0003-4975/$36.00
https://doi.org/10.1016/j.athoracsur.2023.05.021

Congenital & Pediatric: Research

Optimal Fat-Modified Diet Duration for the Treatment of Postoperative Chylothorax in Children

Melissa M. Winder, CPNP-AC,[1] Stephanie Schwartz, MD,[2] Jason R. Buckley, MD,[3] Kristi L. Fogg, RD,[4] Megan Matiasek, CPNP-AC/PC,[5] Alissa Lyman, PA-C,[6] Alisa Tortorich, RDN, CSPCC,[7] Kathy Holmes, MD, MPH,[6] Deborah U. Frank, MD, PhD,[8] Mandy Nasworthy, MD,[9] Piyagarnt E. Vichayavilas, RD,[10] Rebecca A. Bertrandt, MD,[11] Cam Kasmai, MD,[11] Jill C. Kuester, CPNP-AC,[11] Tia T. Raymond, MD,[12] Lawrence E. Greiten, MD, MSc,[13] Ron W. Reeder, PhD,[14] and David K. Bailly, DO[14]

ABSTRACT

BACKGROUND Dietary modification is the mainstay of treatment for postoperative chylothorax in children. However, optimal fat-modified diet (FMD) duration to prevent recurrence is unknown. Our aim was to determine the association between FMD duration and chylothorax recurrence.

METHODS Retrospective cohort study conducted across 6 pediatric cardiac intensive care units within the United States. Patients aged <18 years who developed chylothorax within 30 days after cardiac surgery between January 2020 and April 2022 were included. Patients with a Fontan palliation, who died, or were lost to follow-up or within 30 days of resuming a regular diet were excluded. FMD duration was defined as the first day of a FMD when chest tube output was <10 mL/kg/d without increasing until the resumption of a regular diet. Patients were classified into 3 groups (<3 weeks, 3-5 weeks, >5 weeks) based on FMD duration.

RESULTS A total of 105 patients were included: <3 weeks (n = 61) 3-5 weeks (n = 18), and >5 weeks (n = 26). Demographic, surgical, and hospitalization characteristics were not different across groups. In the >5 weeks group, chest tube duration was longer compared with the <3 weeks and 3-5 weeks groups (median, 17.5 days [interquartile range, 9-31] vs 10 and 10.5 days; $P = .04$). There was no recurrence of chylothorax within 30 days once chylothorax was resolving regardless of FMD duration.

CONCLUSIONS FMD duration was not associated with recurrence of chylothorax, suggesting that FMD duration can safely be shortened to at least <3 weeks from time of resolving chylothorax.

(Ann Thorac Surg 2023;■:■-■)

Dietary modification is the mainstay of treatment for chylothorax, which occurs in 2.8%-9% of children after cardiothoracic surgery and is associated with increased morbidity, mortality, and cost.[1-3] The primary dietary modifications are a

The Supplemental Table can be viewed in the online version of this article [https://doi.org/10.1016/j.athoracsur.2023.05.021] on http://www.annalsthoracicsurgery.org.

[1]Division of Pediatric Cardiology, Department of Pediatrics, University of Utah, Salt Lake City, Utah; [2]Division of Pediatric Critical Care Medicine, Department of Pediatrics, University of North Carolina, Chapel Hill, North Carolina; [3]Division of Pediatric Cardiology, Department of Pediatrics, Medical University of South Carolina, Charleston, South Carolina; [4]Medical University of South Carolina, Charleston, South Carolina; [5]Division of Cardiology, Department of Pediatrics, Ann and Robert H. Lurie Children's Hospital of Chicago, Chicago, Illinois; [6]Division of Pediatric Cardiology, Department of Pediatrics, Oregon Health and Science University, Portland, Oregon; [7]Division of Pediatric Gastroenterology, Department of Pediatrics, Oregon Health and Science University, Portland, Oregon; [8]Division of Pediatric Critical Care Medicine, Department of Pediatrics, University of Virginia, Charlottesville, Virginia; [9]Division of Pediatric Cardiology, Department of Pediatrics, University of Virginia, Charlottesville, Virginia; [10]Department of Clinical Nutrition, Children's Hospital Colorado, Aurora, Colorado; [11]Division of Pediatric Critical Care, Department of Pediatrics, Medical College of Wisconsin/Children's Wisconsin, Milwaukee, Wisconsin; [12]Department of Pediatrics, Cardiac Critical Care, Medical City Children's Hospital, Dallas, Texas; [13]Division of Pediatric Cardiothoracic Surgery, Department of Surgery, Arkansas Children's Hospital, Little Rock, Arkansas; and [14]Division of Pediatric Critical Care Medicine, Department of Pediatrics, University of Utah, Salt Lake City, Utah

