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Research Article

Effect of Postoperative Medium-Chain Triglyceride Diet Management in Lung Cancer Patients: A Randomized Controlled Trial

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Objective: Lung cancer surgery can lead to postoperative complications such as pleural effusion and chylothorax. This study aims to investigate the impact of a medium-chain triglyceride (MCT) diet on recovery and complications in lung cancer patients.
Methods: This randomized controlled trial enrolled lung cancer patients at the Ningbo University First Affiliated Hospital between February 2022 and December 2023. Participants were randomly assigned to either the MCT group or the routine diet group. The MCT group received an MCT diet from the first to the third day postoperatively and resumed a normal diet thereafter. The RD group received a staple regular diet with no restrictions. The primary outcome was chylothorax incidence within 72 h. The secondary outcomes included the pleural effusion volume, protein, triglycerides, and mononuclear cells in pleural effusion at 24 h and 48 h postoperatively.
Results: A total of 127 patients (46 males) were enrolled, with 57 (mean age 54.91 ± 11.21 years, 21 males) receiving MCT and 70 (mean age 56.54 ± 11.84 years, 25 males) receiving RD. No chylothorax cases were observed in either group at 72 h. At 48 h, the MCT group had significantly lower pleural effusion volume (123.07 vs. 166.79 mL, $p = 0.006$), protein concentration (33.64 vs. 36.34 g/L, $p = 0.007$), and triglyceride levels (0.43 vs. 0.63 mmol/L, $p = 0.001$) compared to the RD group. No significant differences were observed in mononuclear cell counts between the two groups, but significant differences in mononuclear cell counts ($p = 0.04$) were observed at 24 h and 48 h in the MCT group, while no significant differences were observed in the RD group.
Conclusion: The MCT diet reduced protein and triglyceride levels in pleural fluid and decreased pleural effusion volume after 48 h. While no cases of chylothorax were noted, MCT dietary modifications may enhance postoperative recovery in lung cancer patients.

Trial Registration: Chinese Clinical Trial Registry: ChiCTR2400089381

Keywords: lung neoplasms; medium-chain triglycerides; pleural effusion

1. Introduction

Lung cancer, the most prevalent malignant tumor in China, has seen its incidence and mortality rates continuously rising, which reflects a growing public health concern [1]. Surgical treatment remains the standard of care for patients with non–small-cell lung cancer as outlined in the Chinese Expert Consensus on Multidisciplinary Minimally Invasive Diagnosis and Treatment of Pulmonary Nodules (2023 Edition) [2]. During lung cancer surgery, lymphatic vessel damage often occurs secondary to the required sampling and dissection of mediastinal masses and hilar lymph nodes. This frequently leads to lymphatic leakage postoperatively, increased thoracic drainage volume, chylothorax progression, and prolonged duration of chest tube placement [3, 4]. Therefore, postoperative management plans that reduce pleural drainage and shorten the duration of catheter placement are essential for promoting rapid recovery in

thoracic surgery. These strategies not only help minimize postoperative complications but also alleviate the economic burden on patients and healthcare systems.

Among various approaches, dietary management plays an important role in enhancing recovery, with nutritional status and tailored dietary plans being crucial in preventing complications such as chylothorax, supporting overall health, and improving treatment outcomes [5]. The dietary plan of many postoperative lung cancer patients remains relatively unstructured with a focus on high-fat and high-protein foods in order to meet their nutritional and caloric demands. However, studies have demonstrated that high-fat and high-protein diets contribute to chylothorax development and an increase in pleural drainage volume [6]. Medium-chain triglycerides (MCTs) are absorbed through the intestines and enter the portal vein system directly without entering the lymphatic circulation, thus not increasing lymphatic pressure. Dietary management plans including dietary modification with low-fat diets supplemented with MCT reduce chyle production and thoracic duct flow, thereby reducing chylothorax incidence, and are therefore commonly used as a mitigating precaution [7]. These findings underscore the importance of nutritional intake postoperatively in order to prevent chylothorax complications and optimize recovery.

It was hypothesized that MCT diet management could improve chylothorax incidence within 72 h in lung cancer patients compared with a staple regular diet with no restrictions. This study aims to explore the effects of MCT diet management in lung cancer patients.

