Cardiology in the Young

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A protocol to decrease postoperative chylous effusion duration in children

Melissa M. Winder[1], Aaron W. Eckhauser[2], Claudia Delgado-Corcoran[3], Randall J. Smout[4], Jennifer Marietta[5] and David K. Bailly[3]

[1]Department of Pediatric Critical Care, Primary Children's Hospital, Salt Lake City, UT, USA, [2]Division of Pediatric Cardiothoracic Surgery, University of Utah, Salt Lake City, UT, USA, [3]Division of Pediatric Critical Care, University of Utah, Salt Lake City, UT, USA, [4]Continuous Improvement, Primary Children's Hospital, Salt Lake City, UT, USA and [5]Heart Center, Primary Children's Hospital, Salt Lake City, UT, USA

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Author for correspondence:
M. M. Winder, CPNP-AC, Department of Pediatric Critical Care, Primary Children's Hospital, 100 N Mario Capecchi Dr, Salt Lake City, UT 84113, USA. Tel: 801 647 1680; Fax: 801 662 2412;
E-mail: melissa.winder@imail.org

Abstract

Objective: Our primary goal was to decrease time to resolution of postoperative chylothorax as demonstrated by total days of chest tube utilisation through development and implementation of a management protocol. *Methods:* A chylothorax management protocol was implemented as a quality improvement project at a tertiary-care paediatric hospital in July, 2015. Retrospective analysis was completed on patients aged 0–17 years diagnosed with chylothorax within 30 days of cardiac surgery in a pre-protocol cohort (February, 2014 to June, 2015, n = 20) and a post-protocol cohort (July, 2015 to March, 2016, n = 22). *Measurements and results:* Patient characteristics were similar before and after protocol implementation. Duration of mechanical ventilation and cardiac ICU and hospital lengths of stay were unchanged between cohorts. Following protocol implementation, total duration of chest tube utilisation decreased from 12 to 7 days ($p = 0.047$) with a decrease in maximum days of chest tube utilisation from 44 to 13 days. Duration of medium-chain triglyceride feeds decreased from 42 days to 31 days ($p = 0.01$). In total, three patients in the post-protocol cohort underwent additional surgical procedures to treat chylothorax with subsequent resolution of chylothorax within 24 hours. There were no chest tube re-insertions or re-admissions related to chylothorax in either the pre- or post-protocol cohorts. Protocol compliance was 81%. *Conclusions:* Adoption of a chylothorax management protocol is feasible, and in our small cohort of patients implementation led to a significant decrease in the duration of chest tube utilisation, while eliminating practice variability among providers.

Chylothorax occurs in 2.8–3.9% of children following cardiac surgery. Despite its relative infrequency, it is associated with increased mortality, hospital length of stay, cardiac ICU length of stay, time on mechanical ventilation, extracorporeal membrane oxygenation use, and cost.[1,2] In addition, as a result of chylous drainage, these patients are at a higher risk for developing thrombi and poor nutrition.[3]

Despite several generally accepted treatment modalities, including medium-chain triglyceride feeds/fortified defatted human milk/low-fat diet – medium-chain triglyceride feeds – nothing-by-mouth with enteral nutrition, octreotide, and surgical interventions, there remains a lack of evidence to guide duration and progression of treatments. Consequently, wide practice variation is found in the clinical setting, as well as in the treatment protocols that are available in the literature.[4–11] Our centre is no exception, as discussions with providers and analysis of a cohort of chylothorax patients revealed considerable variation in the treatment of these patients, specifically in the timing and duration of nothing-by-mouth, medium-chain triglyceride feed duration, and a lack of utilisation of additional interventions – octreotide, surgical intervention, etc. Importantly, Yeh et al[10] demonstrated significant improvement in outcomes in the treatment of postoperative chylothorax following the standardisation of practice through the implementation of a protocol.

Our primary aim was to decrease the duration of postoperative chylothorax in children with CHD, as demonstrated by the duration of chest tube utilisation, through creation and implementation of a chylothorax management protocol.

Materials and methods

Study population and setting

All children undergoing cardiac surgery at Primary Children's Hospital (February, 2014–October, 2016) who developed a postoperative chylothorax within 30 days of surgery were included. Patients were excluded from analysis if they had congenital chylothorax or had undergone a Fontan operation, as we felt these patients deserved a more aggressive approach.

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Patients were also excluded if their chylothorax duration was <24 hours, as these effusions probably resolved with little or no influence from the protocol. The study was approved and a waiver of informed consent granted by the University of Utah Institutional Review Board and Primary Children's Hospital Private Board. The pre-intervention period was from February, 2014 through June, 2015. The cases were selected retrospectively from the cardiothoracic surgery database. After implementation of a chylothorax management protocol, the post-intervention period was from July, 2015 to October, 2016, and cases were identified prospectively.

Definitions

Chylothorax was diagnosed with one or more of the following findings: pleural fluid triglycerides >110 mg/dl, pleural fluid lymphocytes >80%, and/or pleural fluid triglycerides greater than serum triglycerides.

Patient weight used for analysis and in calculations was the patient's preoperative admission weight in kilograms.

Chest tube output was defined as the cumulative output of all chest tubes for a 24-hour period in relation to the patient's weight (ml/kg/day).

Low chest tube output (low output) was defined as ⩽20 ml/kg/day during the first 48 hours or <10 ml/kg/day at any time.

High chest tube output (high output) was determined after a 24-hour trial of medium-chain triglyceride feeds and is defined as >20 ml/kg/day. In addition, patients in the low-output arm whose chest tube output remains ⩾10 ml/kg/day after at least 48 hours on medium-chain triglyceride feeds are subsequently redefined as having high output.

Net daily fluid balance was identified by calculating the daily fluid balance – total volume intake minus total volume output – from postoperative day 0 through the date of chylothorax resolution in relation to the patient's weight (ml/kg/day).

Chylothorax resolution was defined as the day the last chest tube was removed.

