Langenbeck's Archives of Surgery (2022) 407:1357–1367
https://doi.org/10.1007/s00423-022-02484-x

SYSTEMATIC REVIEWS AND META-ANALYSES

Is there a role for preoperative liver reducing diet in hepatectomy? A systematic review

Charlotte R. Hitchins[1] · Rebecca M. Jones[1] · Aditya Kanwar[1] · Somaiah Aroori[1]

Received: 25 August 2021 / Accepted: 24 February 2022 / Published online: 1 March 2022

Abstract

Purpose Preoperative very low-calorie diets (VLCDs) have been shown to reduce liver volume, reduce the risk of liver injury and improve safety during bariatric surgery. Hepatic steatosis (HS) has been associated with poorer outcomes in liver resection. VLCD can be used to improve HS. We aim to explore if preoperative VLCD could improve outcomes for patients with HS undergoing liver resection.

Methods We performed a systematic review of MEDLINE, EMBASE, PubMed and Cochrane databases. Studies were included if they were full-text articles investigating the effect of a preoperative dietary intervention in patients undergoing liver resection on intra-operative and post-operative outcomes. The last search was performed on 11 Jun 2020. Evidence quality was assessed by "GRADE". A narrative review was undertaken.

Results Five studies were found: one RCT and four cohort studies including 133 patients in intervention groups and 181 controls. Three used diet-only strategies and two diet and exercise strategies with varying time courses and monitoring. The quality of evidence assessed by GRADE was "high" for the RCT and "low" for the four cohort studies. Steatosis objectively improved in three studies, with evidence of reduced liver volume and increased attenuation on imaging in one. All studies showed a reduction in body weight and body mass index (BMI). Intra-operative blood loss was decreased following a diet-only intervention in two studies, and liver mobility improved in one. No difference was found in morbidity, mortality or hospital length of stay between intervention and control groups.

Conclusions There is evidence of poorer outcomes in liver resection patients with existing HS. There is an expected role for a preoperative VLCD to optimise these patients for surgery. Existing publications support this, but diet interventions and outcome measures are inconsistent, and patient numbers are small. There is scope for a well-designed, multi-centre randomised trial to investigate this further.

Keywords Liver · Hepatectomy · Fatty liver · Non-alcoholic fatty liver disease · Diet

Introduction

Hepatic steatosis (HS) is now the commonest parenchymal disorder of the liver in Western society [1–3] and affects between 10 and 40% of the general population [1, 3, 4]. According to the amount of lipid accumulation within hepatocytes, HS is defined under the umbrella term non-alcoholic fatty liver disease (NAFLD). NAFLD includes hepatic steatosis, steatohepatitis and more advanced disease with irreversible changes and cirrhosis. A direct correlation between the extent and severity of steatosis and body mass index (BMI) has been shown [1, 4]. With increasing rates of obesity, this is likely to become more, rather than less of a problem in the future [2]. In those undergoing hepatic resections for colorectal metastases, the prevalence of HS is thought to be even greater (30–50%) [5]. Many patients selected for liver resection are more comorbid, including underlying parenchymal disease such as steatosis [5]. In addition, the use of some chemotherapy treatments, most notably irinotecan-based therapy, has been associated with steatosis [5].

Several studies have shown a link between HS and poorer outcomes in liver resection for tumours and following donor hepatectomy. These include increased risk of complications,

✉ Charlotte R. Hitchins
charlotte.hitchins@nhs.net

1 Department of Hepatobiliary and Pancreatic Surgery, University Hospitals Plymouth NHS Trust, Derriford Hospital, Plymouth PL6 8DH, UK

higher blood loss and the need for blood transfusion and increased mortality in those with severe (> 30%) steatosis [6–8]. In addition, in transplantation, steatotic livers are associated with poorer graft function and even primary non-graft function, potentially resulting in complications for both donor and recipient [9, 10].

Very low calorie or very low energy diets (VLCD/VLED) have been shown to reduce liver fat content and liver volume [11–13] measured on serial imaging with ultrasound (US), magnetic resonance (MRI) or nuclear magnetic resonance (NMR) spectroscopy. One study found that biopsy-proven steatosis was reduced to < 10% with a very low energy Optifast diet ("Optifast" is a liquid meal replacement diet that can be tightly controlled (Nestle Nutrition, Vevey, Switzerland)) [14]. The duration of the prescribed diet interventions varied from two to twelve weeks [11–13]. Despite this inconsistency, all showed positive outcomes.