2. Materials and Methods

2.1. Study Design and Participants. This randomized controlled study enrolled participants at the Thoracic Surgery Department of Ningbo University First Affiliated Hospital from February 2022 to December 2023. Approval was obtained from the Ethics Committee of The First Affiliated Hospital of Ningbo University (Ethics approval number: 2021-R124), and all participants signed informed consent forms.

Inclusion criteria included 1) age 19–75 years; 2) pathologically diagnosed with primary lung cancer; 3) surgical procedure was thoracoscopic segmentectomy (single segment), lobectomy (single lobe) + mediastinal lymph node dissection; and 4) complete clinical data and signed informed consent. Exclusion criteria included 1) neoadjuvant therapy before surgery; 2) use of antithrombotic or antiplatelet drugs for more than 3 weeks before surgery, or coagulation dysfunction; 3) presence of pleural adhesions or confirmed injury to the thoracic duct requiring ligation during surgery; 4) massive bleeding or conversion to open surgery during surgery; and 5) other conditions deemed unsuitable for inclusion in the study by the researchers.

2.2. Randomization. Participants were randomly assigned to the MCT or RD group in a 1:1 ratio using simple randomization. An independent research nurse generated 200 random numbers (0 = RD, 1 = MCT) with Microsoft Excel 2019, without blocking or stratification. Each number was printed, sealed in an opaque envelope labeled with a consecutive number, and stored securely. After providing informed consent, each participant drew the next envelope in sequence. Surgeons and attending physicians were blinded to group allocation.

2.3. Interventions. RD group: 4 h postoperatively, patients can orally take an appropriate amount of warm water when they are conscious, and if there is no nausea or vomiting, they can have a small amount of liquid diet at 6–8 h postoperatively. A normal diet can be resumed on the first postoperative day.

MCT group: 4 h postoperatively, patients may drink 100 mL of warm water once conscious. If neither nausea nor vomiting is present, patients are permitted to ingest 250 mL of a liquid diet 6–8 h following the operation. From postoperative days 1–3, patients should follow the MCT diet prescribed by the nutrition department, with water and fruit permitted. No other foods could be consumed during this period. A normal diet may be resumed on the fourth postoperative day. The main composition of MCT foods was as follows: On the first day, the staple food was mainly semiliquid, which is easy for patients to digest: total energy: 1500 kcal, protein: 51 g (14%), fat: 34 g (20%, including 22 g of fat from coconut oil), and carbohydrates: 249 g (65%). On the second day, the staple food was mainly soft food: total energy: 1500 kcal, protein: 57 g (15%), fat: 33 g (20%, including 22 g of fat from coconut oil), and carbohydrates: 244 g (65%). On the third day, the staple food was regular food: total energy: 1500 kcal, protein: 55 g (15%), fat: 33 g (20%, including 21 g of fat from coconut oil), and carbohydrates: 247 g (65%).

2.4. Outcomes. The primary outcome was chylothorax incidence within 72 h. The secondary outcomes included the pleural effusion volume, protein, triglycerides, and mononuclear cells in pleural effusion at 24 h and 48 h postoperatively. The 24-h pleural effusion volume represents the total drainage collected within the first 24 h after surgery, whereas the 48-h value reflects the drainage volume collected during the subsequent 24–48-h period. The 24-h and 48-h data represent measurements taken at 24 and 48 h postoperatively, respectively. Mononuclear cell counts in pleural effusion were measured using the body fluid analysis mode of the Mindray BC-6800Plus automated hematology analyzer (Mindray, Shenzhen, China) with manufacturer-provided reagents.

Diagnostic criteria for chylothorax were that the triglyceride level in the pleural effusion is > 110 mg/dL and the daily drainage volume is greater than 500 mL. The pleural effusion volume was evaluated from the placement to the removal of the thoracic drainage tube. The triglyceride, protein, and mononuclear cells in the pleural effusion were measured using biochemical examination.

2.5. Statistical Analysis. Statistical analysis was conducted using SPSS 22.0 (IBM Corporation, Armonk, NY, USA). The continuous data were described using means ± standard

deviations and analyzed using the *t*-test or Mann–Whitney *U* test. Categorical data were presented as *n* (%) and analyzed using the chi-squared test or Fisher's exact test. Two-sided *P* values < 0.05 were considered statistically significant.

