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Tackling the dual burden of malnutrition in pregnancy – pregnancy after weight loss surgery

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The dual burden of malnutrition is characterised by the coexistence of undernutrition alongside overweight/obesity and diet-related noncommunicable diseases. It is a paradox which disproportionately affects women and is applicable to those who become pregnant after weight loss surgery. Obesity before and during pregnancy is associated with increased risk of adverse perinatal outcomes in both mother and child. Overall lifestyle interventions targeting weight loss in the preconception period have not proven effective, with people, and women in particular, increasingly seeking weight loss surgery. In women with severe obesity, surgery may normalise hormonal abnormalities and improve fertility. In those who become pregnant after surgery, evidence suggests a better overall obstetric outcome compared to those with severe obesity managed conservatively; however, there is heightened risk of maternal nutritional deficiencies and infants born small for gestational age. Specifically, pregnancy soon after surgery, in the catabolic phase when rapid weight loss is occurring, has the potential for poor outcomes. Lifelong micronutrient supplementation is required, and there is considerable risk of malnutrition if nutritional aftercare guidelines are not adhered to. It is therefore recommended that pregnancy is delayed until a stable weight is achieved and is supported by individualised advice from a multidisciplinary team. Further research is required to better understand how weight loss surgery affects the chances of having a healthy pregnancy and to ultimately improve nutritional management and patient care. In this review, we aim to summarise the evidence and guidance around nutrition during pregnancy after weight loss surgery.

pregnancy: bariatric surgery: maternal obesity: perinatal nutrition

The dual burden of malnutrition

The dual burden of malnutrition (DBM) is characterised by the coexistence of undernutrition, along with overweight and obesity and diet-related noncommunicable diseases, such as type 2 diabetes[1]. It may occur at the individual, household or population level and throughout the lifecourse, affecting all regions worldwide[1,2].

The 'undernutrition' component consists of wasting, stunting (in infants and children) and micronutrient deficiency. In many countries, women are disproportionately affected by the DBM at population level, for example 264 million women of reproductive age are affected by iron-deficiency anaemia[1], whilst there are an estimated 38·9 million pregnant women living with overweight/obesity globally[3].This population group are a critical demographic to target in order to

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prevent the intergenerational transfer of malnutrition to the offspring[2].

This paradox of the DBM is specifically applicable to women who become pregnant after weight loss surgery. Although weight loss surgery may result in an average decrease of 27 % body weight[4], many women are still living with obesity at the time of becoming pregnant[5]. Combined with their excess weight, their intake and absorption of both macro and micronutrients may be suboptimal to support the demands of pregnancy[6], potentially leaving them and the offspring at risk of nutritional deficit[7,8]. This is especially relevant for those who may become pregnant very soon after surgery, during the highly catabolic phase of rapid weight loss[9]. Prevention of nutritional deficits and optimisation of nutritional status during the preconception and pregnancy stages can be achieved with individualised advice and monitoring from a multidisciplinary team[9–11]. The aim of this narrative review is to discuss the DBM in the context of pregnancy after weight loss surgery, summarising the existing evidence and highlighting gaps in knowledge requiring further research. Topics related to postpartum health, such as breastfeeding and postpartum weight loss, are outside the scope of this review and as such are not described.

Preconception and maternal obesity: epidemiology and consequences

In Europe, whilst most countries do not systematically report obesity rates in their pregnant population, the prevalence of maternal obesity varies from 7 to 25 %[12]. More specifically, in Great Britain, between 2015 and 2017, it was estimated that 21·8 % of women giving birth were living with obesity, although 16·9 % did not have a BMI recorded in their medical notes, suggesting the prevalence could be greater[13]. Obesity in women has been linked to a number of adverse reproductive outcomes including delayed time to conception, increased rate of miscarriage and later pregnancy complications, such as gestational diabetes, instrumental and caesarean birth, preterm birth and large for gestational age (LGA) babies[14,15]. The effects of obesity may be worsened by the high incidence of abnormal glucose tolerance and excessive gestational weight gain (GWG) found in this group[12].

Recommendations on appropriate GWG are based on pre pregnancy BMI, with those who start pregnancy in the overweight or obese categories advised to gain less weight than those in the healthy weight or underweight categories[16]. Both excess and inadequate GWG are linked to adverse outcomes such as preterm birth, infant death and offspring weight status in childhood[14,17–19]. Due to the abundant evidence that overweight and obesity prior to pregnancy and excessive GWG incur perinatal risks, it is increasingly emphasised that aiming for achievement of a healthy weight *before* conception is fundamental[20–22]. A wealth of research exists investigating the most effective intervention for weight loss in this population group, however, no one strategy is effective[23–26], meaning more extreme interventions, such as weight loss medications[27] or surgery may be sought.

Overview of weight loss surgery

Weight loss surgery, also known as 'bariatric' or 'metabolic' surgery, is a viable treatment option for people with severe and complex obesity (BMI $\geq$ 40 kg/m^2)[28]. It can result in significant and sustained weight loss[29], with a Cochrane review demonstrating that surgery results in greater improvement in weight loss and weight-associated comorbidities, compared with non-surgical interventions, regardless of the type of surgical procedure used[30]. Nevertheless, weight regain is not uncommon, and revisional surgery may be required where complications arise[31,32]. Bariatric surgery modifies the anatomy and functioning of the gastrointestinal tract, leading to changes in capacity and nutrient absorption. Although bariatric surgery was historically categorised as either restrictive, reducing the size of the stomach, and/or malabsorptive, reducing absorption of nutrients, this is over simplistic and it is now understood that more complex neuroendocrine mechanisms contribute to weight loss and metabolic improvements[33–35]. Common procedures include sleeve gastrectomy (SG), Roux-en-Y gastric bypass (RYGB) and laparoscopic adjustable gastric banding (LAGB), although other surgery types and subtypes exist.

