Techniques in Coloproctology (2019) 23:887–892
https://doi.org/10.1007/s10151-019-02074-y

ORIGINAL ARTICLE

# Pelvic fat volume reduction with preoperative very low energy diet (VLED): implications for rectal cancer surgery in the obese

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Received: 26 May 2019 / Accepted: 23 August 2019 / Published online: 4 September 2019


## Abstract

**Background** Obese patients have higher complication rates after pelvic surgery. Laparoscopic rectal surgery may not be possible in the obese individual due to mesorectal, total pelvic and general visceral fat volumes. Very low energy diets reduce visceral fat but the changes within the pelvis and mesorectum are unknown. The aim of the present study was to quantify the proportion of fat lost from total pelvic and mesorectal fat with a very low energy diet (VLED) and define simple, accessible measurements that correlate with expected volume reduction.

**Methods** A study was conducted on proportion change in mesorectal and intrapelvic fat volumes in patients on a VLED prior to bariatric surgery at the Alfred Hospital in Melbourne. The VLED was a standardized 4-week meal replacement. Proportion change in mesorectal and intrapelvic fat volumes were measured. Patients had standardized pre-diet and post-diet magnetic resonance imaging (MRI) of the pelvis. Body mass index, weight and girth measures were obtained. Adipose quantification analysis was performed using Q-Fat.

**Results** Nine patients were included in this study, who were preparing for bariatric (not colorectal) surgery (5 females, median age 42 years, range 27–59 years) pre-protocol body mass index was 55.8 (range 39.5–60.6 kg/m$^2$); median weight was 163 kg. Median mesorectal fat reduction was 29.9% (range 11.6–66.6%). Linear regression showed a relationship between the amount of mesorectal fat reduction and two variables: patient height and the distance from S1 to the posterior aspect of the rectum on MRI. The relationship predicted response to the diet ($R^2$ 67%, $p = 0.040$).

**Conclusions** Very low energy diets result in a clinically significant reduction in mesorectal fat with a lesser change in total pelvic fat, suggesting that very low energy diets may be useful for preparation for pelvic surgery in the obese. The distance from S1 to the posterior rectum correlates well with mesorectal reduction, making this a valuable clinical tool when volumetric analysis is not possible. This analysis is limited to the quantification of the effect of the diet and cannot comment on the safety of this approach before pelvic cancer surgery.

**Keywords** Obesity · Rectum · Surgical procedures · Operative · Diet therapy

## Introduction

Obesity is neither an epidemic nor a disease—instead it is the predictable result of our modern, sedentary lifestyle. This "by-product" has ultimately necessitated an entire bariatric industry—as well as the modified hospital equipment to deal with the safe transport, perioperative and general ward care of the obese patient. The rate of obesity has doubled in the last 35 years [1] with 1.9 billion overweight adults in the world and 600 million formally classified as obese—representing a staggering 13% of the adult population. Forty-two million children worldwide are also classed as either overweight or obese.

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There are numerous negative effects in colorectal surgery which are obvious in all areas of perioperative care [2–4]. There is heterogeneity in the literature which stems from variations in the definition of obesity [2, 5, 6]. Obesity is currently defined by body mass index (BMI) [1]—a ratio of patient height to weight without modification for patient build. There are other, possibly better, measures of obesity that exist, but require either more onerous clinical assessment—such as skin fold measurement—or employ imaging techniques to calculate a visceral adipose tissue score (VAT) derived from computed tomography (CT) scans or magnetic resonance imaging (MRI). MRI is part of the routine preoperative staging for rectal cancer in most Australian practices and offers us the opportunity to make an assessment of pelvic and mesorectal fat during staging.

With respect to pelvic surgery, the literature reflects mostly anecdotal surgical experiences: visceral obesity results in longer operating times [7], increased blood loss and increased rates of anastomotic leak [4]. Increased complication rates persist beyond the immediate perioperative period with more frequent incisional herniae and more frequent stomal complications; in the context of colorectal cancer, disease-free and overall survival decrease as the VAT score increases [6]. It is likely that these outcomes relate at least in part to the difficulty of the procedure.