Very low energy diets have been implemented pre-operatively for some time in bariatric surgery. The rationale behind this is to reduce the size of the left liver and improve its mobility to enhance safe retraction and access to the proximal stomach and distal oesophagus. Randomised trials have shown such diets to reduce the difficulty of the surgery and improve long-term outcomes [15].

With increasing rates of HS in western populations and poorer outcomes including blood loss, morbidity and mortality in such patients undergoing liver surgery, an intervention must be sought. There is good evidence for reducing liver volume and fat with VLCD and improved safety in bariatric surgery when used as a preoperative intervention. Therefore, it seems possible that preoperative VLCD could have a role in improving HS and thus improve outcomes in patients undergoing liver resection surgery. To date, no reviews of this topic have been undertaken. This review aims to explore the existing evidence for patients thought to have or be at risk of HS undergoing hepatic resection, treated with a preoperative very low-calorie diet versus no diet. Evidence related to adherence and acceptability of the diet, effect on HS and operative clinical outcomes will be sought.

Material and methods

No patient or public involvement was required for this review. No confidentiality or consent issues were encountered, and ethical approval and trial registration were not needed.

Search strategy

A systematic search of MEDLINE, EMBASE, PubMed and Cochrane databases was conducted, using the following terms: liver-reducing diet, very low-calorie diet (VLCD), liver diet, OR weight loss AND hepatectomy, liver resection, OR liver surgery AND preoperative. A further search was made of the Cochrane database excluding the term "preoperative", as zero results were yielded initially. No time limitations were applied. The final search of all databases was made on 11 June 2020.

Two senior surgical trainees (CH and RJ) screened titles and abstracts. The full-text articles of the remaining results were then reviewed independently by the same two authors. If discrepancies arose, they were discussed and decided upon by consensus with AK and SA. Both CH and RJ reviewed bibliographies of the selected full-text articles to identify further studies missed by the initial search.

English language full-text studies that used a low-calorie diet as a preoperative intervention in patients undergoing liver resection surgery were included. Indications for liver resection were for neoplasms and live donation for transplantation. Conference abstracts and trial registrations without published results were excluded.

Quality was assessed using the GRADE technique described in the "GRADE Handbook" [16]. This was done independently by CH and AK, and the results were compared. If discrepancies arose, these were discussed and decided upon by consensus.

Studies were compared for the type and nature of the dietary intervention, its effect on HS and how this was measured, and patient compliance and acceptability. In addition, outcomes related to operative difficulty, intra-operative blood loss, complications, mortality and hospital length of stay were sought.

Results

The initial search identified 69 articles. After removing duplications, screening of titles and abstracts resulted in four reports sought for retrieval. Unfortunately, one trial registration, one conference abstract and a review article had to be excluded, resulting in one full-text article for review [17–19]. However, an examination of references and other sources identified four further full-text articles for inclusion (see Fig. 1 PRISMA diagram for details). The five articles examined included one randomised controlled trial (RCT) and four cohort studies. These had 133 patients who underwent a dietary intervention and 181 controls. Details of the studies are summarised in Table 1. Due to the small number of studies and inconsistency of outcome measures, meta-analysis was not possible.

Study details

Two studies undertaken in the same unit, Reeves et al. and Barth et al., used a preoperative diet intervention before