Address correspondence to Ms Winder, Heart Center, Primary Children's Hospital, 100 N Mario Capecchi Dr, Salt Lake City, UT 84113; email: melissa.winder@imail.org.

transition to a fat-modified diet (FMD), commonly referred to as a medium-chain triglyceride diet, (ie, low long-chain triglyceride [LCT] formulas, defatted fortified human milk, and low-fat diets) and periods of nil per os (NPO), based on the rationale that minimizing LCTs in the diet will reduce flow of chyle through the lymphatic system.[4-6] Many centers utilize a FMD for 6 weeks even after chylothorax is resolving (ie, when chest tube output [CTO] is <10 mL/kg/d without increasing), due to the historic belief that this practice will prevent recurrence.[7-13] However, a recent single-center quality improvement project decreased FMD duration from 6 weeks to 2 weeks, regardless of surgical complexity or chylothorax severity, and reported no recurrences.[14]

In order to promote the postoperative healing process, it is important to limit use of a FMD to the shortest duration possible because of the inherent risks, including suboptimal nutrition, inadequate growth, appetite suppression, decreased fat deposition, diarrhea, and the negative impact of poor weight gain on neurodevelopment.[15-19] Additionally, parental dissatisfaction may stem from an inability to breastfeed, the labor of defatting and fortifying human milk,[20] sourcing specialized formulas,[21] the cost burden of specialty products, and the inconvenience of protracted follow-up appointments. Compounding these issues has been the current increasing cost and shortage of formulas in the United States, which is especially pronounced in specialty formulas.[21,22]

In November 2020, the Chylothorax Work Group (CWG) was formed to study and improve outcomes in children diagnosed with chylothorax after cardiac surgery.[23] Using the CWG data registry, our aim was to determine if there is an association between FMD duration and recurrence of chylothorax. Our hypothesis is that FMD duration is not related to recurrence, regardless of severity of chylothorax, and that the optimal FMD duration could safely be reduced to 2 weeks.

PATIENTS AND METHODS

A retrospective cohort study was conducted across 6 pediatric cardiac intensive care units that participate in the CWG.[23] During the study period, a chylothorax management protocol was used at the participating sites, which suggests a FMD duration of 2-4 weeks after chylothorax is resolving (Figure 1). The study was approved by each center's institutional review board.

PATIENT POPULATION. We included patients aged <18 years and diagnosed with chylothorax (see definition below) within 30 days after cardiac surgery, during the encounter associated with the index cardiac operation. Patients were excluded if the patient died or was lost to follow-up prior to 30 days from completing the prescribed FMD duration. Additionally, patients diagnosed with chylothorax after Fontan operations were excluded, as these patients are physiologically predisposed to development of chylothorax throughout their lifetime.[24,25] All eligible patients diagnosed with chylothorax were enrolled consecutively at each site between January 2020 and April 2022, with start dates staggered depending on when the site began participating in the CWG. Patients were classified into 3 groups (<3 weeks, 3-5 weeks, >5 weeks) based on the FMD duration received once chylothorax was resolving (ie, CTO <10 mL/kg/d without subsequent increase). These groups were chosen in order to encompass the most common FMD durations of 2, 4, and 6 weeks (often considered short, mid-range, and long durations, respectively), while allowing for brief deviations from the prescribed durations.

The following variables were collected: demographics, Society of Thoracic Surgeons-European Association for Cardio-Thoracic Surgery (STAT) category, cardiopulmonary bypass time, unplanned reoperation, and measures of resource utilization (mechanical ventilation days, intensive care unit and hospital lengths of stay, and in-hospital mortality). Chylothorax-related diagnosis and treatment variables included pleural fluid test results, postoperative chest tube duration, daily CTO, presence of thrombus, use of NPO, secondary interventions for treatment of chylothorax, FMD duration, and recurrence of chylothorax.

