



# Effectiveness, Compliance, and Acceptability of Preoperative Weight Loss with a Liquid Very Low-Calorie Diet Before Bariatric Surgery in Real Practice

Kamthorn Yolsuriyanwong<sup>1,2</sup> · Komdej Thanavachirasin<sup>1</sup> · Kimberly Sasso<sup>3</sup> · Lauren Zuro<sup>3</sup> · Jessica Bartfield<sup>1</sup> · Eric Marcotte<sup>1</sup> · Bipan Chand<sup>1</sup>

Published online: 20 August 2018

© Springer Science+Business Media, LLC, part of Springer Nature 2018

## Abstract

**Objective** A preoperative very low-calorie diet (VLCD) is a common method to reduce weight before bariatric surgery. However, patient compliance and acceptability are not always known. The aim of this study is to evaluate the effectiveness, compliance, and acceptability of our regimen in a metropolitan academic quaternary care center.

**Methods** Patients with a BMI < 50 kg/m<sup>2</sup> and a BMI ≥ 50 kg/m<sup>2</sup> were instructed to be on a liquid VLCD for 1 week and 2 weeks, respectively. The primary outcome was the amount of weight loss. Secondary outcomes were patient compliance and acceptability of either regimen using a questionnaire for hunger, satisfaction, desire, and deviation for solids.

**Results** The study included 128 patients. Ninety-four patients were in the BMI < 50 kg/m<sup>2</sup> group, and 34 patients were in the BMI ≥ 50 kg/m<sup>2</sup> group. The BMI ≥ 50 kg/m<sup>2</sup> group had a greater percentage of total weight loss (mean ± SD) than that of the BMI < 50 kg/m<sup>2</sup> group without statistical differences (4.4 ± 1.3% vs. 3.8 ± 1.6%, *p* = 0.072). There were no statistical differences between the groups in terms of hunger, satisfaction with a liquid diet, or satisfaction of eating over drinking. However, hunger sensation (median [IQR]) tended to be higher in the BMI < 50 kg/m<sup>2</sup> group than that in the BMI ≥ 50 kg/m<sup>2</sup> group (2 [2] vs. 2 [2, 3]; *p* = 0.06). There was no statistical difference in the percentage of patient compliance between the groups (75.5% [*n* = 71] vs. 61.8% [*n* = 21], *p* = 0.18).

**Conclusions** Preoperative liquid VLCD provided a modest amount of weight loss and showed a high rate of patient compliance and acceptability.

**Keywords** Preoperative weight loss · Very low-calorie diet · Weight loss surgery · Bariatric surgery · Compliance · Acceptability · Hunger · Satisfaction

---

✉ Bipan Chand  
bchand@lumc.edu

Kamthorn Yolsuriyanwong  
kamthorn.y@psu.ac.th

Komdej Thanavachirasin  
theconductor@gmail.com

Kimberly Sasso  
ksasso@lumc.edu

Lauren Zuro  
lauren.zuro@luhs.org

Jessica Bartfield  
jbartfield@lumc.edu

Eric Marcotte  
eric.marcotte@lumc.edu

<sup>1</sup> Department of Surgery, Division of GI/Minimally Invasive Surgery, Loyola University Medical Center, Stritch School of Medicine, Maywood, IL, USA

<sup>2</sup> Department of Surgery, Faculty of Medicine, Songklanagarind Hospital, Prince of Songkla University, Songkhla, Thailand