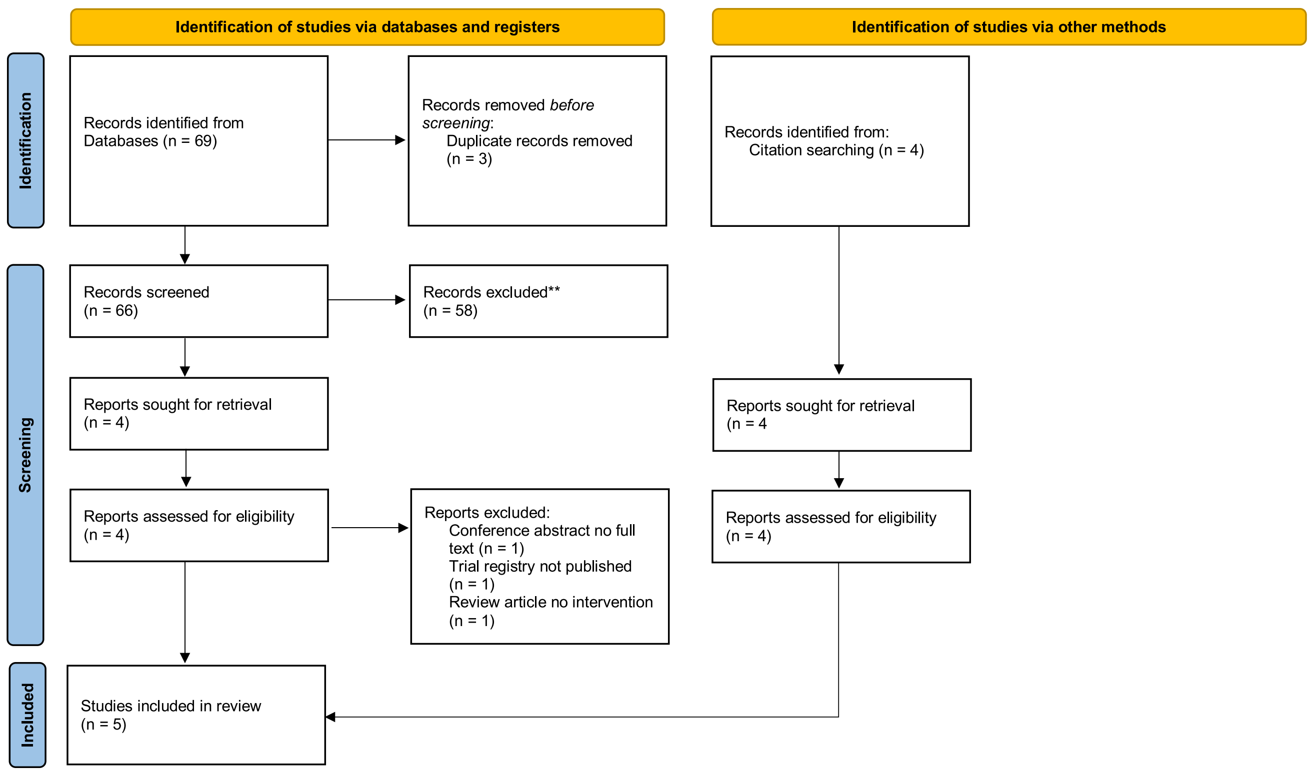

Fig. 1 PRISMA 2020 flow diagram Diagram Template From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. 10.1136/bmj.n71. For more information, visit: http://www.prisma-statement.org/

hepatic resection surgery [3, 20]. The initial study was a retrospective analysis of 51 patients undergoing hepatic surgery following a 1-week calorie-restricted diet under the care of a single surgeon. Outcomes were compared with the preceding 60 patients who had undergone surgery without dietary restriction [3]. This was followed by a RCT where patients with a BMI greater than 25 were randomised to a 1-week preoperative “Optifast” diet or standard care [20]. It was undertaken in the above and one other centre, with operations performed by five surgeons. A dietician made telephone contact with participants twice weekly, and food diaries were kept to evaluate compliance. A sample size calculation suggested 55 patients would be needed in each group. However, analysis after 32 controls and 31 diet intervention patients found significant results, and the trial was stopped. In both studies, the degree of steatosis was determined retrospectively from the resection specimens at the time of operation, and no baseline levels of steatosis were measured.

Nakamuta et al. used a combined strategy in 11 potential living donors with moderately steatotic livers [9]. This included a low-calorie diet, exercise and administration of bezafibrate. The diet (alongside the other two interventions) reduced stepwise from 1400 to 1000 kCal over a few days, then maintained for an overall duration of between 15 and 64 days. The seven patients who donated their liver were maintained on 1800 kCal per day until their surgery.

A second study from the transplant literature by Chen et al. used a diet and exercise strategy in 23 potential living donors identified to have a fatty liver on pre-transplantation sonography and computed tomography (CT) [10]. The potential donors were advised to reduce body weight via 1 to 3 months of calorie restriction and exercise. Unfortunately, no further details of this are published. Hepatic steatosis was measured in both studies by liver biopsy before and after weight loss.

A third study from the transplant literature by Doyle et al. used the Optifast meal replacement diet in 16 potential living donors identified to have hepatic steatosis on pre-transplantation CT or MRI (confirmed on liver biopsy in 8) [14]. Calorie intake was limited to 900 kCal per day for a variable duration (4–15 weeks, median 7.3 weeks), aiming for a BMI reduction of 10%.