DEFINITIONS. Chylothorax was defined using the Pediatric Cardiac Critical Care Consortium registry definition as follows: the presence of lymphatic fluid in the pleural space secondary to a leak from the thoracic duct or its branches that can be determined by clinical status as documented in a note or by laboratory data (fluid with elevated triglyceride [>110 mg/dL] and/or lymphocyte count [>80%]). Resolving chylothorax was defined as the day when CTO was <10 mL/kg/d without subsequent increase in CTO volume. Fat-modified diet was defined as a diet consisting of medium-chain triglyceride or low-LCT formula, defatted human milk with medium-chain triglyceride formula fortification, or a low-fat diet (<10 g/d). FMD duration began on the day a patient was receiving a FMD and chylothorax was resolving (CTO reached <10 mL/kg/d without increasing), until the day a regular diet resumed. If CTO was <10 mL/kg/d from the time of chylothorax diagnosis until chest tube removal, FMD duration began with the first day of a FMD. Chylothorax recurrence was defined as a return of a chylous effusion requiring chest tube placement within 30 days

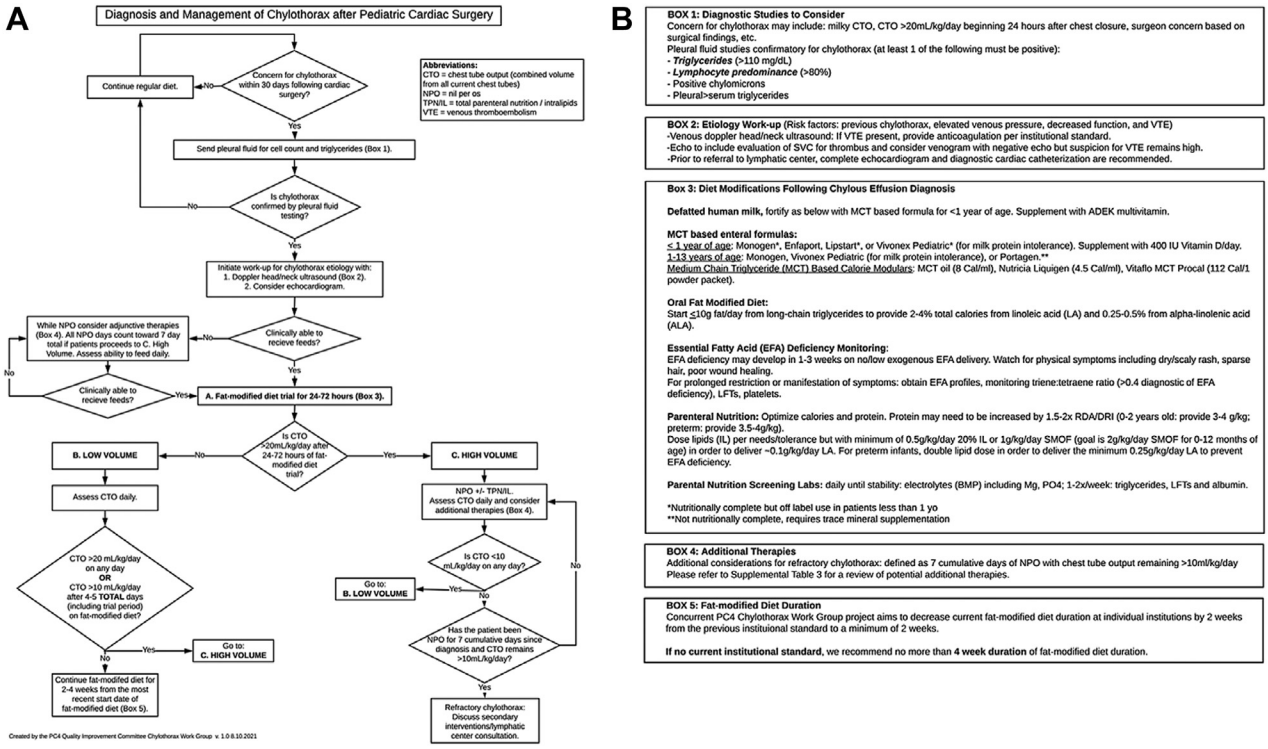

FIGURE 1 (A) Clinical management algorithm for postoperative chylothorax and (B) reference boxes for clinical management algorithm.[23] (ADEK, fat-soluble vitamins A, D, E, and K; CTO, chest tube output; EFA, essential fatty acid; LA, linoleic acid; LFT, liver function test; MCT, medium-chain triglycerides; NPO, nil per os; RDA/DRI, recommended daily allowance/dietary reference intake; SMOF, intravenous fat mixture containing soybean oil, medium-chain triglycerides, olive oil, and fish oil; SVC, superior vena cava; TPN/IL, total parenteral nutrition/intralipids; VTE, venous thromboembolism.) Reproduced with permission from Lion RP, Winder MM, Amirnovin R, et al. Development of consensus recommendations for the management of post-operative chylothorax in paediatric CHD. *Cardiol Young*. 2022;32:1202-1209. © The Author(s), 2022. Published by Cambridge University Press.