Chylothorax recurrence was defined as re-insertion of a chest tube draining diagnostic fluid after chylothorax resolution and within 30 days of resuming full-fat/regular feeds.

Protocol Compliance was affirmative if the instruction was carried out within 24 hours of eligibility. The authors tracked compliance through monthly retrospective chart reviews, rounding on qualifying patients at least every 2–3 days, and contact from providers to discuss rationale for deviations.

Intervention: protocol development and implementation

In December, 2014, literature regarding chylothorax treatment was reviewed at a Cardiac ICU journal club at our institution. The subsequent discussion revealed wide variation in the treatment of chylothorax, including nothing-by-mouth utilisation and duration, duration of medium-chain triglyceride feeds, and lack of surgical intervention. After identifying the need for standardisation, a key driver diagram was developed (Fig 1) using an investigation of 13 patients diagnosed with chylothorax from January to June, 2015. Data analysis confirmed wide variation in the decisions to make a patient nothing-by-mouth (chest tube output ranged from 10–77 ml/kg/day),

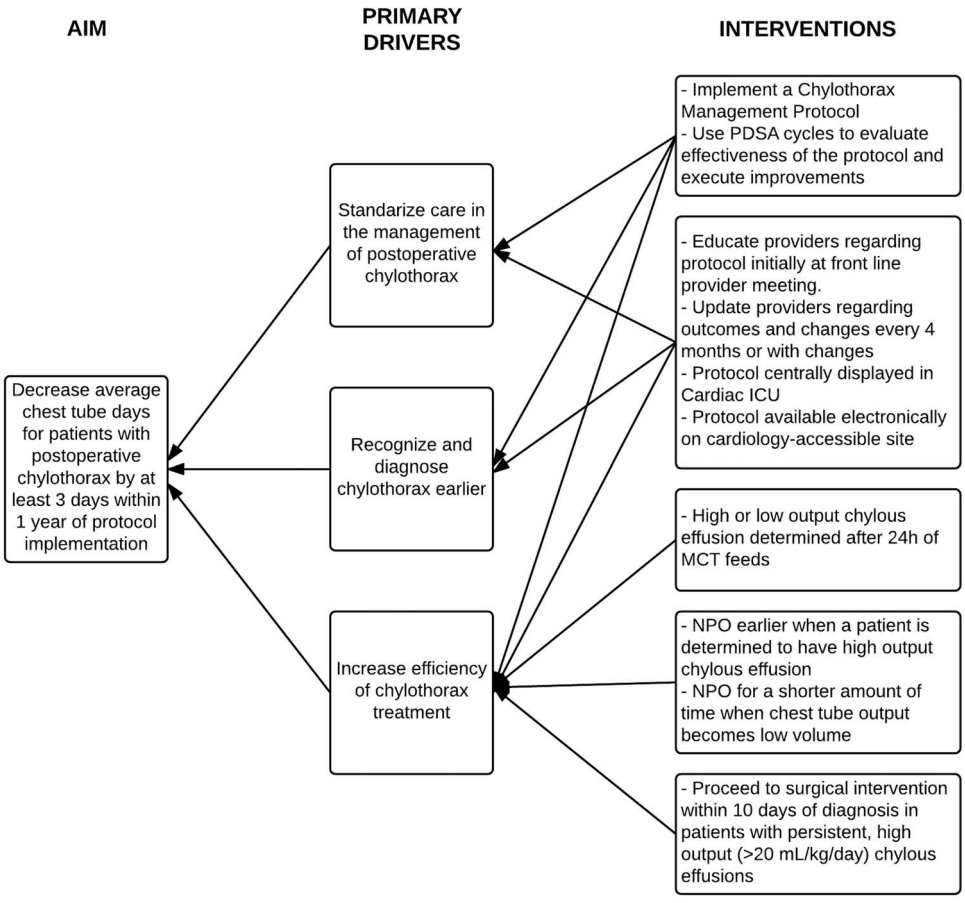


Figure 1. Key driver diagram for developing a protocol to reduce chylothorax duration. MCT = medium-chain triglyceride; NPO = nil per os; PDSA = Plan-Do-Study-Act.

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timing to initiate nothing-by-mouth status (0–5 days), duration of nothing-by-mouth status (1–17 days), and duration of medium-chain triglyceride feeds (2–6 weeks). Out of 13 patients, eight had chest tubes for ⩾10 days, and two of these patients had persistent output >20 ml/kg/day, suggesting that nothing-by-mouth status and medium-chain triglyceride feeds were ineffective, although there were no additional surgical interventions performed on this subset of patients. We concluded that utilising nothing-by-mouth sooner and more rapid progression to surgical intervention would reduce the duration of chest tube utilisation.

The protocol was developed over 6 months (December, 2014 to June, 2015) using literature[4–10] and local expert opinions of a multidisciplinary team that included paediatric cardiothoracic surgeons, cardiologists, cardiac intensive care physicians, nurse practitioners, and registered nurses.

The protocol was implemented on 1 July, 2015 following presentation at a meeting to review new policies related to cardiac patients, with front-line providers in attendance including nurse managers and educators. The protocol was distributed via e-mail, hard copies were placed throughout the cardiac ICU, and electronic copies were made available in a shared drive accessible to cardiac intensive care and cardiology providers. Once a patient was diagnosed with a chylothorax, the protocol was placed in the chart and one of the authors was notified. The authors were available for questions and followed up each patient throughout the hospital course. Iterative interventions occurred using Plan-Do-Study-Act cycles.