Quality of evidence

Quality was assessed using the GRADE system [16]. The RCT by Barth et al. fulfilled “high” quality evidence criteria. The rest all fulfilled “low” quality evidence criteria. In all cases, this was influenced by study design as all were

Table 1 Summary of studies

Study	Type of study	Inclusion and participants	Intervention	Measurement of steatosis	Results	Limitations	Grade assessment
Reeves et al. Short-term preoperative diet modification reduces steatosis and blood loss in patients undergoing liver resection. Surgery. 2013;154(5):1031–7	Cohort study	Patients undergoing hepatic resection by single surgeon ($n=51$) Control — preceding cohort of patients ($n=60$)	Calorie restriction 900 kCal/day for 1 week Control no diet	Retrospective histology from specimens	Groups: - more pre-op chemotherapy in diet group (57% vs 0%, $P=.004$) - more T2DM in control group (4% vs 18%, $P=.020$) Outcomes: - Hepatocytes containing fat inclusions lower in diet group (15.7% vs 25.5%, $P=.050$) - Steatohepatitis lower in diet group (15% vs 27%, $P=.020$) - Intra-Operative blood loss lower in diet group (600 mL vs 906 mL, $P=.002$) - No difference in complications, mortality or length of stay	No baseline measurement of steatosis No measure of: -- operative difficulty -- acceptability of diet -- adherence to diet	Low

Table 1 (continued)

Study	Type of study	Inclusion and participants	Intervention	Measurement of steatosis	Results	Limitations	Grade assessment
Barth et al. Short-term Preoperative Diet Decreases Bleeding After Partial Hepatectomy. Annals of Surgery. 2019;269(1):48–52	Randomised controlled trial - block randomisation - two centres - operating surgeons blinded	Patients requiring hepatic resection, age > 18, BMI > 25 ($n = 32$ diet, 31 control)	Optifast meal replacement (800 kCal/day) vs. standard care for 1 week. Dietician phone contact twice weekly Control no diet	Retrospective histology from specimens	Groups: - Comparable for age, BMI, known cirrhosis and T2DM - Compliance with diet 94%. Calorie intake significantly lowers than controls (805 kCal/day vs 1991 kCal/day, $P < .001$; 19 g fat/day vs 84 g fat/day, $P < .001$) Outcomes: - Lower graded hepatocyte glycogen in diet group (1.6 vs 2.5, $P = .060$) (No difference in steatosis/steatohepatitis) - Intra-Operative blood loss lower in diet group (mean 452 mL vs 863 mL, $P = .020$; median 250 mL vs 500 mL) - Trend to lower blood transfusion in diet group (NS) - Liver mobility easier in diet group ($P = .004$) - No difference in complications, post-op liver function tests or length of stay	No baseline measurement of steatosis	High

Table 1 (continued)

Study	Type of study	Inclusion and participants	Intervention	Measurement of steatosis	Results	Limitations	Grade assessment
Nakamuta et al. Short-Term Intensive Treatment for Donors with Hepatic Steatosis in Living-Donor Liver Transplantation. Transplantation. 2005;80:608–12	Cohort study	Potential living donors with moderate steatosis (10–50% macrovesicular) ($n = 11$) Control — patients without steatosis ($n = 37$)	Calorie restriction (1000kCal/day) + Exercise (600 kCal/day) + bezafibrate (400 mg/day) for 15–64 days	Pre and post diet liver biopsy	Post-intervention: - improvement in steatosis (30% vs 12%, $P = .003$) - significant reduction in weight (73.7 kg vs 66.9 kg, $P < .010$) and BMI (26.4 kg/m^2 vs 24.2 kg/m^2, $P < .010$) - improvement in liver function tests and lipid profile Outcomes (livers actually transplanted, $n = 7$) - no adverse complications in donors or recipients - no difference in donor liver function or length of stay compared to control	No measure of: - operative difficulty - acceptability of intervention - adherence to intervention Variable time of intervention	Low

Table 1 (continued)

