the chylothorax was protracted (≥10 chest tube days) out of concern that chylothorax that took longer to resolve would be more likely to recur if regular feedings were introduced earlier. This hesitancy was overcome with increased awareness of success and continued education, and compliance during the final 12 months of the 2-week FMD instruction increased by 200% for those patients with ≥10 days chest tube days.

Invasive interventions, such as thoracic duct ligation or embolization, are reserved for patients in whom dietary modifications fail. In these difficult patients, we found increased reluctance to shorten FMD duration. Resuming a regular diet in patients who have undergone secondary interventions is especially important because these patients typically have experienced prolonged duration of nothing by mouth and additional procedures. Of our 9 patients who underwent a secondary intervention for chylothorax, 1 received 5 weeks of FMD, 5 received 4 weeks, 2 received 2 weeks, and none of these patients had recurrence of chylothorax. In this small subset of patients who underwent secondary interventions for chylothorax, we found they could be treated with a reduced FMD duration without chylothorax recurrence, thereby allowing earlier resumption of adequate nutrition.

Similar to the report by Yeh and colleagues,[14] our chylothorax treatment bundle compliance was high (90%). Compliance with the 2-week duration FMD instruction was initially low at 40% for the first 6 months but improved to 79% with intensified education by emails, heart center newsletter content, and personal communications specifically with the surgeons and floor providers. Additionally, because data reviews were conducted quarterly, we were slow to recognize deviations, and compliance improved once we started tracking compliance on a monthly basis.

In addition to the impact on health and nutrition, FMD can impose a significant cost burden, whether absorbed by the patient or by the health care system. MCT formulas are rarely available at standard retailers and require coordination with home health services or purchase through online vendors. Compared with standard infant formula, MCT formulas are at least 25% more expensive than liquid prepared formula and 45% more expensive than powder prepared formula, and they represent a completely new cost to families of previously breastfed infants. We effectively decreased FMD days by 55% and therefore saved the associated cost of MCT formula. Future studies are necessary to determine the impact of decreased FMD duration on growth, parental satisfaction, and cost, and to determine efficacy and generalizability through a multi-institutional effort.

To increase initial buy-in, we opted to exclude patients with Glenn or Fontan physiology, given the strongly held local beliefs and literature suggesting that this group is at particularly high risk for protracted chylothorax and late recurrence. Future iterations of this project including patients with cavopulmonary anastomoses are underway.

STUDY LIMITATIONS. Limitations of this study include the lack of generalizability associated with a single-center cohort. We did not control for other variables associated with chylothorax recurrence, including residual lesions, fluid status, thrombosis, increased venous pressures, or decreased capillary permeability.[1-3,20,22] Notably, our management protocol does not dictate fluid balance or use of afterload-reducing agents, although we found no difference in net fluid balance or milrinone use between groups. Although we are a regional care provider, it is possible that we did not capture patients who presented to outside hospitals with chylothorax. Compliance with the duration of FMD after discharge was determined on the basis of parental reporting only.

CONCLUSION. At our center, FMD duration was decreased from 6 weeks to 2 weeks without any recurrence of chylothorax. We also demonstrated decreased duration of FMD in patients with high surgical complexity, protracted chest tube drainage and duration of nothing by mouth, and need for secondary interventions for chylothorax, without recurrence of chylothorax.

REFERENCES

1. Mery CM, Moffett BS, Khan MS, et al. Incidence and treatment of chylothorax after cardiac surgery in children: analysis of a large multi-institution database. *J Thorac Cardiovasc Surg*. 2014;147:678-686.e1. https://doi.org/10.1016/j.jtcvs.2013.09.068

2. Buckley JR, Graham EM, Gaies M, et al. Clinical epidemiology and centre variation in chylothorax rates after cardiac surgery in children: a report from the Pediatric Cardiac Critical Care Consortium. *Cardiol Young*. 2017;27:1678-1685. https://doi.org/10.1017/S104795111700097X

3. Bauman ME, Moher C, Bruce AK, et al. Chylothorax in children with congenital heart disease: incidence of thrombosis. *Thromb Res*. 2013;132:e83-e85. https://doi.org/10.1016/j.thromres.2013.06.014

4. Tutor JD. Chylothorax in infants and children. *Pediatrics*. 2014;133:722-733. https://doi.org/10.1542/peds.2013-2072

5. McCray S. Nutritional management of chyle leaks: an update. *Practical Gastroenterology*. 2011;April:12-32.

6. Biewer ES, Zürn C, Arnold R, et al. Chylothorax after surgery on congenital heart disease in newborns and infants – risk factors and efficacy of MCT-diet. *J Cardiothorac Surg*. 2010;5:127.