Acknowledging that obesity complicates both the performance of a procedure and the outcome, some surgeons have started to utilize preoperative very low energy diets (VLED) to improve operative conditions, and although we have evidence of a reduction in abdominal VAT with VLED, we have no evidence to suggest it improves conditions in the pelvis or the mesorectum [8]. Indeed, the only current proven role for preoperative VLED is preparation for bariatric procedures, reducing hepatic steatosis and thus improving liver compliance which would otherwise impact access to the fundus and body of the stomach [9, 10]. This study was designed as proof of concept to assess the changes in pelvic fat volumes in patients already undertaking a VLED prior to bariatric surgery.

The primary aim of this study was to objectively quantify the proportion of fat lost from the total intrapelvic fat volume (IPAT) and from the mesorectum (MAT) in response to a VLED utilizing an imaging modality already routinely employed for rectal cancer staging. Secondary aims include determination of a single slice measurement that may be employed to identify patients in whom preoperative VLED may be indicated and to create the foundation of a protocol for preoperative caloric restriction in the obese patient with rectal carcinoma.

## Materials and methods

### Patients and MRI

Patients scheduled for bariatric procedures routinely undertake a standardized preoperative diet of 4 weeks of Optifast™ VLED as a complete meal replacement diet in the Upper Gastrointestinal Unit at our institution. These patients were offered one pre-VLED and one post-VLED MRI of the pelvis. Optifast™ meal replacement was complete, with a single piece of fruit with breakfast supplement and one cup of vegetables with the lunch and dinner supplements. Coffee and alcohol were not permitted.

These patients did not have a pelvic malignancy and their selection as the population of interest was made to facilitate objective measurement of reduction in IPAT and MAT only. The preoperative Optifast™ VLED was supervised and compliance was measured with a food diary. Demographic, weight and girth measures were obtained prior to VLED and upon completion. All imaging and clinical measures were performed prior to the intended bariatric procedure.

### Image analysis

Pre-VLED and post-VLED MRI scans of the rectum were acquired. Two specific sequences were obtained: a regular T1W GRE sequence and a similar sequence but with a water-saturation pre-pulse. Images were acquired from the L4 vertebra to the pelvic floor. The scan parameters used were TR/TE = 112/2.66 ms, flip angle = 50°, field of view (FOV) = 500 mm (frequency encode direction), pixel size = 1.95 × 1.95 mm$^2$, readout bandwidth = 560 Hz/pixel, slice thickness = 5 mm, slice gap = 5 mm, and NSA = 1.

Linear measurements were taken from the anterior aspect of S1 and S2 vertebrae to the posterior aspect of the rectal muscle wall and to the symphysis pubis in a line on a standard MRI workstation. Ratios were constructed to represent the proportion of distance from the vertebra to the symphysis occupied by the mesorectum.

Adipose quantification analysis was performed using the Q-Fat software package and involved intensity correction (iteratively applying a two-dimensional polynomial field correction to find the minimal entropy of the image grayscale histogram) and fat pixel differentiation from non-fat pixels (a fully automated method) to generate a fat-only image. All non-fat pixels were thus set to zero and excluded from fat quantification. IPAT and MAT voxels were identified based on a contour separating the areas of interest, and contour boundaries were manually defined by the first author. The total volumes were calculated by summing fat areas from all slices for each technique, in cm$^3$.

**Table 1** Regression modelling factors

| |
|---|
| Height |
| Body mass index |
| Weight |
| Girth |
| Sex |
| Patient compliance |
| Distance from S1 to rectum (distance a) |
| Distance from S2 to rectum (distance b) |
| Distance from S1 to symphysis (distance c) |
| Distance from S2 to symphysis (distance d) |
| Ratio a–c |
| Ratio c–d |

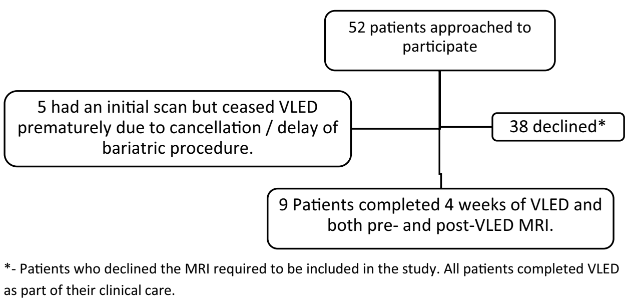


**Fig. 1** Recruitment

## Statistical analysis

Statistical analysis was performed with SPSS ver 23 (IBM). All pertinent clinical variables were included in an initial linear regression model (Table 1) and the final model was achieved by stepwise backward elimination. Factors likely to have high predictive value within the model (e.g. BMI and weight) were modelled separately to determine their individual effects.