3. Results

3.1. Characteristics of the Participants. A total of 185 consecutive patients who underwent curative lung cancer surgery at the Department of Thoracic Surgery, the First Affiliated Hospital of Ningbo University, between February 2022 and December 2023, were initially screened for eligibility. Of these, 58 did not meet the inclusion criteria, and 35 were unavailable for inclusion due to logistical reasons (24 operations finished after hospital cafeteria service hours and 11 during night shifts when no research nurse was available). The remaining 127 eligible patients were enrolled and randomized, with 57 assigned to the MCT group and 70 to the RD group (Figure 1). The mean age was comparable between the MCT and RD groups (54.91 ± 11.21 vs. 56.54 ± 11.84, $p = 0.324$). Gender distribution was similar between the two groups, with 21 (36.8%) males and 36 (63.2%) females in the MCT group, and 25 (35.7%) males and 45 (64.3%) females in the RD group ($p = 0.895$). Smoking status also did not differ significantly (12 vs. 10, $p = 0.316$), as was BMI (23.26 ± 2.29 vs. 23.54 ± 2.88, $p = 0.589$). The majority of patients had junior high school education or below (78.9% vs. 74.3%), with no significant difference across education levels ($p = 0.315$). Occupational distribution was comparable ($p = 0.544$), with retirees constituting the largest group in both MCT (35.1%) and RD (41.4%) groups. Regarding medical history, no significant differences were found in the prevalence of various preexisting diseases ($p = 0.313$), including hypertension (13 vs. 20), diabetes (2 vs. 7), hypertriglyceridemia (4 vs. 2), gout (1 vs. 0), hepatitis B infection (1 vs. 1), and cardiac conditions (0 vs. 2). Preoperative serum triglyceride levels were also comparable between groups (1.46 ± 0.70 vs. 1.37 ± 0.78, $p = 0.439$). Surgical approaches were similar ($p = 0.819$), with the majority undergoing lobectomy (38 vs. 48) and the rest of the participants undergoing segmentectomy (19 vs. 22). Tumor staging was comparable ($p = 0.885$), with most patients presenting with Stage I disease (48 vs. 60) and a smaller proportion in Stages II (2 vs. 4) and III (3 vs. 3). Only one patient in the MCT group was diagnosed with Stage IV disease (Table 1).

3.2. Outcomes. There was no occurrence of chylothorax in the two groups at 72 h. The total pleural effusion volume at 24 h showed no significant difference between the MCT and RD groups (92.19 ± 77.58 vs. 122.00 ± 101.12 mL, $p = 0.097$), whereas at 48 h, the volume was significantly lower in the MCT group compared to the RD group (123.07 ± 81.43 vs. 166.79 ± 97.40 mL, $p = 0.006$). Regarding pleural effusion protein levels, no significant difference was observed at 24 h between the MCT and RD groups (37.25 ± 5.37 vs. 39.65 ± 8.06 g/L, $p = 0.059$); however, at 48 h, the protein concentration was significantly lower in the MCT group (33.64 ± 5.56 vs. 36.34 ± 5.07 g/L, $p = 0.007$). Similarly, triglyceride levels at 24 h showed no significant difference between the groups (0.65 ± 0.29 vs. 0.69 ± 0.47 mmol/L, $p = 0.749$) but were significantly lower in the MCT group at 48 h (0.43 ± 0.29 vs. 0.63 ± 0.42 mmol/L, $p = 0.001$). Mononuclear cell counts in pleural effusion at 24 h were comparable between the MCT and RD groups (2339.00 ± 2350.53 vs. 2466.56 ± 4909.19 10^6/L, $p = 0.072$), as were the counts at 48 h (1212.74 ± 1655.84 vs. 1291.63 ± 2339.26 10^6/L, $p = 0.327$) (Table 2, Figures 2 and 3).

4. Discussion

These results demonstrated that though there was no occurrence of chylothorax in the two groups, patients in the MCT group exhibited significantly lower pleural effusion volume, protein concentration, and triglyceride levels at 48 h postoperatively compared to the RD group. These results suggest that implementing an MCT diet may enhance postoperative recovery of lung cancer patients and alleviate the healthcare burden associated with thoracic surgery.