Study	Type of study	Inclusion and participants	Intervention	Measurement of steatosis	Results	Limitations	Grade assessment
Chen et al. Correlation Between Hepatic Steatosis, Hepatic Volume, and Spleen Volume in Live Liver Donors. Transplantation Proceedings. 2008;40:2481–3	Cohort study	Potential living donors with fatty liver on sonography and CT ($n = 23$) No control	Calorie restriction (no detail) + exercise (no detail) for 1–3 months	Pre and post diet liver biopsy	Post-intervention: - reduction in body-weight (73 kg vs. 70 kg, $P < .050$) - reduction in BMI (26.8 vs. 25.3, $P < .050$) - reduction in fat content of liver on biopsy (16.9% vs 6.6%, $P < .050$) - increased CT attenuation values in left and right lobes of liver (54HU vs 60HU and 51HU vs 58HU respectively, $P < .050$) - reduced volume of left and right lobes of liver (497 cm^3 vs 451 cm^3 and 927 cm^3 vs 846 cm^3 respectively, $P < .050$) 20 livers actually donated. All recipients alive	No control group No details of intervention No post-operative outcomes for donors or recipients presented	Low
Doyle et al. Treatment With Optifast Reduces Hepatic Steatosis and Increases Candidacy Rates for Living Donor Liver Transplantation. Liver Transplantation. 2016;22:1295–1300	Cohort study	Potential living donors with hepatic steatosis (> 10%) at baseline ($n = 16$) Control group — patients without steatosis ($n = 53$)	Optifast meal replacement (900 kCal/day). Duration varied, aimed for 10% BMI reduction (4–15 weeks, median 7.3)	Pre diet: imaging with CT/MR ± liver biopsy Post diet: liver biopsy	Post-intervention: - reduction in BMI (32.7 vs. 28.3, $P < .001$) - reduction in mean steatosis on biopsy (pre and post-diet biopsy $n = 8$: 29.3% vs 4.75%, $P < .001$) (all post biopsies < 10% steatosis) - diet "well tolerated" in all patients Outcomes (livers actually transplanted $n = 14$) Optifast vs controls - no difference in complications or length of hospital stay - 90-day mortality 0%	Variable time of intervention No measure of operative difficulty	Low

cohort studies and included retrospective data collection [3], inconsistencies in diet duration [9, 14], lacked information regarding the intervention [10] and had small numbers.

The effect of pre-op diet on steatosis

Three studies from the transplant literature demonstrated a significant reduction in steatosis (respectively) on liver biopsy following diet and exercise interventions [9, 10, 14]. This also corresponded to a significant reduction in body weight and BMI. In addition, Chen et al. found increased attenuation and decreased liver volume on CT following weight reduction [10].

On histological examination of the resection specimens, Reeves et al. found significantly lower steatosis and steatohepatitis in the diet group than controls. They also found that diet and lower BMI were associated with less steatosis [3]. On a similar examination, Barth et al. found significantly lower graded hepatocyte glycogen in the diet group than the control group. However, there was no significant difference between groups in steatosis or steatohepatitis [20]. It is important to note that a pre-op baseline measure of steatosis is not available in either of these studies.

Adherence to diet

Adherence to the diet intervention was only measured by Barth et al. [20]. They found that 94% of their patients were compliant with the meal replacement diet, and significantly fewer calories and fats were consumed per day than in the control group. Doyle et al. comment that the diet was "well-tolerated" by all patients, but unfortunately give no further information [14]. As the duration of diets varied between and within studies (1 week in two and variable duration in three), more data on compliance and acceptability to patients would have been interesting to compare.

Operative difficulty

Barth et al. are the only team who report on operative difficulty or liver mobility. They measured liver mobility as reported by the operating surgeon using a Likert scale (1 = easy, 5 = hard). The mean score was significantly better in the dietary intervention group compared to the control group (1.8 vs 2.9, $P = 0.004$) [20]. This infers an easier and thus potentially safer operation in the diet group. None of the studies comment on the duration of procedures or any other operative markers of difference between groups.

Intra-operative blood loss

Reeves et al. and Barth et al. found significantly lower mean intra-operative blood loss in the diet groups than controls (600 mL vs 906 mL, $P = 0.002$ and 452 mL vs 863 mL, $P = 0.020$ respectively) [3, 20]. In the latter, we suspect data should have been analysed with a non-parametric test, as median values reported do not suggest a normal distribution (250 mL diet vs 500 mL control). However, the numbers indicate a significant difference may still have been found. In addition, Barth et al. found a trend towards lower blood transfusion (autologous and allogenic) in these patients, but this was not significant.