# Results

Five female and 4 male patients were recruited and completed the 4-week VLED program and serial MRI scans out of a total of 14 patients who commenced the study as detailed in Fig. 1.

Table 2 outlines the demographics and clinical measurements for the nine patients throughout the study. Median preoperative BMI was 55.8 kg/m$^2$ (range 39.5–60.6 kg/m$^2$) with a median weight of 163 kg. Median age was 42 years (range 27–59 years). Median weight loss was 12 kg and median reduction in abdominal girth was 9 cm—thus the median proportion of total body weight lost was only 6.3% (range 1.2–12.2%). Two patients were poorly compliant with the regimen: one consumed extra Optifast™ supplements and the other consumed food not permitted by the regimen.

Linear measurements from the first two sacral vertebrae to the symphysis and rectum are detailed in Table 3.

The changes in MAT and IPAT achieved by individual patients are listed in Table 4. Median mesorectal fat volume reduction was 29.9% (range 11.6–66.6%). Median total intrapelvic fat volume reduction was 19.7% (range 41.7% reduction to 8.9% increase).

## Regression modelling for factors predicting mesorectal and total intrapelvic fat volume reduction

Linear regression modelling demonstrated that the most important factors associated with the proportion reduction

**Table 2** Patient demographics and clinical variables

| | Sex | BMI (kg/m$^2$) | Height (m) | Girth (cm) | Weight lost (kg) | Girth reduction (cm) | VLED compliance |
|---|---|---|---|---|---|---|---|
| Patient 1 | Male | 55.77 | 1.72 | 163 | 8 | 12 | Good |
| Patient 2 | Male | 56.74 | 1.83 | 169 | 12 | 10 | Good |
| Patient 3 | Female | 46.82 | 1.79 | 147 | 13 | 10 | Good |
| Patient 4 | Female | 59.17 | 1.69 | 160 | 19 | 10 | Good |
| Patient 5 | Female | 60.6 | 1.64 | 152 | 2 | 1 | Poor[a] |
| Patient 6 | Male | 55.85 | 1.76 | 162 | 12 | 8 | Good |
| Patient 7 | Male | 39.47 | 1.91 | 139 | 9 | 5 | Poor[b] |
| Patient 8 | Female | 47.84 | 1.61 | 135 | 7 | 6 | Good |
| Patient 9 | Female | 48.65 | 1.59 | 127 | 15 | 9 | Good |

*BMI* body mass index

[a]Daily non-compliance with regimen

[b]Non-compliance in the form of extra Optifast™ supplements

**Table 3** Linear pelvic measurements in centimetres

| | S1 to rectum | S1 to symphysis | S2 to rectum | S2 to symphysis |
|---|---|---|---|---|
| Patient 1 | 2.4 | 11.4 | 2.3 | 11.5 |
| Patient 2 | 3.4 | 12 | 3.4 | 13 |
| Patient 3 | 2.7 | 12.8 | 2.4 | 12.4 |
| Patient 4 | 2 | 11 | 2 | 11.7 |
| Patient 5 | 3.1 | 11.8 | 3.1 | 11.9 |
| Patient 6 | 3.2 | 10.8 | 3.3 | 11 |
| Patient 7 | 2.6 | 12.3 | 1.6 | 12.7 |
| Patient 8 | 6.2 | 11.9 | 1.6 | 12.5 |
| Patient 9 | 2.6 | 11.7 | 2.7 | 11.7 |

of mesorectal fat was the ratio of distance from s1 to rectum and patient height such that:

Percentage reduction mesorectal fat anticipated with 4 weeks preoperative Optifast™ VLED equals 13.3 x (distance from S1 to rectum in cm) + 83.8 x (patient height in m) – 148.961

($R^2$ 67%, p 0.040)

No linear association could be ascertained between any clinical or radiological variable and the effect of VLED on total intrapelvic fat volume.