Excessive drainage can prolong chest tube placement, delay recovery, and raise complication risks [8]. Thus, reducing chyle formation and pleural effusion is crucial for improving postoperative outcomes, yet no clear consensus exists on dietary management to prevent chylothorax [9]. A diet primarily based on MCT has the potential to be the new strategy for improving lung cancer patient outcomes. Due to their small molecular size, MCTs are directly absorbed through the portal vein without passing through the lymphatic system [10]. In contrast, long-chain triglycerides (LCTs) in a regular diet are absorbed through intestinal lymphatic transport as chylomicrons, which enter the thoracic duct before reaching the systemic circulation. This process increases lymphatic flow and triglyceride concentration within the lymph, thereby elevating the risk of lymphatic leakage or chylothorax formation after thoracic surgery [6]. This unique absorption pathway can reduce fat loss and drainage fluid production due to lymphatic fistula in surgical patients [11], thereby reducing lymphatic leakage. Adopting an MCT diet has also been previously found to affect chyle composition by reducing the triglyceride and protein content [12]. Decreasing fatty acid consumption by implementing an MCT diet can meet the patient's nutritional demands while simultaneously decreasing chyle production by approximately 10-fold and subsequent chylothorax formation [13]. Our study's primary outcome revealed no occurrences of chylothorax in either the MCT diet group or the RD group. This result is understandable given the relatively low incidence of postoperative chylothorax, which has been reported recently to range from 0.25% to 3% after pulmonary resection and lymph node dissection [14]. Regarding the efficacy of MCT diets in previous studies, Biewer et al. reported that an MCT-based diet successfully managed chylothorax in 71% of pediatric patients undergoing thoracic surgery [15]. Wang et al. conducted an analysis of 63 patients and reported the MCT diet to be an effective conservative measure in up to 90% of patients in preventing and managing chylothorax formation [9]. Further large-scale, multicenter studies are warranted to

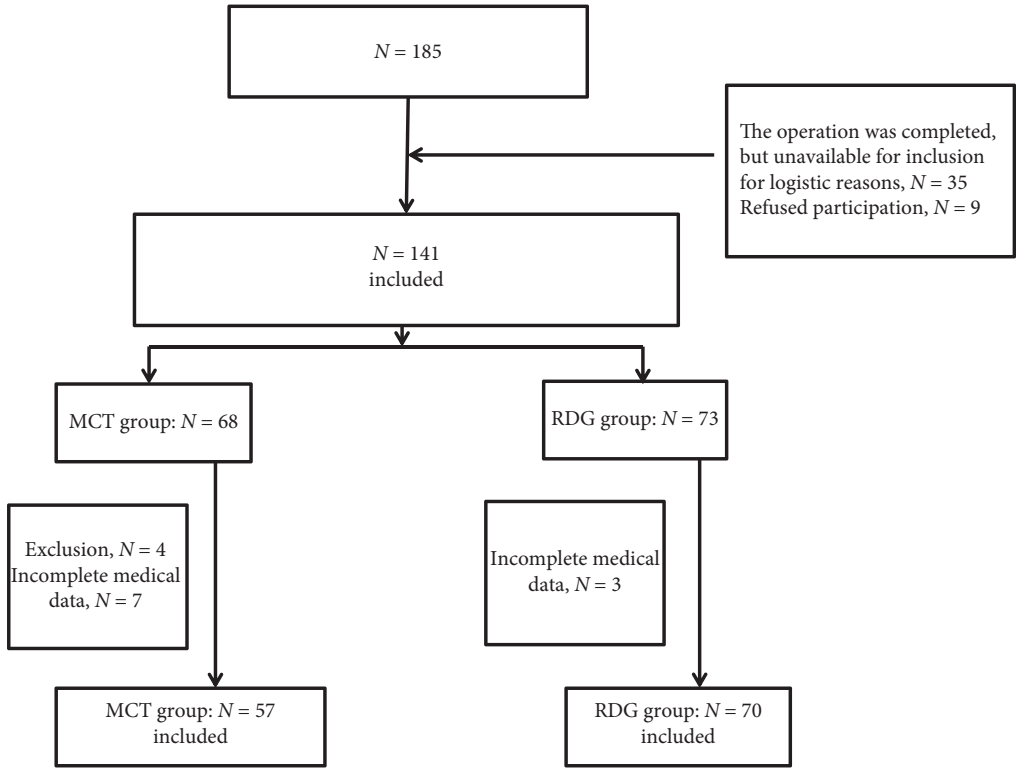

Figure 1: Flowchart of the screening research population.

confirm these findings and explore the preventive potential of dietary interventions on postoperative chylothorax in our cohort.