<sup>3</sup> Loyola University Medical Center, Maywood, IL, USA

## Introduction

Obesity has become a serious health problem throughout the world. Over 650 million or an estimated 13% of the adult population were obese in 2016 [1]. Obesity carries a major risk factor for non-communicable diseases such as cardiovascular diseases, diabetes, musculoskeletal disorders, and some cancers. There are many methods to treat obesity including diet control, exercise, lifestyle modification, medications, endoscopic therapy, and surgery. Bariatric surgery is one of the most successful treatment options for morbidly obese people. Approximately 200,000 bariatric operations are performed annually in the USA [2]. Surgery has shown higher long-term weight loss and higher resolution of obesity-related conditions including sleep apnea, hypertension, diabetes, and other medical problems compared to all other methods of weight loss [3–7]. Prior to bariatric surgery, a preoperative weight loss regimen is conducted in most weight loss surgery centers. Even though there is no obvious evidence to support the benefits of any particular regimen [8, 9], preoperative weight loss may have some advantages including reduction in liver and intra-abdominal fat volume which may result in improvement of visibility during the procedure. This may lead to a reduction of intra- and postoperative complications [10–13] and sustained improved postoperative weight reduction [14]. However, an insurance-mandated preoperative weight loss program may lead to an unnecessary delay of treatment which can lead to progression of life-threatening comorbid conditions [15]. A preoperative very low-calorie diet (VLCD) is one method, in addition to preoperative lifestyle modification, to reduce weight before surgery and has shown some benefits on perioperative outcomes [10, 16]. VLCD is defined as a diet of 800 kcal/day or less. However, the type and duration of a VLCD vary across centers, and no standard regimen has been established. Also, some patients may not tolerate a particular VLCD regimen which can lead to poor compliance and poor weight loss. A study reported that patient compliance and tolerance were significantly better after a standard ordinary product compared to a commercial protein shake [17]. In our center, we used a liquid VLCD instead of a standard ordinary product. Patients with a body mass index (BMI) < 50 kg/m<sup>2</sup> were asked to take the VLCD for 1 week, and those with a BMI ≥ 50 kg/m<sup>2</sup> were asked to take the VLCD for 2 weeks. The aim of this study was to evaluate the effectiveness, compliance, and acceptability of our preoperative VLCD regime in a real practice setting.

## Materials and Methods

This study was performed at a metropolitan academic quaternary care center. Written informed consent was obtained from every patient. We prospectively collected and reviewed the

patients' data from October 2016 to September 2017. All patients were screened by a multidisciplinary team consisting of an internist, a nurse practitioner, dietician, psychologist, and surgeon as to whether they were suitable for bariatric surgery. The inclusion criteria were patients aged 18 years or older, a BMI ≥ 40 or ≥ 35 kg/m<sup>2</sup> with at least two obesity-related comorbidities. Patients were excluded if they had uncontrolled psychiatric illness, drug or alcohol addiction, serious cardiopulmonary disease, a contradiction for surgery, malignancy, uncontrolled systemic infection, or debilitating disease. All patients received our standard preoperative care and counseling that included diet and exercise instructions, lifestyle modification, and preparation for surgery. During one of the preoperative counseling sessions with the attending surgeon, patients were asked to follow a preoperative VLCD using a commercial 800-kcal formula-balanced liquid diet of high protein content including Atkins shake (Atkins Nutritionals, Inc., Denver, CO, USA) or another product brand that had a similar nutrient composition. All patients who received our diet regimen obtained detailed diet instructions and the recommended daily vitamins, minerals, and trace elements by the dietitians. The patients were instructed to take five shakes per day which provided 800 kcal (75 g of protein, 45 g of fat, and 25 g of carbohydrate). If the patients wanted to eat more than our diet instructions, they were allowed to consume only one serving size per day of sugar-free fluid including sugar-free popsicles, sugar-free gelatin, or a cup of broth which contained 20 kcal or less per serving in order to reduce patient stress. Patients with a BMI < 50 kg/m<sup>2</sup> were instructed to be on the VLCD for 1 week before surgery, and those with a BMI ≥ 50 kg/m<sup>2</sup> were on the VLCD for 2 weeks.

## Evaluations

Patient variables were collected including age, gender, body weight (BW), and BMI at initial visit and before starting the VLCD course, the amount and percentage of total weight loss (%TWL) after taking the liquid VLCD, total weight loss after starting the preoperative weight loss program, and the number of actual days that patients had the liquid VLCD. Patient compliance and acceptability of the liquid VLCD were measured by a self-designed questionnaire including a four-question assessment. The consumption of solid food during the liquid VLCD course was included in this questionnaire (Table 1). The consumption of solid food was used as frequency instead of a “yes” or “no” answer in order to avoid patient bias. For example, patients who occasionally or rarely took solid food and were afraid of criticism tend to answer “no” more than “yes.” Therefore, answers of frequently, occasionally, and rarely were counted as a “yes” for solid food consumption. Patient compliance in this study was defined as consuming the diet as prescribed without taking any solid food and

**Table 1** Self-designed preoperative diet assessment and scoring

Assessment	Frequency (score 1–4)			
	Frequently	Occasionally	Rarely	Never
1. I felt hungry all the time while on the full liquid diet.	1	2	3	4
2. I felt satisfied after drinking my liquid diet.	4	3	2	1
3. I would have felt more satisfaction with eating than drinking.	1	2	3	4
4. I ate solid food while on the full liquid diet.	1	2	3	4

maintaining the liquid VLCD course for at least 1 week (BMI < 50 kg/m<sup>2</sup>) or at least 2 weeks (BMI ≥ 50 kg/m<sup>2</sup>). Patient satisfaction in the liquid VLCD was concluded as “satisfied” if they answered frequently and occasionally to this question and assumed as “unsatisfied” if answering others. The questionnaire was administered on the day of surgery.