7. Kocel SL, Russell J, O'Connor DL. Fat-modified breast milk resolves chylous pleural effusion in infants with postsurgical chylothorax but is associated with slow growth. *JPEN J Parenter Enteral Nutr*. 2016;40:543-551. https://doi.org/10.1177/0148607114566464

8. Łoś-Rycharska E, Kieraszewicz Z, Czerwionka-Szaflarska M. Medium chain triglycerides (MCT) formulas in paediatric and allergological practice. *Prz Gastroenterol*. 2016;11:226-231. https://doi.org/10.5114/pg.2016.61374

9. Densupsoontorn N, Jirapinyo P, Tirapongporn H, et al. Fat-soluble vitamins and plasma and erythrocyte membrane fatty acids in chylothorax pediatric patients receiving a medium-chain triglyceride-rich diet. *J Clin Biochem Nutr*. 2014;55:174-177.

10. DiLauro S, Russell J, McCrindle BW, Tomlinson C, Unger S, O'Connor DL. Growth of cardiac infants with post-surgical chylothorax can be supported using modified fat breast milk with proactive nutrient-enrichment and advancement feeding protocols; an open-label trial. *Clin Nutr ESPEN*. 2020;38:19-27. https://doi.org/10.1016/j.clnesp.2020.05.001

11. Fogg KL, Dellavalle DM, Buckley JR, Graham EM, Zyblewski SC. Feasibility and efficacy of defatted human milk in the treatment for chylothorax after cardiac surgery in infants. *Pediatr Cardiol*. 2016;37:1072-1077. https://doi.org/10.1007/s00246-016-1393-8

12. Neumann L, Springer T, Nieschke K, et al. ChyloBEST: chylothorax in infants and nutrition with low-fat breast milk. *Pediatr Cardiol*. 2020;41:108-113. https://doi.org/10.1007/s00246-019-02230-z

13. Benton D. The influence of children's diet on their cognition and behavior. *Eur J Nutr*. 2008;47:25-37. https://doi.org/10.1007/s00394-008-3003-x

14. Yeh J, Brown ER, Kellogg KA, et al. Utility of a clinical practice guideline in treatment of chylothorax in the postoperative congenital heart patient. *Ann Thorac Surg*. 2013;96:930-936. https://doi.org/10.1016/j.athoracsur.2013.05.058

15. Winder MM, Eckhauser AW, Delgado-Corcoran C, Smout RJ, Marietta J, Bailly DK. A protocol to decrease postoperative chylous effusion duration in children. *Cardiol Young*. 2018;28:816-825. https://doi.org/10.1017/S1047951118000392

16. Church JT, Antunez AG, Dean A, et al. Evidence-based management of chylothorax in infants. *J Pediatr Surg*. 2017;52:907-912. https://doi.org/10.1016/j.jpedsurg.2017.03.010

17. Marino LV, Bell KL, Woodgate J, Doolan A. An international survey of the nutrition management of chylothorax: a time for change. *Cardiol Young*. 2019;29:1127-1136. https://doi.org/10.1017/S1047951119001525

18. Chan EH, Russell JL, Williams WG, Van Arsdell GS, Coles JG, McCrindle BW. Postoperative chylothorax after cardiothoracic surgery in children. *Ann Thorac Surg*. 2005;80:1864-1871.

19. Milonakis M, Chatzis AC, Giannopoulos NM, et al. Etiology and management of chylothorax following pediatric heart surgery. *J Card Surg*. 2009;24:369-373. https://doi.org/10.1111/j.1540-8191.2008.00781.x

20. Panthongviriyakul C, Bines JE. Post-operative chylothorax in children: an evidence-based management algorithm. *J Paediatr Child Health*. 2008;44:716-721. https://doi.org/10.1111/j.1440-1754.2008.01412.x

21. Cabrera AG, Prodhan P, Bhutta AT. Nutritional challenges and outcomes after surgery for congenital heart disease. *Curr Opin Cardiol*. 2010;25:88-94. https://doi.org/10.1097/HCO.0b013e3283365490

22. Day T, Zannino D, Golshevsky D, et al. Chylothorax following paediatric cardiac surgery: a case-control study. *Cardiol Young*. 2017;28:1-7.