of resuming a regular diet. Follow-up monitoring for recurrence across institutions included chest x-ray films and/or monitoring for respiratory distress at follow-up outpatient appointments or during the hospital stay. Noncompliance was defined as a FMD duration above the prescribed range (<3 weeks, 3-5 weeks, >5 weeks).

PRIMARY OUTCOME. The primary outcome was recurrence of chylothorax within 30 days of resuming a regular diet after completing the prescribed FMD duration.

ANALYSIS. Demographic and clinical characteristics of enrolled patients were summarized by FMD duration (<3 weeks, 3-5 weeks, and >5 weeks) using counts and percentages for binary variables and medians and interquartile ranges (IQRs) for continuous variables. The association of characteristics with FMD duration was assessed with the Cochran-Armitage trend test for binary variables and the Jonckheere-Terpstra test for ordinal variables. These statistical tests were chosen to appropriately account for the ordered nature of the FMD duration categories. Outcomes were analogously reported and analyzed. Demographic and clinical characteristics are additionally reported by site. Fisher's exact test was used for binary variables and the Kruskal-Wallis test was used for ordinal variables because clinical site has no inherent ordering. Analyses were performed using SAS 9.4 (SAS Institute) with reported *P* values based on a 2-sided alternative and considered significant if less than .05.

RESULTS

Between January 2020 and April 2022, a total of 105 patients (<3 weeks, n = 61; 3-5 weeks, n = 18; >5 weeks, n = 26) with postoperative chylothorax were analyzed across 6 centers. Twenty-two patients were excluded prior to analysis: 5 dying prior to completing FMD duration, 4 without confirmed outpatient end date of FMD, and 13 with Fontan physiology.

Overall, median age at surgery was 9.9 weeks (IQR, 1.1-23.6) (Table 1). At the time of surgery, 41 patients were neonates (<30 days; 39%), 56 were infants (30 days to 1 year; 53%), and 8 were pediatric (>1 year;

TABLE 1 Overall Characteristics of Children Diagnosed With Chylothorax

Variable	All Chylothorax Patients (N = 105)
Demographics	
Age at surgery, wk	9.9 (1.1-23.6)[a]
Weight at surgery, kg	4.5 (3.4-6.4)[a]
Female	49 (47)[b]
Race, white	79 (76)[b]
Genetic abnormality present	34 (32)[b]
Surgical characteristics	
STAT category	
1-3	59 (56)[b]
4-5	46 (44)[b]
CPB time, min	144 (95-178)[a]
Unplanned reoperation	27 (26)[b]
Hospitalization characteristics	
Mechanical ventilation, d	5.4 (0.5-16)[a]
CICU length of stay, d	14 (6-33)[a]
Hospital length of stay, d	28 (11-55)[a]
In-hospital mortality	4 (3.8)[b]
Chylothorax characteristics	
Postoperative day at diagnosis	4 (2-7)[a]
Pleural triglyceride levels, mg/dL	177 (72-316)[a]
Pleural lymphocytes, %	84 (58-90)[a]
Markers of chylothorax severity	
Median daily CTO, mL/kg/d	16.3 (10.1-23.6)[a]
High CTO, >20 mL/kg/d	87 (83)[b]
Total chest tube utilization, d	11 (7-19)[a]
Treated with NPO	50 (48)[b]
Treated with octreotide	8 (8)[b]
Invasive intervention	12 (11)[b]
FMD	
Duration	
<3 weeks, n = 61	2 (1.9-2.1)[a]
3-5 weeks, n = 18	4 (3.6-4.1)[a]
>5 weeks, n = 26	7.2 (6-9)[a]
Compliance	20 (19)[b]
Recurrence of chylothorax	0 (0)[b]

[a]Jonckheere-Terpstra test; [b]Cochran-Armitage trend test. Values are provided as n (%) or median (interquartile range). CICU, cardiac intensive care unit; CPB, cardiopulmonary bypass; CTO, chest tube output; FMD, fat-modified diet; NPO, nil per os; STAT, Society of Thoracic Surgeons-European Association for Cardio-Thoracic Surgery.