### Statistical Analysis

Categorical variables were calculated and shown as frequencies (%), and continuous variables as mean and standard deviation (SD) or median and interquartile range (IQR). Chi-square test was used to compare the categorical variable frequencies between groups or, if having small expected frequencies, Fisher’s exact test was used. Unpaired *t* test or Wilcoxon rank-sum test was used to compare continuous data between groups. A multivariate logistic regression model was used to analyze the influent factors for patients who could lose ≥ 5% of total body weight from the VLCD course and patients who were satisfied in the liquid VLCD in each group. Variables used in the multivariate analyses included age, gender, BMI before starting the VLCD course, and product brand of the VLCD. The level of significance was set at *p* < 0.05. The statistical analysis was performed using R version 3.5.0 (Vienna, Austria).

## Results

### Demographic Data

One hundred and twenty-eight patients were included in this study. One hundred and six were female, and mean (SD) age was 45.6 (12.1) years (range 20–85). Mean (SD) BW and BMI before starting the VLCD were 129.5 (26.3) kg (range 77.9–199.8) and 46.5 (8.0) kg/m<sup>2</sup> (range 34.3–76.1), respectively. Atkins shake was used in 83.6% of patients.

Ninety-four patients were in the BMI < 50 kg/m<sup>2</sup> group, and 34 patients were in the BMI ≥ 50 kg/m<sup>2</sup> group. The patient characteristics at baseline before starting the VLCD course are summarized in Table 2. Some patients in both groups did not

consume the VLCD for the assigned number of days. In the BMI < 50 kg/m<sup>2</sup> group, 4 patients consumed the VLCD for less than 7 days (range 3–5), and 3 patients consumed the VLCD for more than 7 days (range 13–14). In the BMI ≥ 50 kg/m<sup>2</sup> group, 5 patients consumed the VLCD for less than 14 days (range 7–9), and 1 patient consumed the VLCD for 21 days.

In the group of BMI < 50 kg/m<sup>2</sup> patients who consumed the VLCD for less than 7 days (4 patients), one was because of an early surgical date, and no reasons were available for the other 3 patients. There was no recorded information on why the other 3 patients in the BMI < 50 kg/m<sup>2</sup> group consumed the VLCD for more than 7 days. In the group of BMI ≥ 50 kg/m<sup>2</sup> patients who consumed the VLCD for less than 14 days (5 patients), 1 patient said it was a holiday period, and regular food was consumed during that period, while the reasons for the other 4 patients were unknown. One patient in the BMI ≥ 50 kg/m<sup>2</sup> group consumed the VLCD for more than 14 days because the patient was super-super obese (BMI of 76.1 kg/m<sup>2</sup>) and was asked to continue for a longer duration of the VLCD.

### Weight Loss

Patients with a BMI ≥ 50 kg/m<sup>2</sup> lost significantly more weight than those with a BMI < 50 kg/m<sup>2</sup> and had a greater %TWL (mean ± SD) without statistical difference (4.4 ± 1.3% vs. 3.8 ± 1.6%, *p* = 0.072) (Table 2). Analysis after exclusion of the patients who did not follow the assigned days (excluding those on the VLCD less than 7 days and more than 7 days in the BMI < 50 kg/m<sup>2</sup> group and those who consumed the VLCD less than 14 days or more than 14 days in the BMI ≥ 50 kg/m<sup>2</sup> group) and ate a solid diet during the course showed significantly higher weight loss from the VLCD in the BMI ≥ 50 kg/m<sup>2</sup> group than that in the BMI < 50 kg/m<sup>2</sup> group (7.1 ± 2.2 vs. 4.8 ± 1.6 kg). However, there was still no statistical difference between the groups in terms of %TWL from the VLCD (4.5 ± 1.3 vs. 4.1 ± 1.4%, *p* = 0.228). The percentages of patients who lost ≥ 5% of total body weight from the VLCD course were 20.2% (19/94) in the BMI < 50 kg/m<sup>2</sup> group and 41.2% (14/34) in the BMI ≥ 50 kg/m<sup>2</sup> group.