Figure 2 displays the current protocol, and Table 1 outlines Plan-Do-Study-Act iterations to arrive at the current protocol. After the diagnosis of chylothorax, all patients are trialed on 24–36 hours of medium-chain triglyceride feeds, defatted human milk fortified with medium-chain triglyceride formula, or a low-fat diet (<10 g/day) before enrolment in the high- or low-output treatment arms. Low chest tube output is managed by providing medium-chain triglyceride feeds for 6 sequential weeks. The high-output state is managed with nothing-by-mouth status for 6 days with re-evaluation every 3 days for re-entry back into the low-output (<10 ml/kg/day) treatment arm. For persistent drainage following nothing-by-mouth for 6 days, a 3-day trial of octreotide is initiated. If chest tube output fails to drop <10 ml/kg/day, the patient will then undergo invasive interventions – thoracic duct ligation, embolisation, or pleurodesis – within 10 days of diagnosis. The invasive intervention is chosen by discussion with the cardiac ICU attending and primary surgeon and depends on patient size, cardiac anatomy, and clinical status. Chest tubes may be removed when output is <3 ml/kg/12 hours.

The protocol also recommends testing levels and replacing anti-thrombin III and immunoglobulin G every 1–3 days in patients with high chest tube output. Values warranting replacement were based upon age-appropriate normal values as determined by our laboratory, suggesting intravenous immunoglobulin replacement for immunoglobulin G levels <400 mg/dl and anti-thrombin administration for anti-thrombin III <60% in patients 0–89 days or <80% in patients >89 days.

Study of the interventions

The first 15 patients in the post-protocol cohort demonstrated no recurrence of chylothorax, and three of these patients had feeds shortened to 2 weeks secondary to feeding intolerance. For these reasons, our first intervention was to reduce the duration of medium-chain triglyceride feeds from 6 to 4 weeks – initiated on 30 May, 2016.

The second intervention – initiated on 15 August, 2016 – involved decreasing the timing for re-evaluation of nothing-by-mouth status from every 3 days to daily. This was based upon the observation that once chest tube output drops <10 ml/kg/day it typically did not increase again regardless of subsequent timing of restarting feeds.

Third, a chylothorax detection algorithm was created to achieve earlier diagnosis – initiated on 15 August, 2016. The algorithm was derived by establishing a chest tube output volume threshold (>15 ml/kg/day; see Results section) for testing pleural fluid rather than relying on milky appearance, which is subjective and may be absent in patients on low-volume or no feeds.

Measures

Our primary intervention was the implementation of a chylothorax management protocol, with outcomes measured by comparing pre- and post-protocol cohorts.

Primary outcomes

The primary outcome of this quality improvement project was chylothorax duration as measured by postoperative duration of chest tube utilisation. Secondary outcomes were postoperative days to chylothorax diagnosis, ICU and hospital lengths of stay, mechanical ventilation days, nothing-by-mouth days, and medium-chain triglyceride feed duration.

Balance measures

Balance measures included chylothorax recurrence as demonstrated by chest tube re-insertion and hospital re-admission related to chylothorax.

Data collection included patient demographics, such as age, sex, race, ethnicity, weight, preoperative cardiac diagnosis, surgical intervention, date of initiation of feeds, date of chylothorax diagnosis, chest tube output, daily fluid balance, nothing-by-mouth days, chest tube days, milrinone use, mechanical ventilation days, head/neck venous ultrasound results, ICU and hospital lengths of stay, re-admission date(s) and diagnosis, additional surgical interventions, and in-hospital mortality.

Statistical analysis

Descriptive statistics were used to provide frequencies and percentages for categorical variables and means, medians, and standard deviations for continuous variables. For discrete variables, we used the χ^2 test to determine significance. For continuous variables, we used t-tests assuming unequal variance. A two-sided p-value <0.05 was considered statistically significant. Analyses were performed using Microsoft Excel version 2010.

Results

Clinical characteristics

We analysed a total of 42 patients, divided into pre-protocol (n = 20) and post-protocol (n = 22) cohorts. Patient characteristics – age, sex, race, ethnicity, weight, and genetics – surgical procedures, pleural triglyceride levels, and daily chest tube output were similar in both cohorts (Table 2).

Net daily fluid balance (p = 0.25) and milrinone use (p = 0.29) were also found to be similar across cohorts. On average, chest tubes were removed when 24-hour output was 2.5 ml/kg/day in the pre-protocol cohort and 2.0 ml/kg/day in the post-protocol