8%), with the oldest patient being 9 years. Median intensive care unit length of stay was 14 days (IQR, 6-33), and median hospital length of stay was 28 days (IQR, 11-55). In-hospital mortality occurred in 4 patients in the study cohort (4%).

Across all groups, median time to chylothorax diagnosis was 4 days postoperative (IQR, 2-7) (Table 1). Median daily CTO was 16 mL/kg/d (IQR, 10-24), and 87 patients (83%) had CTO >20 mL/kg/d on any given day. Median chest tube duration was 11 days (IQR, 7-19). Fifty patients (48%) were treated with NPO, 8 (8%) were treated with octreotide, and 12 (11%) underwent a secondary invasive intervention (thoracic duct ligation [n = 2], lymphangiogram with thoracic duct embolization [n = 1], pleurodesis [n = 1], or cardiac cath [n = 8]). Ten patients (10%) had CTO drop to <10 mL/kg/d, followed by >1 day of increase >10 mL/kg/d, prior to achieving resolving chylothorax (ie, CTO dropping <10 mL/kg/d without increasing). Four patients (3 infants, 1 child), were diagnosed with chylothorax but never received a FMD (ie, continued on a regular diet). In these 4 cases, a regular diet was continued because CTO was low (<10 mL/kg/d) at the time of chylothorax diagnosis; none had recurrence of chylothorax. Demographic, surgical, and chylothorax characteristics at a center level are represented in Supplemental Table 1.

Weight at surgery significantly varied across the three groups, with those in the <3 weeks FMD group weighing the least (median 3.9 kg [IQR, 3.1-6]; $P = .009$) (Table 2). There were no other significant differences in patient demographics, surgical or hospitalization characteristics, or time to chylothorax diagnosis. Pleural triglycerides varied significantly across groups, with the lowest values in the <3 weeks group (median 133 mg/dL [IQR, 55-257]; $P = .002$).

CHYLOTHORAX SEVERITY. Median total chest tube utilization was highest in the >5 weeks group (17.5 days [IQR, 9-31] vs 10 [<3 weeks] and 10.5 [3-5 weeks]; $P = .04$). Any day(s) of high CTO (>20 mL/kg/d) were similar across groups. Other factors suggesting increased severity of chylothorax, including use of NPO or octreotide, or need for invasive secondary intervention for chylothorax, were not significantly different across the groups.

PRIMARY OUTCOME. There was no recurrence of chylothorax in any group (Table 2).

RESOURCE UTILIZATION. Compared with the traditional standard of 6 weeks, the <3 weeks group was exposed to a median FMD of 2 weeks/patient (IQR, 1.9-2.1) and the 3-5 weeks group was exposed to 4 weeks/patient (IQR, 3.4-4.1) (Table 1). This reduction of FMD duration in the <3 weeks and 3-5 weeks groups represents a savings of 185 FMD weeks, a 39% reduction from the traditional standard.

NONCOMPLIANCE. Twenty patients (19%) were noncompliant, with FMD duration longer than directed by the institutional standard. Noncompliant patients were more likely to have longer chest tube duration ($P = .02$), require a thoracic duct ligation ($P = .003$), or undergo a catheter lab intervention ($P = .001$) (Table 3).

COMMENT

Efforts to decrease FMD duration are important in order to mitigate the negative health effects associated with FMDs, including suboptimal nutrition and poor growth.[15-17] We performed a multicenter retrospective

TABLE 2 Characteristics and Outcomes of Chylothorax Patients Based on Fat-Modified Diet Duration