**Table 2** Patient characteristics, weight loss, and diet assessment outcomes

	BMI < 50 kg/m <sup>2</sup> (n = 94)	BMI ≥ 50 kg/m <sup>2</sup> (n = 34)	p value
Demographic data			
Sex (M:F), n (%)	15:79 (16/84)	7:27 (21/79)	0.728
Age, mean (SD), year	45.7 (11.8)	45.3 (12.9)	0.863
BW before start VLCD, mean (SD), kg	118.4 (18.1)	160.3 (20.1)	< 0.001
BMI before start VLCD, mean (SD), kg/m <sup>2</sup>	42.7 (4.2)	57.2 (6)	< 0.001
Average days of VLCD, mean (SD), day	7.1 (1.4)	13.3 (2.6)	< 0.001
Weight loss outcomes, mean (SD)			
Weight loss after finished VLCD, kg	4.4 (1.8)	7 (2.3)	< 0.001
% Total weight loss after finished VLCD	3.8 (1.6)	4.4 (1.3)	0.072
Total weight loss from 1st visit to date of surgery, kg	7.9 (6.9)	15.3 (9)	< 0.001
Diet assessment, scores, median (IQR)			
Hunger	2 (2, 2)	2 (2, 3)	0.060
Satisfaction after a full liquid VLCD	3 (3, 4)	3 (3, 4)	0.899
Satisfaction with eating over drinking	2 (1, 3)	2 (1.2, 2.8)	0.631
Deviation with solid diets	4 (4, 4)	4 (3, 4)	0.544

M, male; F, female; BW, body weight; BMI, body mass index; VLCD, very low-calorie diet; SD, standard deviation; IQR, interquartile range

## Compliance and Acceptability

There was no statistical difference in the percentage of patients who consumed solid food during the VLCD course between the groups (24.5% vs. 29.4%). The percentage of patients who were able to maintain the minimum period of the liquid VLCD (at least 7 days and 14 days for the patients with a BMI < 50 kg/m<sup>2</sup> and ≥ 50 kg/m<sup>2</sup>, respectively) and did not consume any solid food during the course was higher in the BMI < 50 kg/m<sup>2</sup> group than that in the BMI ≥ 50 kg/m<sup>2</sup> group, without statistical difference (75.5% [*n* = 71] vs. 61.8% [*n* = 21], *p* = 0.18).

The percentages of patients who felt hungry frequently, occasionally, rarely, and never were 23.4%, 52.1%, 20.2%, and 4.3% in the BMI < 50 kg/m<sup>2</sup> group, respectively, and were 2.9%, 67.7%, 23.5%, and 5.9% in the BMI ≥ 50 kg/m<sup>2</sup> group, respectively. Satisfaction after a liquid VLCD in the BMI < 50 kg/m<sup>2</sup> and BMI ≥ 50 kg/m<sup>2</sup> groups was reported as frequently in 46.8% and 44.1%, occasionally in 41.5% and 47.1%, rarely in 7.4% and 5.9%, and never in 4.3% and 2.9%, respectively. In patients with a BMI < 50 kg/m<sup>2</sup>, the percentages of satisfaction with eating over drinking were frequently in 33%, occasionally in 40.4%, rarely in 17%, and never in 9.6%; while in those patients with a BMI ≥ 50 kg/m<sup>2</sup>, the percentages were 26.5%, 47.1%, 14.7%, and 11.7%, respectively.

Overall, patient satisfaction was 89% (114/128). The percentages of patients who were satisfied with the VLCD in the BMI < 50 kg/m<sup>2</sup> and BMI ≥ 50 kg/m<sup>2</sup> groups were 88.3% and 91.2%, respectively. In an analysis after excluding patients

who ate solid food, the percentages of satisfaction from the entire cohort, the BMI < 50 kg/m<sup>2</sup> group and the BMI ≥ 50 kg/m<sup>2</sup> group, were 91.6%, 90.1%, and 95.8%, respectively. There was no statistical difference between groups for either exclusion or non-exclusion of patients who ate solid food. There is no statistical difference in the number of patients who were satisfied with the VLCD between the Atkin-formula diet and the other formula diet for either the BMI < 50 kg/m<sup>2</sup> and BMI ≥ 50 kg/m<sup>2</sup> groups.

There was a trend for hunger sensation more in the BMI < 50 kg/m<sup>2</sup> group than that in the BMI ≥ 50 kg/m<sup>2</sup> group (median [IQR]; 2 [2] vs. 2 [2, 3], *p* = 0.06), while there were no statistical differences between groups in terms of satisfaction with a liquid diet, satisfaction of eating over drinking, or deviation of solid food (Table 2).

## Logistic Regression Analysis

Patient's age, gender, BMI before starting the VLCD course, and product brand of the VLCD had no effect on the preoperative weight loss ≥ 5% of total body weight and no impact on patient satisfaction in both groups.