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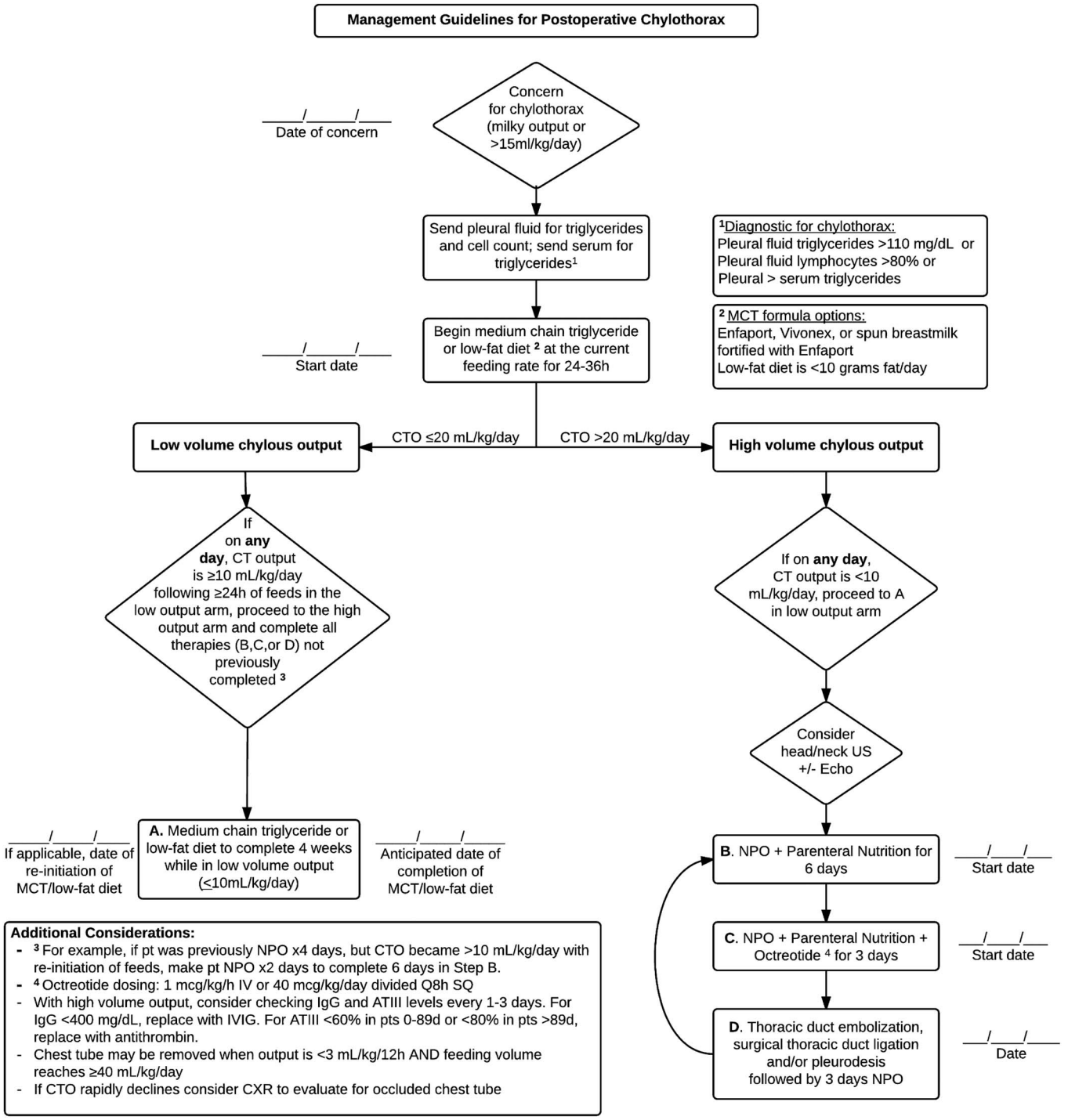


Figure 2. Chylothorax management protocol. ATIII = anti-thrombin III; CT = chest tube; CTO = chest tube output; CXR = chest X-ray; IV = intravenous; IVIG = intravenous immunoglobulin; MCT = medium-chain triglyceride; NPO = nil per os; SQ = subcutaneous; US = ultrasound.

cohort (p = 0.58). Incidence of chylothorax did not change over the study period (pre = 4%, post = 5%, overall = 5%, p = 0.66).

Primary and balance measure outcomes

Mean duration of chest tube utilisation decreased significantly from 12 to 7 days (p = 0.047). Maximum duration of chest tube utilisation decreased from 44 to 13 days (Fig 3).

Postoperative days to diagnosis were unchanged between cohorts (p = 0.76). No difference in ICU and hospital lengths of stay or duration of mechanical ventilation was found (Table 3). Mortality was similar across both cohorts. Total nothing-by-mouth duration decreased from 5 to 3 days (p = 0.43). As directed by the protocol, medium-chain triglyceride feed duration significantly decreased in the post-protocol cohort (p = 0.01).

No chest tubes re-insertions or re-admissions occurred owing to chylothorax in either cohort, including following any protocol interventions – for example, decreasing medium-chain triglyceride feed duration from 6 to 4 weeks and decreasing interval to re-evaluate chest tube output for ability to resume feeds.

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Table 1. Description of Plan-Do-Study-Act cycles.

Goal	Date of change	Plan/do	Study	Act
1. Implement chylothorax management protocol	7/1/15	Plan: protocol developed using literature and local experts. Begin using in postoperative cardiac patients with chylothorax Do: providers educated on protocol at staff meeting and provided with access to protocol	Significant decrease in chest tube days with no recurrence of chylothorax Issues identified: two patients with shortened MCT feeds	Maintain protocol without revisions Re-educate providers regarding need for 6 weeks of MCT feeds to establish a baseline
2. Maintenance phase	11/5/15	Plan: maintain the protocol as initially written Do: discussed maintaining MCT feeding length at 6 weeks with surgeons, who are involved in all decisions about deviations	Significant decrease in chest tube days with no recurrence of chylothorax Issues identified: additional patient with shortened MCT feeds (total of 3)	Decrease MCT feeding duration to 4 weeks. A total of 12 patients treated with 6 weeks of MCT feeds now available as a baseline for comparison
3. Decrease treatment durations	5/30/16	Plan: shorten duration of MCT feeds from 6 weeks to 4 weeks Do: protocol revised and providers educated of change and provided with revised protocol by e-mail and on shared site	No recurrence of chylothorax or re-insertion of chest with 4-week duration of MCT feeds Issues identified: NPO in 3-day intervals effective, but able to shorten? No decrease in time to diagnosis. Analysis showed significantly higher chest tube output in chylothorax patients days before diagnosis	Maintain MCT feeds at 4 weeks. Consider trialing shorter duration of MCT feeds if no adverse events in 20 + patients. Shorten NPO duration (see Goal 4). Diagnose chylothorax earlier (see Goal 5)
4. Shorten NPO duration	8/15/16	Plan: resume feeds when chest tube output reaches <10 ml/kg/day regardless of NPO duration Do: protocol revised. Providers educated at staff meeting and revised protocol distributed	Two patients treated with NPO, 1–3 days in accordance with revised protocol. Neither patient had increase in chest tube output >10 ml/kg/day after resuming MCT feeds or recurrence of chylothorax	Maintain daily evaluation of NPO status
5. Diagnose chylothorax in <4 days	8/15/16	Plan: analysis revealed significantly higher chest tube output in chylothorax patients in the first 5 postoperative days when compared with non-chylothorax patients. Send pleural fluid for chylothorax studies when chest tube output >15 ml/kg/day, despite feeding status or appearance of pleural fluid Do: protocol revised. Providers educated at staff meeting and revised protocol distributed	Issues identified: three patients tested positive for chylothorax since implementation of revision. One patient tested the 1st day chest tube output >15 ml/kg/day. Two tested on POD 5 and met criteria for testing on POD 2	Provide further education to providers regarding rationale for testing for chylothorax based upon chest tube output. Build prompt for testing into new computer charting system when implemented in 2017

MCT = medium-chain triglyceride; NPO = nil per os; POD = postoperative day

Table 2. Demographic and clinical characteristics of children diagnosed with chylothorax.