## Discussion

This study demonstrates a significant reduction in mesorectal and intrapelvic fat volumes after a 4-week VLED. Prior research demonstrated a reduction in abdominal visceral adipose tissue (VAT) of 37% with 8 weeks of VLED [8]. A similar reduction in mesorectal fat volume (MAT) was achieved in the study group in 4 weeks. VLED-induced fat volume reduction has been consistently shown to be greater in visceral fat than in the subcutis or total body; it would appear to be most marked in the mesorectum specifically.

BMI remains an easy index to measure for obesity, but its validity in determining treatment outcomes is questionable. These data demonstrate no relationship between BMI and reduction of fat volumes in MAT or IPAT; BMI was excluded very early from both regression models, and simple linear regression demonstrated no relationship (*p* 0.73) nor was there an association with total weight. Height was the only useful clinical measure, such that for each 10-cm increase in patient height, there is an 8.4% increase in the percentage fat volume lost from the mesorectum with a 4-week Optifast™ VLED.

**Table 4** Individual changes in total pelvic and mesorectal adipose volumes

| | Mesorectal adipose volumes | | | | Total intrapelvic adipose volumes | | | |
|---|---|---|---|---|---|---|---|---|
| | Pre-Optifast mesorectal adipose volume (cm$^3$) | Post-Optifast mesorectal adipose volume (cm$^3$) | % Change | Increase or decrease | Pre-Optifast total intrapelvic adipose (cm$^3$) | Post-Optifast total intrapelvic adipose in (cm$^3$) | % Change | Increase or decrease |
| Patient 1 | 215.67 | 155.80 | −28 | Decrease | 356.98 | 272.14 | −24 | Decrease |
| Patient 2 | 77.15 | 25.78 | −67 | Decrease | 200.78 | 116.97 | −42 | Decrease |
| Patient 3 | 60.58 | 46.96 | −22 | Decrease | 293.69 | 289.80 | −1 | Decrease |
| Patient 4 | 98.60 | 87.13 | −12 | Decrease | 223.79 | 243.64 | 9 | Increase |
| Patient 5 | 67.00 | 35.80 | −47 | Decrease | 148.18 | 91.24 | −38 | Decrease |
| Patient 6 | 80.24 | 56.25 | −30 | Decrease | 132.68 | 118.45 | −11 | Decrease |
| Patient 7 | 158.15 | 82.12 | −48 | Decrease | 324.60 | 211.24 | −35 | Decrease |
| Patient 8 | 23.74 | 8.62 | −64 | Decrease | 41.32 | 33.19 | −20 | Decrease |
| Patient 9 | 16.51 | 13.04 | −21 | Decrease | 41.31 | 37.93 | −8 | Decrease |