## Discussion

In order to decrease visceral fat and improve outcomes during and after bariatric surgery, several strategies have been introduced. Preoperative weight loss is a method to decrease cardiovascular risks and reduce the liver volume and intra-

abdominal fat, leading to improved visibility during surgery and therefore decrease intra- and postoperative complications. Moreover, a study demonstrated a significant correlation between weight loss attained preoperatively and sustained long-term weight loss at 3 and 4 years following Roux-en-Y gastric bypass [18]. A recent systematic review of 12 studies on the effect of preoperative weight loss before gastric bypass is supportive of the idea that preoperative weight loss is additive to postoperative weight loss as predicted from the weight at the time of surgery [19]. However, no weight loss strategy has been established as a standard of care. A VLCD is a popular method for preoperative weight loss and has shown some benefits on perioperative outcomes including shorter hospital stay, reduced operative time, lower early postoperative complications, and greater short-term postoperative weight loss [8, 10, 11, 16]. It has also shown greater weight loss than that of a low-calorie diet which is usually defined as a diet of 800–1500 kcal/day [20, 21]. However, a VLCD could induce some minor and transient side effects such as asthenia, fatigue, headache, muscle weakness, constipation, hyperuricemia, and nausea more than that of the low-calorie diet [20]. Compared to other more invasive methods, a VLCD has shown to have fewer side effects, and a VLCD is less costly and easier to use than preoperative weight loss with an intragastric balloon [21]. A VLCD also showed comparable weight loss to an endoluminal bypass sleeve used for a 1-week period [17, 22].

However, no standard VLCD regimen exists, and many different regimens are used in various ways. These include different kinds of diet (e.g., liquid or solid and commercial products or standard ordinary products), different diet instruction protocols, and duration periods. A liquid preoperative VLCD was used in our center because previous studies reported that it provided a greater degree of weight loss than that of a regular diet. Faria et al. [11] reported on a randomized trial that compared effects of a VLCD between liquid and normal diets based on preoperative stage. The group given the liquid diet had significantly more weight loss than that of the group given a normal diet during a 14-day period at similar levels of daily energy intake. A study by Carbajo et al. [23] also showed that weight loss was significantly higher with a high protein, balanced energy liquid diet (800 kcal/day) than that of a normal high protein meal with no carbohydrates or fat during a 12-day period followed by 8 days of a liquid diet in both groups.

The duration of a VLCD regimen varies among the centers. A literature review revealed that 10-day to 12-week periods of VLCD regimens have been used and showed that longer periods of VLCD provide greater weight loss [9, 16]. However, patient compliance and adherence may be compromised in longer periods with a greater number of side effects. Moreover, total food cost may be higher. In a study by Colles et al. [24], 80% of total liver volume reduction occurred within the first 2 weeks in patients who received preoperative

VLCD. Van Nieuwenhove et al. [10] reported a randomized multicenter study that compared the outcomes between a preoperative VLCD regimen and no preoperative dietary restriction (control group) over a 2-week period. Results of the study showed that the number of complications was significantly lower in the VLCD group compared to that in the control group at 30-day follow-up. Also, the difficulty of the procedure was lower in the VLCD group from the surgeon's point of view. Furthermore, Faria et al. [11] showed patients lost 20.6% of their average visceral fat after 2 weeks of a liquid VLCD and found a 2-min reduction in surgical time for each centimeter increment of visceral fat loss. Based on these reports, a 14-day period for the VLCD was used in our regimen, particularly for patients with super morbid obesity ( $BMI \geq 50 \text{ kg/m}^2$ ). We reduced the duration of the VLCD to a 7-day period for those with a  $BMI < 50 \text{ kg/m}^2$ , because of concerns about patient compliance and tolerability. Short-duration regimens still showed benefit from weight loss and metabolic improvement as shown in the report by Faria et al. [11].