Mean (SD) or n (%)	Pre-protocol (n = 20)	Post-protocol (n = 22)	p-value
Age at the time of surgery (days)	67 (91)	72 (76)	0.85
Sex, male	13 (65%)	15 (68%)	0.83
Race			0.25
White	17 (85%)	21(95%)	
Other	3 (15%)	1 (5%)	
Ethnicity			0.86
Latino	5 (25%)	5 (23%)	
Non-Latino	15 (75%)	17 (77%)	
Weight on admission (kg)	4.1 (1.6)	4.3 (1.8)	0.63
STAT mortality category			0.74
1	1 (5%)	1 (4%)	
2	3 (15%)	5 (23%)	
3	11 (55%)	8 (36%)	
4	4 (20%)	5 (23%)	
5	1 (5%)	3 (14%)	
Type of operation			0.67
Single ventricle without arch repair	1 (5%)	3 (14%)	
Single ventricle with arch repair	3 (15%)	5 (23%)	
Two ventricles without arch repair	13 (65%)	11 (50%)	
Two ventricles with arch repair	3 (15%)	3 (14%)	
Surgical approach			0.33
Thoracotomy	0 (0%)	1 (5%)	
Sternotomy	20 (100%)	21 (95%)	
Genetic abnormality present	7 (35%)	7 (32%)	0.83
Pleural triglyceride levels	320 (272)	324 (240)	0.97
Average daily CTO (ml/kg/day)	22 (29)	18 (13)	0.51
Maximum daily CTO (ml/kg)	185 (239)	144 (116)	0.49
Net daily fluid balance (ml/kg/day)	13 (15)	8 (10)	0.25
CTO in 24 hours before chest tube removal (ml/kg/day)	3 (3)	2 (2)	0.58
High-CTO patients	8 (40%)	9 (41%)	0.95
Low-CTO patients	12 (60%)	13 (59%)	0.95
Milrinone use	19 (95%)	22 (100%)	0.48

CTO = chest tube output; STAT = The Society of Thoracic Surgeons – European Association for Cardio-Thoracic Surgery Congenital Heart Surgery

Additional treatment characteristics

Protocol intervention outcomes are further detailed in Table 4. Protocol compliance was 81%. Octreotide and thoracic duct ligation were never used in the pre-protocol cohort. Octreotide – in three patients – and thoracic duct ligation – in two patients – were utilised in the post-protocol cohort. Octreotide was used for 3–6 days and chest tube output remained ⩾20 ml/kg/day on all treatment days, and all three patients underwent additional interventions. Thoracic duct ligation resulted in chylothorax resolution within 24 hours without recurrence in both patients. One patient in the post-protocol cohort underwent balloon dilation of the atrial septum in the setting of elevated right atrial pressures (20 mmHg) with resolution of chylothorax within 2 days.

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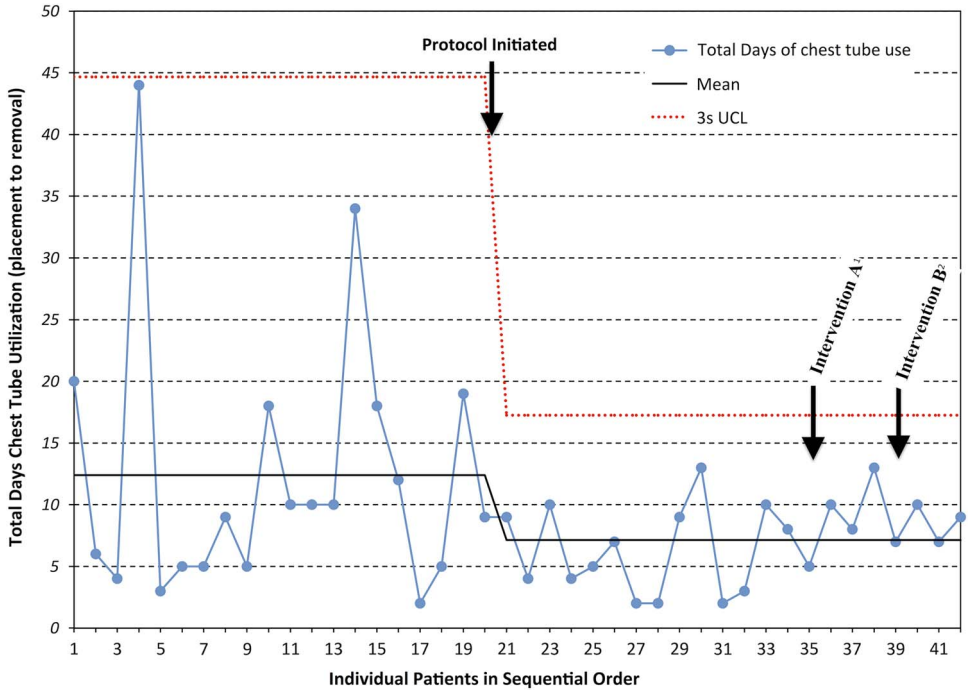


Figure 3. Control chart of total days of chest tube utilisation for 42 patients with chylothorax from February, 2014 to October, 2016. A chylothorax management protocol was implemented on 1 July, 2015 – after patient number 20. [1]Intervention A was to decrease the duration of medium-chain triglyceride feeds/low-fat diet from 6 weeks to 4 weeks. [2]Intervention B was to add a trigger to test for chylothorax when chest tube output was >15 ml/kg/day; also, the need for nothing-by-mouth status was re-evaluated daily instead of every 3 days. UCL = upper control limit.