Variable	<3 Weeks (n = 61)	3-5 Weeks (n = 18)	>5 Weeks (n = 26)	*P* Value
Demographics				
Age at surgery, wk	5.4 (1.1-23.6)	15.1 (4.0-25.7)	18.6 (1.3-29.0)	.08[a]
Weight at surgery, kg	3.9 (3.1-6.0)	4.5 (3.6-6.3)	5.2 (4.4-7.6)	.009[a]
Female	29 (48)	4 (22)	16 (62)	.44[b]
Race, white	50 (82)	12 (67)	17 (68)	.12[b]
Genetic abnormality present	17 (28)	7 (39)	10(39)	.29[b]
Surgical characteristics				
STAT category				.40[b]
1-3	31 (51)	13 (72)	15 (58)	
4-5	30 (50)	5 (28)	11 (42)	
CPB time, min	131 (97-189)	152 (95-163)	152 (90-178)	.99[a]
Unplanned reoperation	15 (25)	4 (22)	8 (31)	.60[b]
Hospitalization characteristics				
Mechanical ventilation, d	5.6 (2.1-16.9)	4.4 (0.2-16)	3.3 (0-13.6)	.17[a]
CICU length of stay, d	12 (6-32)	12 (4-26)	30 (6-81)	.46[a]
Hospital length of stay, d	21 (10-42)	34 (7-43)	32 (17-70)	.28[a]
In-hospital mortality	1 (2)	1 (6)	2 (8)	.16[b]
Chylothorax characteristics				
POD at diagnosis	4 (3-6)	4 (2-7)	5 (2-7)	.47[a]
Pleural triglycerides, mg/dL	133 (55-257)	204 (163-365)	255 (172-327)	.002[a]
Pleural lymphocytes, %	83 (58-87)	87 (72-92)	86 (28-90)	.33[a]
Chylothorax severity markers				
Median daily CTO, mL/kg/d	16.3 (11.2-23.5)	19.6 (8.6-28)	14.2 (7.8-23.6)	.38[a]
High CTO, >20 mL/kg/d	53 (87)	15 (83)	19 (73)	.13[b]
Total chest tube, d	10 (7-17)	10.5 (6-18)	17.5 (9-31)	.04[a]
Treated with NPO	28 (48)	10 (56)	12 (46)	.88[b]
Treated with octreotide	3 (5)	2 (11)	3 (12)	.23[b]
Thoracic duct ligation	0	1 (6)	1 (4)	.16[b]
Catheter lab intervention	2 (3)	3 (17)	3 (12)	.11[b]
Pleurodesis	0 (0.0)	1 (6)	0 (0.0)	.69[b]
Thoracic duct embolization	0	0	1 (4)	.11[b]
Recurrence of chylothorax	0 (0)	0 (0)	0 (0)	…

[a]Jonckheere-Terpstra test; [b]Cochran-Armitage trend test. Values are provided as n (%) or median (interquartile range). CICU, cardiac intensive care unit; CPB, cardiopulmonary bypass; CTO, chest tube output; NPO, nil per os; POD, postoperative day; STAT, Society of Thoracic Surgeons-European Association for Cardio-Thoracic Surgery.

study across 6 pediatric centers that participate in the CWG to determine the association between FMD duration and recurrence of chylothorax. Surgical and hospital characteristics were evenly distributed across all groups. Notably, no patients had recurrence of chylothorax with any FMD duration, regardless of severity of chylothorax.

Our findings challenge a longstanding and widespread clinical practice belief that a FMD should be continued for many weeks after chylothorax resolution in order to prevent recurrence. Our multicenter findings support the generalizability of the previous single-center report that also found no association between FMD duration and recurrence, regardless of STAT category, duration and volume of chest tube drainage, and need for secondary interventions.[14]

Noncompliance to the prescribed FMD duration occurred in 19% of patients (n = 20). Hesitation to reinstate a regular diet is often increased based on severity of chylothorax, including high CTO, long chest tube duration, or need for interventions beyond dietary modification. Consistent with this hesitancy, we found that patients with longer chest tube durations or requiring catheter lab intervention or thoracic duct ligation were more likely to be noncompliant. However, our study showed that once chylothorax was resolving, recurrence of chylothorax was not associated with chest tube duration, invasive interventions, or any other marker of chylothorax severity, regardless of FMD duration. Additionally, half of the noncompliant patients (n = 10) had no clinical basis for prolonged FMD duration, suggesting noncompliance in these patients was more likely related to lack of education regarding the institutional standard for FMD duration, longstanding clinical practice traditions, or an inability to be seen as an outpatient during the designated goal time period. Improved education regarding a lack of

TABLE 3 Characteristics of Patients Treated With the Intended FMD Duration, Compared With Those Treated With a Longer Than Intended FMD Duration