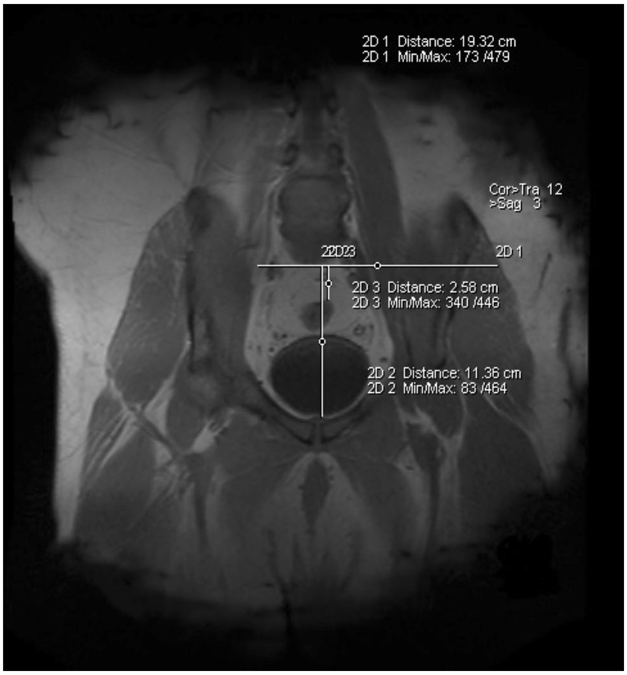


**Fig. 2** The process of linear measurement

Numerous measures have been used to assess the degree of adiposity in obese patients, and the impact this can have on surgery. Chen et al. assessed BMI, visceral fat area (VFA), visceral fat area/body surface area (VFA/BSA), mesorectum fat ratio (MFR), pelvic fat area (PFA), pelvic fat ratio (PFR) and their impact on completion of mesorectal excision, operative time and incision length. This study concluded that VFA was a better index for predicting the influence of visceral obesity on surgical quality and difficulty of laparoscopic rectal surgery compared to the other measures [11]. Yamaoka et al. evaluated the influence of clinical and anatomical factors, including mesorectal fat area, on the difficulty of total mesorectal excision for rectal cancer using MRI-based pelvimetry. They demonstrated that larger mesorectal fat area was associated with longer operative time in the pelvic phase of rectal cancer resection [12]. These are difficult studies to perform and thus far have only been used in a research setting. BMI remains popular because of its ease of use; however, better and simpler measures may well be used more frequently in the future.

Easily reproducible radiological measurements can also predict the outcome of VLED: a single linear measurement from the anterior surface of the S1 vertebra to the posterior aspect of the rectal muscle wall along a line from S1 to the symphysis pubis predicts response to VLED such that each cm increase in pre-VLED distance results in an extra 13.3% reduction. The method of measurement is demonstrated in Fig. 2. When the clinical and radiological measurements are combined, a good estimate of likely improvement in surgical conditions can be achieved.

It was an interesting observation that patient compliance had no effect on mesorectal fat volume reduction in this small patient cohort; the two patients with poor compliance still achieved 46.6 and 48.1% reductions in mesorectal adipose volume, well above the mean values. Both patients did comply with the Optifast™ VLED supplement regimen but either ate additional food or took too many of the supplements to be compliant. Yet total weight loss for both patients was well below the mean weight loss for the study group. This suggests an effect on the mesorectal fat volume with VLED products even when non-compliant with dietary restrictions, an effect that has been anecdotally noted by some surgeons already employing VLED prior to pelvic surgery. This benefit could be explored in further studies, as non-compliance with VLED is common.

There are several limitations to this analysis. Importantly, these results do not demonstrate the safety of VLED in the perioperative period for patients with malignant rectal pathology. The ADIPOSe (Australasian Decrease in IntraPelvic Obesity for Surgery) study is a randomized, international, multi-centre controlled trial which is currently recruiting and will assess these effects in the rectal cancer patient population [13]. Q-Fat™ software is a research tool and is not a component of the standard MRI workstation operating system or its subset programs; for this reason, we investigated the utility of accessible clinical and radiological measurements as a surrogate for predicting the effect of VLED.

## Conclusions

VLED with Optifast™ produces a significant reduction in mesorectal fat volume and a more moderate reduction in total intrapelvic fat volume which should facilitate laparoscopic pelvic surgery in the obese population. The magnitude of the VLED effect on mesorectal fat volume is predicted by the patient's height and the thickness of the mesorectum noted in the plane from S1 to the pubic symphysis, allowing preoperative estimation of the utility of VLED for any patient being staged for rectal resection or other pelvic surgery.

**Acknowledgements** The authors acknowledge the contribution of Mr Michael Sellenger, Radiographer in charge of the Alfred Hospital MRI unit.

**Author contributions** All listed authors contributed to design methodology, draft review, final approval for submission and all authors are accountable for the integrity of the work.

**Funding** This project was entirely funded by a Grant from the Colorectal society of Australia and New Zealand Foundation (CSSANZ). This paper has been accepted as a poster presentation at ASCRS June 10–14, 2017, Seattle, USA.

## Compliance with ethical standards

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

**Ethical approval** Ethics approval was obtained.

**Informed consent** All patients gave appropriate informed consent.

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