Table 3. Outcome measures in patients treated for chylothorax.

Mean (SD) or n (%)	Pre-protocol (n = 20)	Post-protocol (n = 22)	p-value
Duration of chest tube utilisation (days)	12 (11)	7 (3)	0.047
Duration of high output (days)	14 (11) n = 8	6 (2) n = 9	0.08
CLOS (days)	15 (13)	14 (13)	0.83
HLOS (days)	30 (22)	21 (16)	0.15
Mechanical ventilation			
Total duration (days)	9 (11)	7 (4)	0.36
Mortality	2 (10%)	0 (0%)	0.13

CLOS = cardiac ICU length of stay; CTU = chest tube utilisation; HLOS = hospital length of stay

Head/neck ultrasound was performed in seven pre-protocol patients and eight post-protocol patients. Occlusive thrombus was detected in one pre-protocol and two post-protocol patients. All occlusive thrombi were treated with anti-coagulation. One pre-protocol and four post-protocol patients had femoral vein or artery thrombi related to cardiac catheterisation or central venous lines and were treated with anti-coagulation.

Chylothorax detection algorithm

In analysing chylothorax patients, we found that chest tube output was high even before its appearance turned milky. If the output proved to be significantly higher than non-chylothorax patients, we felt this could help diagnose chylothorax earlier and thus lead to earlier resolution. Therefore, a detection algorithm was created using the chylothorax cohorts and 99 consecutive patients in the post-protocol era who were never diagnosed with chylothorax. Supplementary Table 1 compares mean chest tube output on postoperative days 0–5 for chylothorax and non-chylothorax patients. Analysis revealed that chest tube output >15 ml/kg/day provided 88% sensitivity and 68% specificity for detecting chylothorax. In the 8 weeks since implementation of the algorithm, five patients have been tested for chylothorax. Three patients tested positive for chylothorax after meeting criteria for testing but also had a chest tube output that was milky in appearance. Two patients with output >15 ml/kg/day were tested and found not to have chylothorax.

Discussion

We demonstrated a significant decrease in chylothorax duration as measured by chest tube utilisation in postoperative children

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Table 4. Protocol intervention outcomes in patients treated for chylothorax.

Mean (SD) or n (%)	Pre-protocol (n = 20)	Post-protocol (n = 22)	p-value
POD at diagnosis	6 (5)	6 (5)	0.76
NPO			
Treated with NPO for chylothorax	11 (55%)	11 (50%)	0.86
Duration NPO (days)	5 (5)	3 (2)	0.43
Head/neck thrombus			
Head/neck US completed	7 (35%)	8 (36%)	0.93
Patients with occlusive clot(s) identified	1 (5%)	2 (9%)	0.61
Patients treated with anti-coagulation for any clot	2 (10%)	6 (27%)	0.15
Octreotide			
Treated with octreotide	0 (0%)	3 (14%)	
Duration of octreotide use (days)	N/A	4	
Additional surgical intervention			
Thoracic duct ligation	0 (0%)	2 (9%)	
Cath lab intervention	0 (0%)	1 (5%)	
Duration of MCT feeds (days)	42 (15)	30 (11)	0.01
Protocol compliance	N/A	18 (81%)	N/A

MCT = medium-chain triglyceride feeds/fortified defatted human milk/low-fat diet; NPO = nil per os; POD = postoperative day; US = ultrasound

who have undergone cardiac surgery through implementation of a single-centre chylothorax management protocol.

The studies by Yeh et al[10] and Day et al[11] are the only other published studies that present pre- and post-protocol data in the treatment of chylothorax. In comparison with their results, we saw a shorter post-protocol median chest tube utilisation of 7 versus 14[10] and 11.5[11] days.

Importantly, our exclusion criteria varied from these studies, which excluded only patients who underwent surgical repairs via lateral thoracotomy[10] and included all chylothorax patients.[11] However, in the study by Yeh et al[10], Fontan patients were not included until drainage lasted >1 week, which only occurred in 20 out of 118 patients in the early cohort and 4 out of 45 patients in the late cohort (personal communication).

Two additional studies analysed outcomes while utilising protocols in the management of all postoperative children with CHD who developed chylothorax at their respective institutions.[4,7] Beghetti et al[4] separated patients into several cohorts, and thus we only used the group with CHD with thoracic injury for comparison, which did not include patients with high venous pressures, including Fontan patients. Although these studies lacked pre-protocol measurements for comparison, their post-protocol median and mean chest tube utilisation were longer than our post-protocol results – median duration of 7 versus 18 days[7] and mean of 7 versus 20 days[4]. Thus, to our knowledge, the duration of chest tube utilisation we report following implementation of a protocol at our single institution is the shortest in the reported literature.

Although this study was not designed to demonstrate causality or association of the primary outcome with any given instruction in the protocol, we believe the greatest change in chest tube duration came from the ability to treat patients with high-output, persistent chylothorax more effectively and efficiently. Analysis of demographic and clinical data showed similar cohorts in regard to demographics, surgical procedure, and number of patients with high chest tube output. Despite these similarities, the pre-protocol cohort had 7 (35%) patients with chest tube duration of >10 days, and the post-protocol cohort had 2 (9%). In addition, chylothorax duration was probably decreased owing to shortening duration of therapies once a low-output state is achieved. Specific elements in the protocol that potentially influenced success include reduction in practice variability; initial trial of medium-chain triglyceride feeds; early but minimal use of nothing-by-mouth status and frequent evaluation for low- versus high-output treatment; shortened medium-chain triglyceride feed duration; and early progression to surgical intervention.