Complications and mortality

No significant differences were found in postoperative complications (Clavien-Dindo Classification) or mortality in the studies by Reeves et al., Doyle et al. or Barth et al. [3, 14, 20]. Nakamuta et al. did not report any post-operative complications in either donors or recipients [9]. Unfortunately, Chen et al. did not discuss postoperative outcomes in donors; the only outcome reported in recipients was 0% mortality at the time of publication [10].

Length of hospital stay

Four studies measured the postoperative length of stay in hepatectomy patients; no significant difference was found between intervention and control groups [3, 9, 14, 20].

Discussion

Hepatic steatosis is increasingly prevalent within western populations and has significantly increased the risk of morbidity and mortality following hepatic surgery. Very low energy diets have been shown to reduce steatosis substantially, yet there is minimal evidence to demonstrate the role of such diets preoperatively in this area.

Five studies were identified that contributed to this question [3, 9, 10, 14, 20]. They involved a preoperative low-calorie diet with or without exercise or administration of bezafibrate. The studies showed significantly lower hepatic steatosis or graded hepatocyte glycogen on histological examination in diet groups. Improvements in intra-operative blood loss and liver mobility were also found with no significant differences in morbidity, mortality or length of stay. However, the quality of evidence in four out of five of these studies was low, and the numbers in all studies were small. Although significance was achieved for the primary outcome of blood loss in the RCT by Barth et al., it would be interesting to see if differences in secondary outcomes such as morbidity and mortality could have been shown had they recruited their original target or a larger sample size [20].

In a review of the effects of metabolic syndrome on hepatic resection, Agarwal and Daruwala [17] evaluate how outcomes in these patients could be improved. They note the evidence for increased morbidity after liver resection with moderate and severe steatosis, as well as correlations between BMI and Irinotecan chemotherapy with the degree of steatosis, and BMI and severity of the chemotherapy-induced liver injury. As weight loss is a standard of care in treating NAFLD, with evidence that it improves liver histology and insulin resistance, they concur with our hypothesis that a VLCD could have a role in optimising patients before liver resection surgery.

The degree of HS in subjects was measured variably between studies. Barth et al. and Reeves et al. undertook a histological assessment postoperatively, but no preoperative measurement, and therefore no baseline of HS was recorded [3, 20]. Due to the significant correlation between BMI and HS, BMI has been considered the "most promising marker" of steatosis [2], but this is a surrogate with drawbacks. Nakamuta et al., Chen et al. and Doyle et al. (in half of their patients) undertook liver biopsy before and after intervention [9, 10, 14]. This provides a direct comparison; however, it involves an invasive procedure for the patient which is not without risk of morbidity and even mortality [2, 17].

Various imaging techniques can be used to assess HS. Van Werven et al. correlated different modalities with histological assessment [21]. T1-weighted MRI and Proton (hydrogen 1) MR spectroscopic (H MR) measurement correlated with histology most strongly, followed by US and then computed tomography (CT). Only T1-weighted MRI and H MR were able to show differentiation between grades of steatosis, and both of these modalities showed better sensitivity and specificity than US or CT. The US is easier to access and less costly [2]. Chen et al. utilised sonography and CT to identify patients with moderate steatosis in their pre-transplantation investigations [10]. Doyle et al. used CT and MRI to identify patients with hepatic steatosis. Correlation with liver biopsy in the first eight of their patients was sufficiently accurate to use imaging alone in the rest of the cohort [14]. MRI is indicated preoperatively in most patients undergoing liver resection for neoplasms. Thus, it would be reasonable to consider including the relevant image series to make this assessment part of the routine preoperative workup in these patients. If MRI is not appropriate in potential living donors, CT or US could be used.

Patients were identified for inclusion in different ways. The studies involving potential living donors selected those with imaging or biopsy-proven moderate steatosis [9, 10, 14]. Barth et al. selected those with a BMI of 25 or greater [20]. We assume this was based on data showing that BMI correlates strongly with HS. In other studies, 85% of patients with BMI > 40, and 65% of patients with BMI 30–39.9 were found to have steatosis [1, 4]. Reeves et al. included all patients undergoing liver resection with no preoperative measurement of steatosis [3]. To determine both which patients could be at higher risk of complications second to underlying steatosis and to select which patients may benefit from a dietary intervention, a diagnosis should be sought. The most objective tool would be histological assessment with a liver biopsy, but the downsides have been discussed. Imaging such as MRI is likely to represent the best tool to select patients; it is minimally invasive and has good sensitivity and specificity for steatosis [21].