This present study showed that the amount of weight loss after the VLCD course in the  $BMI \geq 50 \text{ kg/m}^2$  patients was 60% higher than that in those with a  $BMI < 50 \text{ kg/m}^2$  ( $7.0 \pm 2.3 \text{ kg}$  vs.  $4.4 \pm 1.8 \text{ kg}$ ). These results can be explained by the longer duration of the VLCD and the higher initial BMI leading to more weight loss. The %TWL in the  $BMI \geq 50 \text{ kg/m}^2$  group (4.4%) was similar to the results at 2 weeks from a study by Colles et al. [24] in which the weight loss was almost 5% and a study by Fris [25] in which the weight loss was 4.1%. The weight loss in this study ( $7.0 \pm 2.3 \text{ kg}$ ) was greater than the results from Faria et al. [11] ( $4.0 \pm 1.6 \text{ kg}$ ) and Van Nieuwenhove et al. [10] ( $4.9 \pm 3.6 \text{ kg}$ ), which may be explained by the higher initial BMI. The weight loss in the  $BMI < 50 \text{ kg/m}^2$  group was higher than that in the 7-day results from Faria et al. ( $4.4 \pm 1.8$  vs.  $2.6 \pm 0.2 \text{ kg}$ ) [11]. This result may be from the higher average energy intake in the study by Faria et al. ( $958 \pm 96 \text{ kcal/day}$ ) [11]. A multicenter randomized study by Schouten et al. [22] compared the efficacy of an EndoBarrier™ Gastrointestinal Liner to diet restriction (liquid VLCD with 600 kcal/day in the first week followed by a normal LCD with 1200–1500 kcal/day up to 12 weeks) in presurgical stage. Results showed that the percentages of excess weight loss (%EWL) at the first week were  $7.5 \pm 5.1\%$  and  $5.3 \pm 1.8\%$  in the EndoBarrier group and diet restriction group, respectively. It was unclear why these results were lower than our weight loss outcome in the group with a  $BMI < 50 \text{ kg/m}^2$  assigned to the 7-day period of the VLCD (%EWL was  $9.7 \pm 4.7\%$ , not shown in the results), despite using a more restrictive energy diet in the first week of their study with similar initial BMIs.

The target of 5–10% total weight loss was shown to be safe and feasible and associated with a reduction of visceral fat and liver volume, even within a few weeks [26]. With this target, there was also an association with significant improvements in cardiovascular disease risk factors [27]. The total weight losses in

our regimens were approximately 4–4.5% which was close to the target, while some patients achieved this target.

Patient compliance and acceptability remain important issues. Patients who cannot tolerate the diet regimen will not be able to adhere and complete the diet course which leads to poor weight loss and less satisfaction in the preoperative stage. Currently, only a few studies have reported patient compliance, adherence, and tolerability to a diet regimen during the preoperative period. The level of compliance and adherence varies among studies due to differences in definitions and measurement methods (i.e., subjective questionnaire vs. objective laboratory test). The study from Van Nieuwenhove et al. [10] reported that 10.7% of the patients who received a liquid VLCD were not able to complete the diet regimen due to intolerance of the diet, lack of adherence to the diet regimen, or both. In contrast, Faria et al. [11] used ketonuria as a biomarker of dietary compliance in their study and reported that the percentage of adherence was only 28% in the liquid VLCD group. In our study, patient compliance was defined as restriction to the prescribed diet, not taking any solid food, and adhering to the minimum number of days in the assigned period. The results showed that the level of compliance was greater in the BMI < 50 kg/m<sup>2</sup> group assigned to the 7-day period than that in the BMI ≥ 50 kg/m<sup>2</sup> group assigned to the 14-day period (75.5% vs. 61.8%) which confirmed that a longer duration of the VLCD can affect patient compliance and adherence. However, both groups still showed good compliance and acceptable rates.

Hunger is a common feeling reported by patients during the preoperative VLCD course. In this study, the feeling of hunger was more in the BMI < 50 kg/m<sup>2</sup> group assigned to the 7-day period of the VLCD than that in the BMI ≥ 50 kg/m<sup>2</sup> group assigned to the 14-day period. This may have occurred because the heavier group had more patients who consumed solid food. The consumption of a solid diet may reduce the hunger sensation more than a liquid diet. This is in agreement with a report from Houchins et al. [28] that showed a reduction in acute hunger response after consuming fruit in the liquid form was lower compared to that in the solid form in overweight and obese subjects. A study from Flood-Obbagy and Rolls [29] also had the same conclusion that consumption of solid fruit can affect satiety more than the liquid form. A further study by Faria et al. [11] reported a significant increase in hunger in patients who received a liquid VLCD compared to that in those with a normal VLCD at 7 and 14 days. The other possible explanation for the lower rate of hunger observed in the heavier group was adaptation by the patients. Klempel et al. [30] reported that hunger scores in the obese subjects increased during the first week of the alternate day modified fasting (ADMF) regimen (i.e., consuming 25% of the baseline energy requirement on the fast day, then eating ad libitum on each alternating feed day) before decreasing over time after 2 weeks throughout the rest of the trial. This

indicated that the subjects become habituated to the ADMF regimen after approximately 2 weeks of the diet. However, the study used ADMF instead of daily energy restriction diets.

Approximately 90% of subjects were satisfied with our preoperative liquid VLCD regimens, and almost 50% reported they felt satisfied frequently. The results were consistent with a study by González-Pérez et al. [31] which reported 80% acceptability with a 6-week liquid VLCD. However, when a liquid form was compared to a regular form, the regular form was better appreciated by patients compared to those with a liquid form [17, 23].