Improvements in outcomes have been shown through the standardisation of chylothorax management.[10] We similarly saw a reduction in practice variation with 81% compliance to the protocol. All post-protocol patients were appropriately classified as low or high output based upon chest tube output and subsequently reclassified in accordance with the protocol where applicable. The majority of patients were also managed based upon the guidelines of the protocol in regard to duration or medium-chain triglyceride feeds, duration of nothing-by-mouth, and timing of additional intervention. Deviations from our protocol included three patients with medium-chain triglyceride feed duration shortened from 4–6 weeks to 2 weeks owing to formula intolerance. The management of these patients was otherwise directed by the protocol; total chest tube days were 9, 4, and 4, respectively, and none had recurrence of chylothorax. After noting these feeding deviations and the lack of recurrence of chylothorax in these patients, medium-chain triglyceride feed duration was decreased to 4 weeks, resulting in 100% compliance

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and no increase in adverse events. The other protocol deviation came from a patient who received earlier use of octreotide and surgical intervention after only 5 days of nothing-by-mouth, based on surgeon concern for surgical damage to the thoracic duct. Chylothorax resolved within 24 hours of thoracic duct ligation, the patient had 10 total chest tube days, and chylothorax did not recur.

Medium-chain triglyceride feeds are used for chylothorax treatment because they are absorbed by intestinal cells and transported directly to the liver via the portal vein, thus bypassing the thoracic duct and minimising chylous leakage into the pleural space.[12,13] We postulated that some patients who initially present with high output would transition to a low-output state after medium-chain triglyceride feeds, thereby reducing the number of patients exposed to the more aggressive high-output treatments. Thus, we trial medium-chain triglyceride feeds for 24 hours before committing to a high- or low-output treatment arm. In contrast, other protocols prescribe moving directly to nothing-by-mouth for at least 7 days for any patient who presents with high output.[8,10] Our method reduced the number of patients in the high-output arm from 12 to 8, thus eliminating at least 12 nothing-by-mouth days across these four patients. The 12 days represent 29% of total potential and actual nothing-by-mouth days across all patients with high output at the time of diagnosis.

Once a patient entered the high-output treatment arm, they were immediately made nothing-by-mouth. In prior studies, nothing-by-mouth duration is 5–21 days before re-evaluation.[4,6–8,10,14] Despite earlier use, our cumulative nothing-by-mouth days were still much lower than prior studies with a median duration of 3 days compared with 6[10] and 7 days[14]. During protocol creation, the decision to shorten nothing-by-mouth duration was guided by an examination of a subset of pre-protocol high-output patients. We noticed that once a low-output state was achieved, eight of nine patients remained in the low-output state after initiation of feeds, regardless of nothing-by-mouth duration, which ranged from 1 to 17 days. The interval to re-evaluation of nothing-by-mouth status was later decreased from 3 days to daily, allowing earlier resumption of enteral nutrition using medium-chain triglyceride feeds. Of the post-protocol patients who were treated with nothing-by-mouth, none had chest tube output $\geqslant$10 ml/kg/day after the resumption of medium-chain triglyceride feeds.

Medium-chain triglyceride feed duration required to prevent recurrence of chylothorax has never been established and reported duration is typically 6 weeks.[6,7,10] However, as directed by our first protocol intervention, medium-chain triglyceride feed duration was decreased from 6 to 4 weeks without an increase in adverse effects. Shortening medium-chain triglyceride feed duration is clinically important as medium-chain triglyceride diets are deficient in nutritional factors present in regular diets and associated with poor weight gain.[3,15]

Another commonly used treatment for persistent chylothorax is octreotide; however, the evidence to support its use for chylothorax management is variable.[6,16,17] Therefore, we prescribed octreotide only for high-output patients who failed 6 days of nothing-by-mouth therapy. Octreotide use was limited to 3 days compared with prior protocols that advocated for 7–14 days before moving to surgical intervention.[6–8,10] No patient in our study had resolution of chylothorax while using octreotide.

Traditionally, medical management is utilised for at least 3–4 weeks before moving to invasive interventions to treat chylothorax.[4,6–8] However, studies indicate that for persistent high output, earlier surgical intervention is successful and carries a relatively low risk.[14,18] Therefore, similar to Yeh et al,[10] our protocol progresses to surgical intervention within 10 days of chylothorax diagnosis. We found this strategy to be successful in the three post-protocol patients that qualified for thoracic duct ligation or percutaneous intervention, with resolution of chylothorax within 24–48 hours. Waiting several more days or weeks could potentially allow chylothorax to resolve without an invasive intervention, but the patients would probably be subject to severe complications related to prolonged high-output drainage, including respiratory insufficiency, infection, poor nutrition and growth, thrombosis, and skin breakdown.[1–3]

Given that no patients in our pre-protocol cohort benefited from octreotide, percutaneous intervention, or thoracic duct ligation, compared with three post-protocol patients, it is plausible that these interventions contributed to our decreased chest tube utilisation. While the number of patients who benefited from these interventions is small, the advantage, as demonstrated by a decrease in maximum duration of chest tube utilisation from 44 to 13 days, is meaningful.

Another goal of protocol implementation was earlier detection of chylothorax. Although there was no change in time to diagnosis, our post-protocol time from surgery to chylothorax diagnosis is lower than other reports with a median of 4 versus 6–8.5 days.[6,10,14] We aim to achieve earlier diagnosis of chylothorax by establishing an objective detection algorithm based on volume of chest tube output rather than on the subjective judgement of pleural fluid appearance. To date, only five patients have used the algorithm without improvement in time to post-surgical diagnosis. The detection algorithm will continue to be refined as additional data are gathered, with plans to automate the testing process.

In addition, postoperative management practices exclusive of the chylothorax protocol content may also contribute to our decreased chest tube utilisation. Potential variables include chest tube removal patterns, central venous pressure management, and feeding practices.

Although our protocol recommends more aggressive chest tube removal at 3 ml/kg/12 hours compared with published recommendations of <2 ml/kg/hour,[6,7] actual practice at our centre demonstrated that removal occurred on average at 2 ml/kg/day (Table 2). It is unlikely that early removal was a significant factor for our decreased chest tube utilisation.