The secondary outcomes of this study align with previous literature demonstrating the role of an MCT diet in reducing pleural fluid volume, lowering protein concentration, and decreasing triglyceride levels, all of which contribute to the prevention of chylothorax formation [9, 10, 13, 15, 16]. The results of this study are consistent with previous literature regarding the role of the MCT diet in reducing pleural fluid drainage volume. Biewer et al. [15] demonstrated that the MCT diet effectively reduced pleural drainage in pediatric patients with postoperative chylothorax, with successfully treated patients showing significantly lower median daily drainage volumes (40 mL/kg/day) compared to those in whom the MCT diet was unsuccessful (119 mL/kg/day). Bryant et al. [16] reported a 90% success rate in chylothorax management with an MCT diet after pulmonary resections, with patients' chest tube outputs decreasing to under 450 mL/day within 48 h. Zhang et al. focused on the metabolic benefits of MCT in nonsurgical contexts but acknowledged its efficacy in reducing lipid absorption and improving recovery times, consistent with the findings of the present study [10]. While the current study only observed one case of chylothorax, the reduction in pleural fluid production parallels these studies, highlighting the preventive potential of MCT diets in thoracic surgical patients. Du et al. conducted a prospective randomized study on 117 lung cancer patients who underwent anatomic resection and found that patients on an MCT diet experienced shorter chest tube drainage times and reduced drainage volumes compared to those on standard diets [17]. Another recent case report demonstrated complete resolution of chylous pleural effusion within 3 months of initiating a ketogenic diet, which is high in MCTs [18].

Interestingly, while no significant differences were seen at 24 h postoperatively, by 48 h, almost all parameters improved in the MCT group. This suggests that the benefits of MCT in reducing lymphatic leakage take time to emerge. Although MCTs are rapidly absorbed and transported directly to the liver via the portal vein, bypassing the lymphatic circulation [19], their delayed impact on reducing lymphatic leakage may be attributed to postoperative physiological adjustments. Early in the recovery phase, residual chylous effusion from prior LCT intake and surgical trauma may mask the effects of MCTs. In addition, inflammatory responses and fluid shifts after surgery could temporarily increase vascular permeability [20], delaying the measurable benefits of an MCT-based diet. As the acute phase subsides and lymphatic demand gradually decreases, the reduction in lymphatic flow and protein leakage becomes more evident, which could explain the observed improvement at 48 h rather than immediately postoperatively. There were significant differences in mononuclear cell counts at 24 h and 48 h, and the number of mononuclear cells in pleural effusion at 48 h was significantly less than that at 24 h in the MCT group. The dynamic changes in the number of mononuclear cells in pleural effusion can serve as an indicator reflecting the changes in the postoperative inflammation [21]. If the number of mononuclear cells in pleural effusion does not decrease continuously or

Table 1: Baseline characteristics.

	RD group ($N = 70$)	MCT group ($N = 57$)	P
Age (years)	56.54 ± 11.84	54.91 ± 11.21	0.324
Gender			
Male	25 (35.7%)	21 (36.8%)	0.895
Female	45 (64.3%)	36 (63.1%)	
Smoking			
Yes	10 (14.3%)	12 (21.1%)	0.316
No	60 (85.7%)	45 (78.9%)	
Education			0.315
Junior high school and below	52 (74.3%)	45 (78.9%)	
Senior high school	9 (12.9%)	3 (5.3%)	
College and above	9 (12.9%)	9 (15.8%)	
Occupation			0.544
Farmer	5 (7.1%)	6 (10.5%)	
Worker	6 (8.6%)	6 (10.5%)	
Retiree	29 (41.4%)	20 (35.1%)	
Staff	12 (17.1%)	11 (19.3%)	
Self-employed	17 (24.3%)	13 (22.8%)	
Others	1 (1.4%)	1 (1.7%)	
Medical history			0.313
Hypertension	20 (28.6%)	13 (22.8%)	
Diabetes	7 (10.0%)	2 (3.5%)	
Cardiology	2 (2.9%)	0 (0%)	
Hypertriglyceridemia	2 (2.9%)	4 (7.0%)	
Gout	0 (0%)	1 (1.8%)	
Hepatitis B infection	1 (1.4%)	1 (1.8%)	
BMI	23.54 ± 2.88	23.26 ± 2.29	0.589
Surgical types			
Segmentectomy	22 (31.4%)	19 (33.3%)	0.819
Lobectomy	48 (68.6%)	38 (66.7%)	
Staging of tumors			
Carcinoma in situ	3 (4.3%)	3 (5.3%)	
I	60 (85.7%)	48 (84.2%)	
II	4 (5.7%)	2 (3.5%)	0.885
III	3 (4.3%)	3 (5.3%)	
IV	0 (0%)	1 (1.8%)	
Preoperative serum triglycerides (mmol/L)	1.37 ± 0.78	1.46 ± 0.70	0.439

Table 2: Outcomes in the two groups.