Preoperative VLCD and VLED have been shown to reduce liver volume and fat content and are acceptable to patients, at least in the short term [11–13]. However, as previously discussed, the duration of such diets has varied greatly from 2 to 12 weeks. In a study that implemented a 12-week diet, 80% of the changes within the liver (as assessed by serial imaging) were already present after 2 weeks, and adherence to the diet declined after 8 weeks [12]. A period of 2 or 3 weeks would seem a good compromise to maximise the benefits of the diet to the liver, balanced with the tolerability for patients. This is supported by other studies that showed significant changes over a much shorter period [11, 13].

Outcomes were measured heterogeneously which unfortunately makes drawing clear conclusions difficult. Reeves et al. and Barth et al. found a significant reduction in intraoperative blood loss following a preoperative VLED [3, 20]. The literature supports this, with other studies showing higher blood loss and blood transfusion requirements in those with severe steatosis [6, 7]. In addition, Barth et al. found an improvement in ease of liver mobility in the intervention group [20]. Similar improvements have been found in operative difficulty in bariatric surgery [15].

Some studies have shown higher rates of liver function derangement, bilirubin levels and even acute liver failure postoperatively in patients with steatosis [6, 7, 22]. This may be related to the steatotic liver being less tolerant of ischaemia–reperfusion injury. Nakamuta et al. found normalisation of liver function tests following their diet, exercise and drug intervention and no difference in postoperative liver function tests between these patients and the non-steatotic controls [9]. It is promising that weight reduction preoperatively could improve or reduce the risk of postoperative liver dysfunction in patients with steatosis.

Steatosis increases the risk of postoperative morbidity [6–8], particularly wound-related, hepatobiliary and gastrointestinal complications [1]. It is well known that morbidity and mortality after liver resection are closely related to remnant liver volume and function [2]. Tolerance of ischaemia–reperfusion and regenerative capacity is crucial. If a functional remnant steatotic liver is more vulnerable to injury, this could explain the higher rates of complications [2, 17]. In addition, if the steatotic liver is more difficult to mobilise and is at higher risk of significant blood loss during parenchymal transection, longer operative times [6] and more extended periods of inflow occlusion (Pringle Manoeuvre) may be required, increasing the duration of the warm-ischaemic time [2].

Conclusions

There is evidence of poorer outcomes in hepatic resection patients with existing hepatic steatosis. It seems likely that there is a role for a preoperative VLED to optimise these patients before surgery. However, few studies address this question directly and quality of evidence is variable. Their numbers are small, and their interventions are inconsistent and difficult to compare directly. Therefore, there is scope for a well-designed, multi-centre, randomised controlled trial to investigate this area further. The following aspects should be considered in designing such a study: duration of the diet intervention, evaluation of adherence to the diet, objective measure of change in HS (radiological or histological), intra-operative outcomes including blood loss and assessment of operative difficulty, postoperative outcomes including morbidity (assessed by Clavien-Dindo), mortality, length of hospital stay, readmission and quality of life measures.

Acknowledgements The HPB Consultant team (C Briggs, M Bowles, D Stell, A Kanwar, S Aroori) at University Hospitals Plymouth NHS Trust is acknowledged for supporting this review.

Authors' contributions Hitchins, C. R. — systematic search, review of search results, composition of the article. Jones, R. M. — systematic search, review of search results, contribution to text and review of the article. Kanwar, A. — supervision and review of search, analysis of results and review of the article. Aroori, S. — supervision and review of search, analysis of results and review of the article.

Data availability Not applicable.

Code availability Not applicable.