High central venous pressures are implicated as a factor in causing and/or prolonging chylothorax.[8] We found no difference in net fluid balance or milrinone use in the pre- and post-protocol cohorts, suggesting that neither intravascular fluid status as measured by fluid balance nor the lusitropic effects of milrinone[19] influenced the effectiveness of the protocol.

Chylothorax diagnosis typically occurs as feeding volumes increase, allowing for enough chyle to spill into the pleural space.[9] Although feeding practices were unchanged between our pre- and post-protocol cohorts, it is possible that our institution advances feedings more quickly, leading to earlier recognition.

Although we achieved our primary aim of decreasing the duration of chylothorax, we did not see a significant decrease in ICU or hospital lengths of stay or duration of mechanical ventilation. Although not statistically significant, we saw a meaningful decrease in hospital length of stay from 30 to 21 days, which equals 198 saved patient days. In comparison with Yeh et al, our post-protocol ICU length of stay is similar – our median of 10 versus theirs of 9 days[10] – and our hospital length of stay is 5 days shorter (17 versus 23 days[10]). Data from institutions

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participating in the Pediatric Cardiac Critical Care Consortium also demonstrate that patients with chylothorax had much higher median lengths of stay, with 17.8 ICU days and 30 hospital days.[2] In addition, we believe that patients with chylothorax are a medically complex population with many factors causing prolonged length of stay. In post-protocol patients, we noted that chest tubes were removed on average 3 days before transfer out of the ICU and 13 days before hospital discharge, indicating that chylothorax was probably not the primary reason for delayed transfer or discharge. Other potential factors that interplay with chylothorax and influence the length of stay include infections, prolonged respiratory insufficiency, and feeding issues. Future iterations will focus on these other comorbidities and aim to improve length of stay.

Limitations of this study include those inherent to quality improvement projects, such as the sequential nature of the pre- and post-protocol cohorts. Our sample size is small, which is expected with studying a relatively rare event, such as chylothorax, from a single institution. Diuretics are often thought to be an adjunct therapy in the treatment of chylothorax; however, we opted not to direct diuretic use in the protocol because of its interplay between so many other aspects of medical care, including cardiovascular stability, renal function, and feeding status. However, there was generally no change in the overall practice of diuretic use at our institution in the study period, and all pre- and post-protocol patients were managed on diuretics at least through removal of chest tubes. Unfortunately, we could not collect central venous pressure data, as many of the studied patients did not have central lines at the time of chylothorax diagnosis. Although we did not specifically measure central venous pressure or the dosage of diuretics, we did measure daily fluid balance, which is the intended outcome of these variables, and found it to be similar in both cohorts. In addition, we did not delineate the likely aetiology of chylothorax, although we do suggest obtaining head/neck ultrasounds and echocardiograms in patients with high output to investigate for the presence of thrombi and to estimate right heart pressures by doppler. Finally, this protocol excludes patients with congenital chylothorax or who have undergone a Fontan operation, as these patients are prone to develop chylothoraces in isolation from surgical procedures.

Conclusions

Our chylothorax management protocol is associated with shorter duration of chest tube utilisation and prescribes reduced duration of nothing-by-mouth status and medium-chain triglyceride feeds compared with prior protocols without an increase in chylothorax recurrence. Further research is required to determine generalisability to other centres and patient populations.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/S1047951118000392

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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.
2. Buckley J, 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: 1–8.
3. 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 Enteral Nutr 2016; 40: 543–551.
4. Beghetti M, La Scala G, Belli D, et al. Etiology and management of pediatric chylothorax. J Pediatr 2000; 136: 653–658.
5. Biewer ES, Zurn C, Arnold R, et al. Chylothorax after surgery on congenital heart disease in newborns and infants – risk factors and efficacy of MCT-diet. J Card Surg 2010; 5: 127–133.
6. Chan EH, Russell JL, Williams WG, et al. Postoperative chylothorax after cardiothoracic surgery in children. Ann Thorac Surg 2005; 80: 1864–1871.
7. Milonakis M, Chatzis AC, Giannopoulos NM, et al. Etiology and management of chylothorax following pediatric heart surgery. J Card Surg 2009; 24: 369–373.
8. Panthongviriyakul C, Bines JE. Post-operative chylothorax in children: an evidence-based management algorithm. J Paediatr Child Health 2008; 44: 716–721.
9. Tutor J. Chylothorax in infants and children. Pediatrics 2014; 133: 722–733.
10. 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.
11. Day T, Zannino D, Golshevsky D, et al. Chylothorax following paediatric cardiac surgery: a case-control study. Cardiol Young 2017; 28: 1–7.
12. Ismail SR, Kabbani MS, Najm HK, et al. Impact of chylothorax on the early post operative outcome after pediatric cardiovascular surgery. J Saudi Heart Assoc 2014; 26: 87–92.
13. McCray S, Parrish CR. Nutritional management of chyle leaks: an update. Pract Gastr 2011; 94: 12–32.
14. Nath DS, Savla J, Khemani RG, et al. Thoracic duct ligation for persistent chylothorax after pediatric cardiothoracic surgery. Ann Thorac Surg 2009; 88: 246–251.
15. 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.
16. Caverly L, Rausch CM, da Cruz E, Kaufman J. Octreotide treatment of chylothorax in pediatric patients following cardiothoracic surgery. Congenit Heart Dis 2010; 5: 573–578.
17. White SC, Seckeler MD, McCulloch MA, et al. Patients with single ventricle anatomy may respond better to octreotide therapy for chylothorax after congenital heart surgery. J Card Surg 2014; 29: 259–264.
18. Matsuo S, Takahashi G, Konishi A, et al. Management of refractory chylothorax after pediatric cardiovascular surgery. Pediatr Cardiol 2013; 34: 1094–1099.
19. Chang AC, Atz AM, Wernovsky G, et al. Milrinone: systemic and pulmonary hemodynamic effects in neonates after cardiac surgery. Crit Care Med 1995; 23: 1907–1914.

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