		RD group ($N = 70$)	MCT group ($N = 57$)	P
Primary outcome				
72 h	Chylothorax incidence	0	0	> 0.999
Secondary outcome				
24 h	Pleural effusion volume (mL)	122.00 ± 101.12	92.19 ± 77.58	0.097
	Protein in pleural effusion(g/L)	39.65 ± 8.06	37.25 ± 5.37	0.059
	Triglycerides in pleural effusion (mmol/L)	0.69 ± 0.47	0.65 ± 0.29	0.749
	Mononuclear cells in pleural effusion(10^6/L)	2466.56 ± 4909.19	2339.00 ± 2350.53	0.072
48 h	Pleural effusion volume (mL)	166.79 ± 97.40*	123.07 ± 81.43*	**0.006**
	Protein in pleural effusion(g/L)	36.34 ± 5.07*	33.64 ± 5.56*	**0.007**
	Triglycerides in pleural effusion (mmol/L)	0.63 ± 0.42	0.43 ± 0.29*	**0.001**
	Mononuclear cells in pleural effusion(10^6/L)	1291.6 3 ± 2339.26	1212.74 ± 1655.84*	0.327

Note: The bold values are p values (0.001, 0.007, 0.006) from intergroup comparisons between the MCT group and RD group. All these p values are less than 0.05, indicating statistically significant differences in the corresponding indicators between the two groups.

*$p < 0.05$ for intragroup comparison (24 h vs. 48 h) within the same treatment group.

P values in the last column represent intergroup comparisons between the MCT and RD groups.

even increases instead, it may suggest the presence of an infection, persistent inflammatory stimulation in the thoracic cavity, or other complications [21, 22]. These findings emphasize the importance of monitoring nutritional interventions beyond the first 24 h to fully assess their impact on postoperative recovery.