Variable	FMD Longer Than Protocol		
	No (n = 85)	Yes (n = 20)	*P* Value
Demographics			
Age at surgery, wk	9.7 (1.1-24.6)	12.4 (1.1-22.2)	.95[a]
Weight at surgery, kg	4.4 (3.3-6.3)	4.7 (3.5-6.4)	.77[a]
Female	40 (47)	9 (45)	.87[b]
Race, white	62 (74)	17 (85)	.29[b]
Genetic abnormality present	27 (32)	7 (35)	.78[b]
Surgical characteristics			
STAT category			.70[b]
1-3	47 (55)	12 (60)	
4-5	38 (45)	8 (40)	
CPB time, min	133 (97-166)	158 (93-178)	.82[a]
Unplanned reoperation	19 (22)	8 (40)	.10[b]
Chylothorax characteristics			
Postoperative day at diagnosis	4 (2-7)	5 (4-8.5)	.20[a]
Pleural triglyceride levels, mg/dL	170 (65-316)	198 (129-319)	.57[a]
Pleural lymphocytes, %	82 (48-87)	89 (85-92)	.005[a]
Markers of chylothorax severity			
Median daily CTO, mL/kg/d	15.5 (10.1-23.5)	20.5 (10.3-28.5)	.31[a]
High CTO, >20 mL/kg/d	70 (82)	17 (85)	.78[b]
Total chest tube utilization, d	11 (7-18)	17.5 (9.5-37)	.02[a]
Treated with NPO	37 (44)	13 (65)	.08[b]
Treated with octreotide	6 (7)	2 (10)	.67[b]
Thoracic duct ligation	0	2 (10)	.003[b]
Catheter lab intervention	3 (4)	5 (25)	.001[b]
Pleurodesis	1 (1)	0	.63[b]
Thoracic duct embolization	1 (1)	0	.63[b]
Recurrence of chylothorax	0	0	…

[a]Jonckheere-Terpstra test; [b]Cochran-Armitage trend test. Values are provided as n (%) or median (interquartile range). CICU, cardiac intensive care unit; CPB, cardiopulmonary bypass; CTO, chest tube output; FMD, fat-modified diet; NPO, nil per os; STAT, Society of Thoracic Surgeons-European Association for Cardio-Thoracic Surgery.

recurrence in patients with shortened FMD durations will likely lead to improved compliance.

Reduction of FMD duration after resolving chylothorax has potential for substantial positive impacts on nutrition and resource utilization. Chylothorax and use of a FMD may result in essential fatty acid deficiencies and electrolyte abnormalities if not closely monitored and supplemented.[18] Neonates and infants are dependent on dietary sources of fat for calories and brain development, and the predominant source of fat in breastmilk and standard formulas is LCTs, amplifying the risk of deficiencies in FMDs.[18,26] Additionally, inadequate weight gain in infancy is associated with poor neurodevelopmental outcomes.[19] Therefore, it is beneficial to minimize exposure to a diet known to provide suboptimal nutrition, especially in a population of children already at high risk for neurodevelopmental impairment due to factors associated with congenital heart disease.[27] For young children, a low-fat diet may also be challenging to maintain, and inadequate protein and caloric intake with subsequent weight loss is anticipated.[28] Furthermore, patients requiring NPO for treatment of chylothorax may be at higher risk of ongoing nutritional deficiency, highlighting the benefit of shortening FMD duration whenever possible.

In addition to the adverse impact on health and nutrition, FMD can lead to a considerable cost burden, whether absorbed by the patient or the healthcare system. Low-LCT formulas are rarely available at standard retailers and require coordination with home health services or purchase through online vendors. Compared with standard infant formulas, low-LCT formulas are 1.5-3 times more expensive, and represent a completely new cost for formula when an infant has previously been breastfed. The cost may be further exaggerated by the current formula shortage. Compared with a traditional standard of 6 weeks, our cohort's FMD duration was decreased by 39%, demonstrating a meaningful reduction in exposure to the negative effects of a FMD and a potentially substantial cost savings to families and the healthcare system. Future studies are necessary to determine the impact of decreased FMD duration on growth, parental satisfaction, and cost.

LIMITATIONS. Limitations of this study include application of study findings to a broad pediatric cohort, as it was limited to children who develop chylothorax after congenital cardiac surgery and excluded patients with Fontan physiology. While a standard chylothorax management algorithm was utilized across all centers, we did not measure compliance to the treatment algorithm beyond FMD duration, and hence the association between the treatments prior to resolution and recurrence cannot be established. Criteria for chest tube removal was not included in the CWG management algorithm; however, FMD duration was calculated based on CTO instead of chest tube removal to mitigate the impact of practice variation. We did not control for other variables associated with chylothorax recurrence including residual lesions, fluid status, thrombosis, increased venous pressures, or decreased capillary permeability.[1-3,10] To mitigate the impact of practice variation and improve generalizability, the CWG continues to enroll patients and collect data across multiple centers to further study management strategies (including shortened FMD duration) and outcomes in children with postoperative chylothorax. Center 4 had a higher prevalence of chylothorax and contributed highly to the <3 weeks group. Compliance to the FMD duration after discharge was based on parental reporting only.