Declarations

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

References

1. Kooby DA, Fong Y, Suriawinata A, Gonen M, Allen PJ, Klimstra DS et al (2003) Impact of steatosis on perioperative outcome following hepatic resection. J Gastrointest Surg Off J Soc Surg Aliment Tract 7(8):1034–1044
2. Vetelainen R, van Vliet A, Gouma DJ, van Gulik TM (2007) Steatosis as a risk factor in liver surgery. Ann Surg 245:20–30
3. Reeves JG, Suriawinata AA, Ng DP, Holubar SD, Mills JB, Barth RJ (2013) Short-term preoperative diet modification reduces steatosis and blood loss in patients undergoing liver resection. Surgery 154(5):1031–1037
4. Gomez D, Malik HZ, Bonney GK, Wong V, Toogood GJ, Lodge JPA et al (2007) Steatosis predicts postoperative morbidity following hepatic resection for colorectal metastasis. Br J Surg 94(11):1395–1402
5. Dokmak S, Fteriche FS, Borscheid R, Cauchy F, Farges O, Belghiti J (2013) 2012 Liver resections in the 21st century: we are far from zero mortality. HPB 15:908–915
6. Behrns KE, Tsiotos GG, DeSouza NE, Krishna MK, Ludwig J, Nagomey DM (1998) Hepatic steatosis as a potential risk factor for major hepatic resection. J Gastrointest Surg 2:292–298
7. McCormack L, Petrowsky H, Jochum W, Furrer K, Clavien P-A (2007) Hepatic steatosis is a risk factor for postoperative complications after major hepatectomy: a matched case-control study. Ann Surg 245:923–930
8. de Meijer VE, Kalish BT, Puder M, Ijzermans JNM (2010) Systematic review and meta-analysis of steatosis as a risk factor in major hepatic resection. BJS 97:1331–1339
9. Nakamuta M, Morizono S, Soejima Y, Yoshizumi T, Aishima S, Takasugi S-i et al (2005) Short-term intensive treatment for donors with hepatic steatosis in living-donor liver transplantation. Transplantation 80:608–12
10. Chen T-Y, Chen C-L, Tsang LL-C, Huang T-L, Wang C-C, Concejero AM et al (2008) Correlation between hepatic steatosis, hepatic volume, and spleen volume in live liver donors. Transplant Proc 40:2481–3
11. Fris RJ (2004) Preoperative low energy diet diminishes liver size. Obes Surg 14(9):1165–1170
12. Colles SL, Dixon JB, Marks P, Strauss BJ, O'Brien PE (2006) Preoperative weight loss with a very-low-energy diet: quantitation of changes in liver and abdominal fat by serial imaging1–3. Am J Clin Nutr 84(2):304–311
13. Lewis MC, Phillips ML, Slavotinek JP, Kow L, Thompson CH, Toouli J (2006) Change in liver size and fat content after treatment with Optifast® very low calorie diet. Obes Surg 16:697–701
14. Doyle A, Adeyi O, Khalili K, Fischer S, Dib M, Goldaracena N et al (2016) Treatment with Optifast reduces hepatic steatosis and increases candidacy rates for living donor liver transplantation. Liver Transpl 22(9):1295–1300
15. Van Nieuwenhove Y, Dambrauskas Z, Campillo-Soto A, van Dielen F, Wiezer R, Janssen I et al (2011) Preoperative very low-calorie diet and operative outcome after laparoscopic gastric bypass. Arch Surg 146:1300–1305
16. Group TGW. GRADE Handbook 2013 [updated October 2013]. Available from: https://gdt.gradepro.org/app/handbook/handbook.html. Accessed 5 Jan 2022
17. Agarwal S, Daruwala C (2011) Metabolic syndrome and hepatic resection: improving outcome. HPB 13:846–859
18. Very low-energy diet before surgery in obese patients undergoing partial liver excision: a pilot randomised control trial (Very SuPPLE Trial). Cochrane Central Register of Controlled Trials (CENTRAL) 2019
19. Reddy MS, Safwan M, Kota V, Narasimhan G, Govil S, Rela M (2015) Impact of pre-operative weight loss on early outcomes of over-weight living liver donors. (varpagings) , 2015 Date of Publication: July 2015 Conference: 21st Annual International Congress of the International Liver Transplantation Society, ILTS 2015 Chicago, IL United States Conference Publication:: Transplantation; p. 281-2

20. Barth RJ, Mills JB, Suriawinata AA, Putra J, Tosteson TD, Axelrod D et al (2019) Short-term preoperative diet decreases bleeding after partial hepatectomy. Ann Surg 269(1):48–52
21. van Werven JR, Marsman HA, Nederveen AJ, Smits NJ, ten Kate FJ, van Gulik TM et al (2010) Assessment of hepatic steatosis in patients undergoing liver resection: comparison of US, CT, T1-weighted dual-echo MR imaging, and point-resolved1H MR spectroscopy. Radiology 256(1):159–168
22. Nagai S, Fujimoto Y, Kamei H, Nakamura T, Kiuchi T (2009) Mild hepatic macrovesicular steatosis may be a risk factor for hyperbilirubinaemia in living liver donors following right hepatectomy. BJS 96:437–444