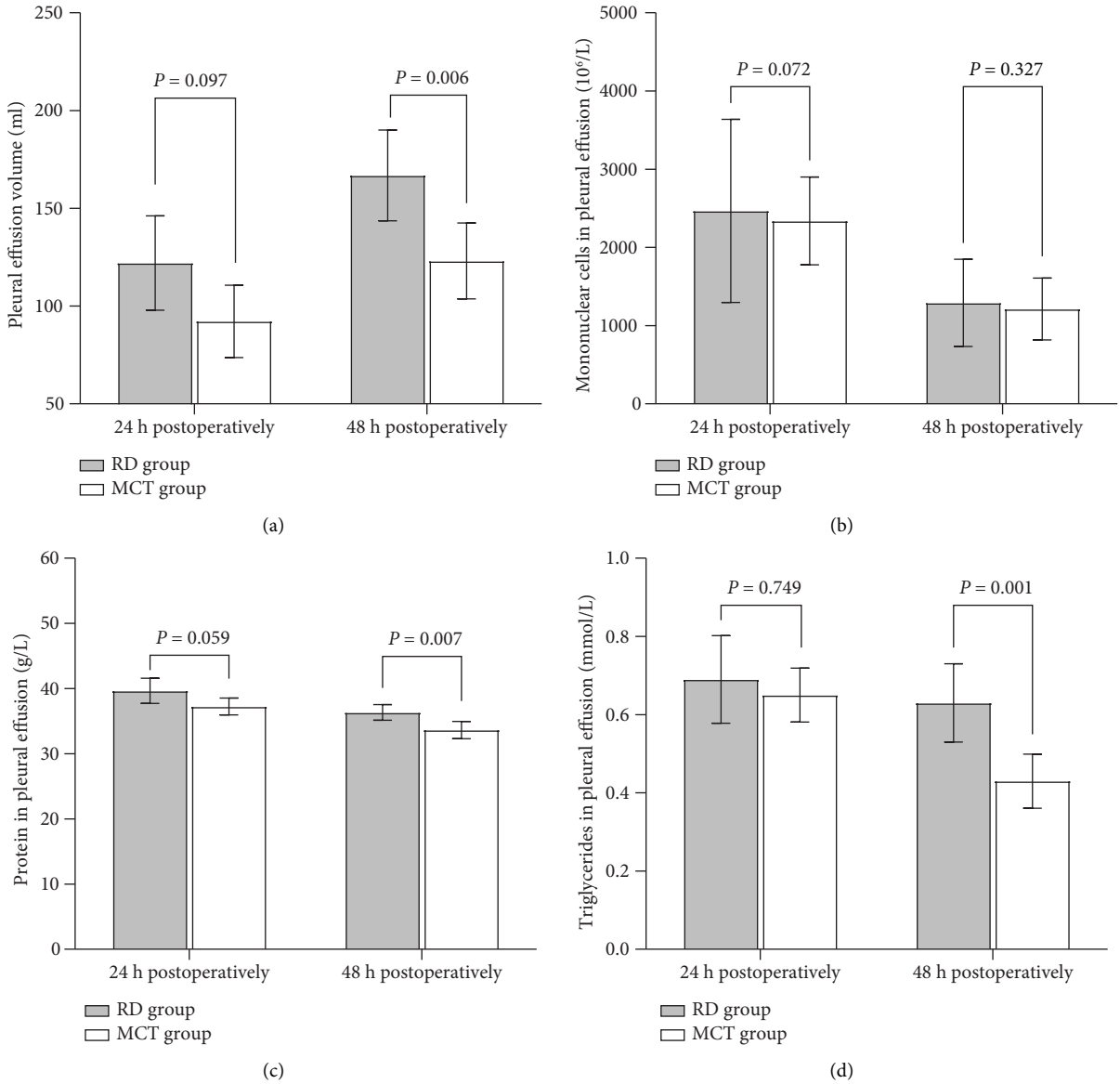

Figure 2: Outcomes between the MCT group and the RD group. (a) Pleural effusion volume. (b) Mononuclear cells in pleural effusion. (c) Protein in pleural effusion. (d) Triglycerides in pleural effusion.

Our findings of significantly reduced pleural effusion volume at 48 h support the efficacy of this intervention approach. However, there remains a notable lack in the literature regarding the duration of the MCT diet implementation and the effect on clinical outcomes [23, 24]. Due to the limitation of the study design, the efficacy of various durations was not explored and is an area for future research.

5. Limitations

This study has several limitations. Firstly, this study is a single-center study with a relatively small sample size; as a result, the risk of selection bias exists, which may limit the generalizability of the findings. Secondly, due to funding constraints, a more detailed analysis of the lymphatic components in pleural effusion was not conducted. Lastly, this study lacks long-term follow-up to evaluate the sustained effects of the MCT diet and potential delayed complications. In addition, some key indicators of postoperative recovery, such as length of hospital stay, pain score, and nutritional parameters, were not systematically recorded, preventing a comprehensive assessment of overall recovery. Moreover, gastrointestinal adverse events (e.g., diarrhea or nausea) potentially associated with the MCT diet were not monitored. Further study should be conducted to compare the MCT diet with other dietary interventions and assess the effect of varying the duration of dietary management on postoperative outcomes. Future research with larger,