CONCLUSION. Across 6 centers, there was no recurrence of postoperative chylothorax, regardless of FMD

duration, even in patients with markers of increased chylothorax severity, such as high CTO, treatment with NPO, or need for secondary medical or surgical interventions. Our findings suggest that <3 weeks of FMD is adequate for treating chylothorax after it is resolving. Further studies are needed to determine whether these findings are also true in patients who have undergone Fontan palliation.

The authors wish to acknowledge their appreciation for the insight and expertise of the Chylothorax Work Group members.

FUNDING SOURCES

The authors have no funding sources to disclose.

DISCLOSURES

The authors have no conflicts of interest to disclose.

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.

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.

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.

4. Tutor JD. Chylothorax in infants and children. *Pediatrics*. 2014;133:722-733.

5. McCray S, Parrish CR. Nutritional management of chyle leaks: an update. *Pract Gastroenterol*. 2011;35:12-32.

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. 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.

8. 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.

9. Milonakis M, Chatzis AC, Giannopoulos NM, et al. Etiology and management of chylothorax following pediatric heart surgery. *J Card Surg*. 2009;24:369-373.

10. Panthongviriyakul C, Bines JE. Post-operative chylothorax in children: an evidence-based management algorithm. *J Paediatr Child Health*. 2008;44:716-721.

11. Cabrera AG, Prodhan P, Bhutta AT. Nutritional challenges and outcomes after surgery for congenital heart disease. *Curr Opin Cardiol*. 2010;25:88-94.

12. 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.

13. 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*. 2020;28:816-825.

14. Winder MM, Vijayarajah S, Reeder RW, et al. Successfully reducing fat-modified diet duration for treating postoperative chylothorax in children. *Ann Thorac Surg*. 2022;114:2362-2371.

15. 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. *J Parenter Enter Nutr*. 2016;40:543-551.

16. Łoś-Rycharska E, Kieraszewicz Z, Czerwionka-Szaflarska M. Medium chain triglycerides (MCT) formulas in paediatric and allergological practice. *Prz Gastroenterol*. 2016;11:226-231.

17. 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.

18. Fogg K, Trauth A, Horsley M, et al. Nutritional management of post-operative chylothorax in children with CHD. *Cardiol Young*. Published online September 30, 2022. https://doi.org/10.1017/S1047951122003109

19. Lu MS, Lu JH, Zhang LF, et al. Infancy weight gain and neurodevelopmental outcomes among term-born infants at age one year: a large prospective cohort study in China. *Child Neuropsychol*. 2022;28:554-567.

20. 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.

21. Abrams SA, Duggan CP. Infant and child formula shortages: now is the time to prevent recurrences. *Am J Clin Nutr*. 2022;116:289-292.

22. Stilwell L, Gennetian LA. *PBS News Hour*. How the baby formula shortage financially strains U.S. families. October 8, 2022. https://www.pbs.org/newshour/economy/how-the-baby-formula-shortage-financially-strains-u-s-families

23. Lion RP, Winder MM, Amirnovin R, et al. Development of consensus recommendations for the management of post-operative chylothorax in paediatric CHD. *Cardiol Young*. 2022;32:1202-1209.

24. Lo Rito M, Al-Radi OO, Saedi A, et al. Chylothorax and pleural effusion in contemporary extracardiac fenestrated Fontan completion. *J Thorac Cardiovasc Surg*. 2018;155:2069-2077.

25. Menon S, Chennapragrada M, Ugaki S, et al. The lymphatic circulation in adaptations to the Fontan circulation. *Pediatr Cardiol*. 2017;38:886-892.

26. Benton D. The influence of children's diet on their cognition and behavior. *Eur J Nutr*. 2008;47:25-37.

27. Rollins CK, Newburger JW. Neurodevelopmental outcomes in congenital heart disease. *Circulation*. 2014;130:e124-e126.

28. Puntis JW, Roberts KD, Handy D. How should chylothorax be managed? *Arch Dis Child*. 1987;62:593-596.