This study has some limitations. In this real world situation, we could not control the number of patients to be the same size, and we used a 1-year period for collecting data. This study has many confounding factors as well as different numbers of actual days of consumption and additional solid food intake which might affect the consistency of this study. The study had a small number of patients, no control group (with a normal diet), no formal records regarding the reasons why the patients could not adhere to the assigned time durations, and why they ate solid foods. We did not exclude patients who ate solid food in our analysis because we wish to present data in a real practice. However, the analysis after exclusion of these patients showed similar results in term of weight loss, compliance, and satisfaction. Furthermore, there was no data collection of adverse events during the liquid VLCD course. This study did not present the intra-, peri-, and postoperative outcomes or any of the correlations between the preoperative weight loss and the postoperative outcomes.

## Conclusions

Preoperative liquid VLCD was well tolerated and provided a modest amount of weight loss in both groups. The 2-week regimen in patients with a BMI ≥ 50 kg/m<sup>2</sup> achieved a greater amount of weight loss than that of the 1-week regimen in the patients with a BMI < 50 kg/m<sup>2</sup>. Even if compliance is affected by a longer time period of the VLCD course, the overall compliance rate was high in both groups. The hunger sensation tended to be greater in the group assigned to the 7-day period of the VLCD than that in those assigned to the 14-day period. However, satisfaction of the diet was high in both groups. Correlations with the degree of visceral fat and liver volume loss and the technical ease of carrying out the procedure should be studied. Postoperative outcomes including blood loss, length of stay, and return to bowel function should also be analyzed.

**Acknowledgments** The authors would like to thank the entire staff of Loyola Center for Metabolic Surgery & Bariatric Care at Melrose Park, IL, U.S.A. for helping with the data retrieval and providing the essential information. We would also like to thank Ms. Nannapat Pruphetkeaw

from the Epidemiology Unit, Faculty of Medicine, Prince of Songkla University, Thailand, for her assistance in performing the statistical analysis of the data and Mr. Glenn Shingledecker, in the Office of International Affairs, Faculty of Medicine, Prince of Songkla University for the proofreading and language support.

## Compliance with Ethical Standards

**Conflict of Interest** The authors declare that they have no conflicts of interest.

**Ethical Approval Statement** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Informed Consent Statement** Informed consent was obtained from all individual participants included in the study.