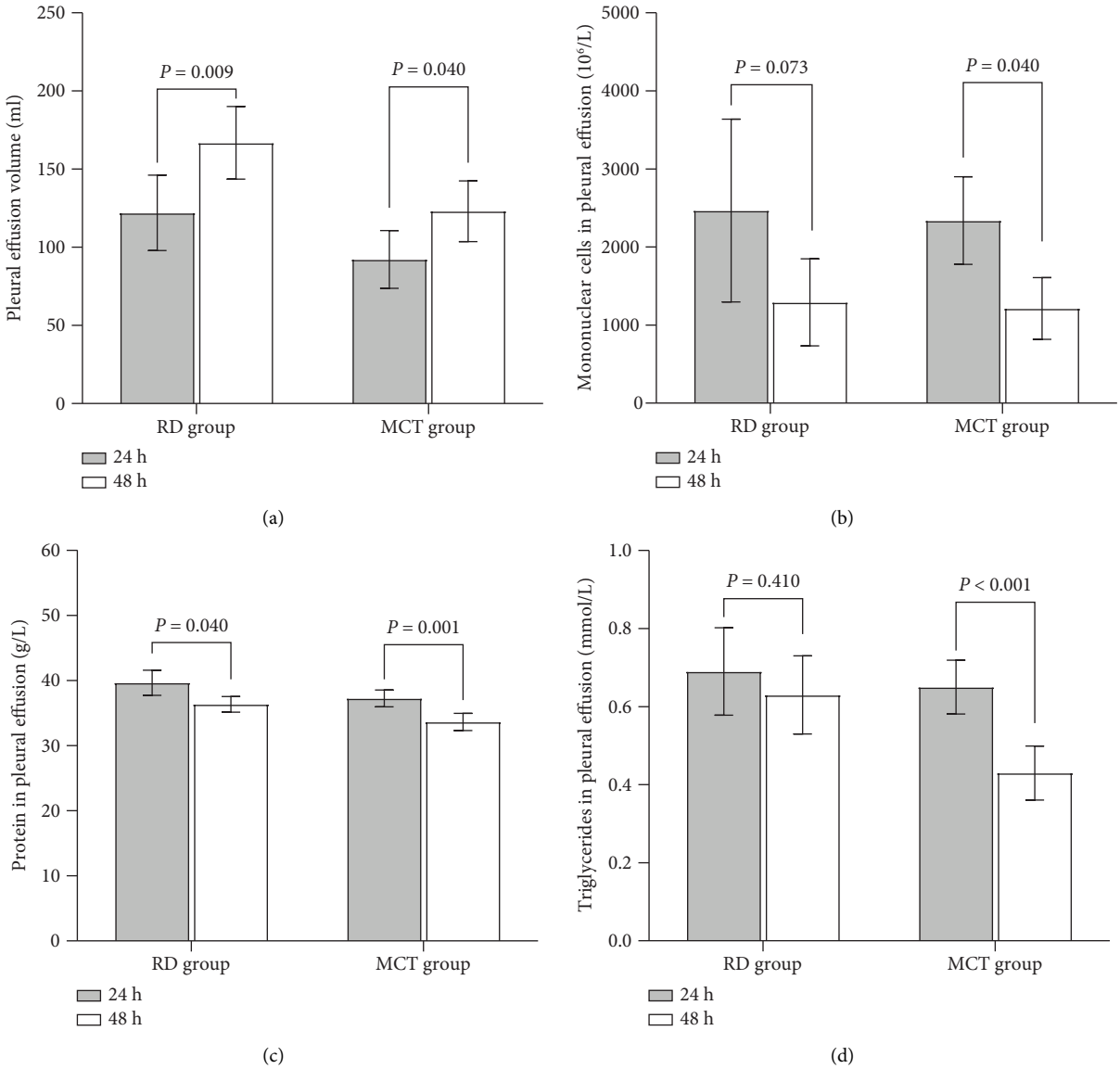

Figure 3: Outcomes between 24 h and 48 h. (a) Pleural effusion volume. (b) Mononuclear cells in pleural effusion. (c) Protein in pleural effusion. (d) Triglycerides in pleural effusion.

multicenter cohorts and longer follow-up periods is warranted to validate these results and explore the broader applicability of dietary strategies in this patient population.

6. Conclusion

Although no cases of chylothorax were observed in this study, postoperative management with an MCT diet was associated with a significant reduction in pleural effusion volume, as well as decreased protein and triglyceride content in the pleural fluid. Adopting an MCT diet may help minimize protein loss, reduce pleural drainage volume, and potentially enhance postoperative recovery. Larger-scale, multicenter studies with longer follow-up are necessary to validate these results and determine their broader applicability in clinical practice.

Data Availability Statement

All data generated or analyzed during this study are included in this published article.

Ethics Statement

This randomized controlled study enrolled participants at the Thoracic Surgery Department of Ningbo University First Affiliated Hospital from February 2022 to December 2023. Approval was obtained from the Ethics Committee of The First Affiliated Hospital of Ningbo University (Ethics approval number: 2021-R124), and all participants signed informed consent forms. I confirm that all methods were performed in accordance with the relevant guidelines. All procedures were performed in accordance with the ethical

standards laid down in the 1964 Declaration of Helsinki and its later amendments.

Consent

Please see the Ethics Statement.

Disclosure

All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

Author Contributions

Xiao Jia and Dini Cao carried out the studies and participated in collecting data, and Xiao Jia drafted the manuscript. Xiao Jia and Zhigang Liang performed the statistical analysis and participated in its design. Xiao Jia and Longfei Wang participated in the acquisition, analysis, or interpretation of data and drafted the manuscript.

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The authors have nothing to report.

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