## References

- WHO Obesity and overweight Fact sheet, Updated 2017. Available from: <http://www.who.int/mediacentre/factsheets/fs311/en>.
- Ponce J, Nguyen NT, Hutter M, et al. American Society for Metabolic and Bariatric Surgery estimation of bariatric surgery procedures in the United States, 2011–2014. *Surg Obes Relat Dis*. 2015;11(6):1199–200.
- Sjostrom L. Review of the key results from the Swedish Obese Subjects (SOS) trial - a prospective controlled intervention study of bariatric surgery. *J Intern Med*. 2013;273(3):219–34.
- Puzziferri N, Roshek 3rd TB, Mayo HG, et al. Long-term follow-up after bariatric surgery: a systematic review. *JAMA*. 2014;312(9):934–42.
- Courcoulas AP, Yanovski SZ, Bonds D, et al. Long-term outcomes of bariatric surgery: a National Institutes of Health symposium. *JAMA surgery*. 2014;149(12):1323–9.
- Maciejewski ML, Arterburn DE, Van Scoyoc L, et al. Bariatric surgery and long-term durability of weight loss. *JAMA surgery*. 2016;151(11):1046–55.
- Sjöström L, Peltonen M, Jacobson P, et al. Association of bariatric surgery with long-term remission of type 2 diabetes and with microvascular and macrovascular complications. *JAMA*. 2014;311(22):2297–304.
- Cassie S, Menezes C, Birch DW, et al. Effect of preoperative weight loss in bariatric surgical patients: a systematic review. *Surg Obes Relat Dis*. 2011;7(6):760–7.
- Gerber P, Anderin C, Thorell A. Weight loss prior to bariatric surgery: an updated review of the literature. *Scand J Surg*. 2015;104(1):33–9.
- Van Nieuwenhove Y, Dambrauskas Z, Campillo-Soto A, et al. Preoperative very low-calorie diet and operative outcome after laparoscopic gastric bypass: a randomized multicenter study. *Arch Surg*. 2011;146(11):1300–5.
- Faria SL, Faria OP, de Almeida CM, et al. Effects of a very low calorie diet in the preoperative stage of bariatric surgery: a randomized trial. *Surg Obes Relat Dis*. 2015;11(1):230–7.
- Alami RS, Morton JM, Schuster R, et al. Is there a benefit to preoperative weight loss in gastric bypass patients? A prospective randomized trial. *Surg Obes Relat Dis*. 2007;3(2):141–5. discussion 5–6
- Anderin C, Gustafsson UO, Heijbel N, et al. Weight loss before bariatric surgery and postoperative complications: data from the Scandinavian Obesity Registry (SOReg). *Ann Surg*. 2015;261(5):909–13.
- Gerber P, Anderin C, Gustafsson UO, et al. Weight loss before gastric bypass and postoperative weight change: data from the Scandinavian Obesity Registry (SOReg). *Surg Obes Relat Dis*. 2016;12(3):556–62.
- Kim JJ, Rogers AM, Ballem N, et al. ASMBS updated position statement on insurance mandated preoperative weight loss requirements. *Surg Obes Relat Dis*. 2016;12(5):955–9.
- Holderbaum M, Casagrande DS, Sussenbach S, et al. Effects of very low calorie diets on liver size and weight loss in the preoperative period of bariatric surgery: a systematic review. *Surg Obes Relat Dis*. 2018;14(2):237–44.
- Schouten R, van der Kaaden I, van't Hof G, et al. Comparison of preoperative diets before bariatric surgery: a randomized, single-blinded, non-inferiority trial. *Obes Surg*. 2016;26(8):1743–9.
- Alger-Mayer S, Polimeni JM, Malone M. Preoperative weight loss as a predictor of long-term success following Roux-en-Y gastric bypass. *Obes Surg*. 2008;18(7):772–5.
- Kadeli DK, Szczepaniak JP, Kumar K, et al. The effect of preoperative weight loss before gastric bypass: a systematic review. *J Obes*. 2012;2012:867540.
- Moreno B, Bellido D, Sajoux I, et al. Comparison of a very low-calorie-ketogenic diet with a standard low-calorie diet in the treatment of obesity. *Endocrine*. 2014;47(3):793–805.
- Adrianzen Vargas M, Cassinello Fernandez N, Ortega SJ. Preoperative weight loss in patients with indication of bariatric surgery: which is the best method? *Nutr Hosp*. 2011;26(6):1227–30.
- Schouten R, Rijs CS, Bouvy ND, et al. A multicenter, randomized efficacy study of the EndoBarrier gastrointestinal liner for presurgical weight loss prior to bariatric surgery. *Ann Surg*. 2010;251(2):236–43.
- Carbajo MA, Castro MJ, Kleinfinger S, et al. Effects of a balanced energy and high protein formula diet (Vegestart complet<sup>®</sup>) vs. low-calorie regular diet in morbid obese patients prior to bariatric surgery (laparoscopic single anastomosis gastric bypass): a prospective, double-blind randomized study. *Nutr Hosp*. 2010;25(6):939–48.
- Colles SL, Dixon JB, Marks P, et al. Preoperative weight loss with a very-low-energy diet: quantitation of changes in liver and abdominal fat by serial imaging. *Am J Clin Nutr*. 2006;84(2):304–11.
- Fris RJ. Preoperative low energy diet diminishes liver size. *Obes Surg*. 2004;14(9):1165–70.
- Kim JJ. Evidence base for optimal preoperative preparation for bariatric surgery: does mandatory weight loss make a difference? *Curr Obes Rep*. 2017;6(3):238–45.
- Wing RR, Lang W, Wadden TA, et al. Benefits of modest weight loss in improving cardiovascular risk factors in overweight and obese individuals with type 2 diabetes. *Diabetes Care*. 2011;34(7):1481–6.
- Houchins JA, Tan SY, Campbell WW, et al. Effects of fruit and vegetable, consumed in solid vs beverage forms, on acute and chronic appetite responses in lean and obese adults. *Int J Obes*. 2013;37(8):1109–15.
- Flood-Obbagy JE, Rolls BJ. The effect of fruit in different forms on energy intake and satiety at a meal. *Appetite*. 2009;52(2):416–22.
- Klempel MC, Bhutani S, Fitzgibbon M, et al. Dietary and physical activity adaptations to alternate day modified fasting: implications for optimal weight loss. *Nutr J*. 2010;9:35.
- Gonzalez-Perez J, Sanchez-Leenheer S, Delgado AR, et al. Clinical impact of a 6-week preoperative very low calorie diet on body weight and liver size in morbidly obese patients. *Obes Surg*. 2013;23(10):1624–31.