Following bariatric surgery, eating habits need to adapt to the new gastrointestinal physiology, which ultimately results in a lower energy intake[11,36]. Procedure-specific nutritional problems and symptoms may occur, which may be complicated by pre-existing nutritional deficiencies[37] and/or disordered eating behaviours[38]. Because of this greatly reduced energy and nutrient intake, protein intake should be optimised[11,39] and daily lifelong supplementation with multiple micronutrients, including iron, calcium and vitamin D is advised[10]. Regular laboratory surveillance for nutritional deficiencies is recommended, and supplementation should be individualised accordingly by a registered dietitian[10,11].

Access to weight loss surgery

Eligibility for weight loss surgery in England is governed by National Institute for Health and Care Excellence criteria guidelines, which were updated in 2023[28]. People should be offered a referral for assessment for surgery with a specialist weight management service if they meet the following criteria:

- Have a BMI $\geq$ 40 kg/m^2 or BMI between 35 and 39·9 kg/m^2 with a significant health condition that could be improved with weight loss and
- Agree to the necessary long-term follow up after surgery (for example, lifelong annual reviews)

Consideration should be given to those of South Asian, Chinese, other Asian, Middle Eastern, Black African or African-Caribbean family background using a lower BMI threshold (reduced by 2·5 kg/m^2), to account for the fact that these groups are prone to central adiposity and their cardiometabolic risk occurs at a lower BMI[28].

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At the initial assessment with the specialist weight management service, several factors will be considered, including:

- Whether all appropriate non-surgical measures have been tried
- Whether the person has or will receive intensive management in a tier 3 weight management service (a multidisciplinary specialist weight management clinic)
- General fitness for anaesthesia and surgery
- Nutritional status

The person's 'plans for conception and pregnancy (if someone is of childbearing age)' is also noted as a factor which should be discussed at this stage.

However, given that 64 % of the adult population in England are living with overweight or obesity, demand for weight loss surgery outstrips supply[40]. Indeed, a recent analysis of routinely collected primary care data in England from 2007 to 2020 reported that only 1 % of the 436 501 adults with severe and complex obesity underwent bariatric surgery[41]. A higher BMI and geographical location were the factors that were most strongly associated with undergoing bariatric surgery. The National Bariatric Surgery Registry[42] provides pooled national data to examine trends and outcomes in bariatric surgery. The most recent report with information up to August 2019 reported an average of approximately 6000–7000 procedures per year, with approximately 75 % conducted in the public National Health Service. Following the COVID-19 pandemic, the number of surgeries decreased to ~1300/year in 2020 with a small increase to ~2500/year in 2021/2022[42], underlying an increasing backlog of unmet need and the need to increase capacity[43]. This has led to an increase in bariatric tourism, whereby people travel abroad for weight loss surgery, motivated by exceedingly long waiting lists and lack of affordable private healthcare[44]. Concerns have been raised about preoperative assessment and perioperative care[44], which includes nutritional follow-up and aftercare.

Weight loss surgery and fertility

Women with obesity who are intending to become pregnant take longer on average to conceive, and time to pregnancy increases with the degree of obesity[45]. Obesity can lead to ovulatory dysfunction, due to the associated suboptimal glycaemic control and insulin resistance. Overweight and obesity can also have a negative effect on fertility through their association with polycystic ovarian syndrome[46]. Women with obesity referred for assisted reproductive technology may find restrictions are imposed until weight loss has occurred, due to potential complications of the surgical procedures and the lower positive fertility rate[47]. In women with severe obesity, bariatric surgery may normalise hormonal abnormalities and improve fertility[48,49]. Moxthe *et al.*[45] undertook a systematic review to assess the impact of surgery on male and female fertility. A total of 18 articles, covering 16 349 individuals, were included in the final review, seven of which included only men, ten included only women and one included both men and women. Bariatric surgery significantly improved hormonal balance in both men and women, sperm count in men and pregnancy in women. However, evidence was weak with a lack of discussion on confounding variables, and many studies did not differentiate between surgery types[45].

Research suggests that future pregnancy is important to 30·3 % of women under 45 years awaiting bariatric surgery[50], indicating that improved fertility may be a motivating factor to women seeking bariatric surgery. In 2019, women accounted for over 80 % of all gastric band insertions and 70 % of other weight loss surgery procedures[42], which does not reflect the gender specific obesity rates in the country[40]. The relatively high rate of women undergoing weight loss surgery is not unique to the UK, with data from 51 countries from 2014 to 2018 indicates that 73·7 % of people who had surgery were female[4]. A qualitative study of women in Sweden without children undertaken a few weeks prior to surgery supported the observation that improved fertility may be a motivating factor[51]. Participants (*n* 12) were aware that obesity can lead to a high-risk pregnancy, with potential risks to both mother and offspring. Although the participants were not necessarily seeking bariatric surgery for fertility reasons alone, there was a perception of enhanced fertility after surgery, which was viewed as important. Interestingly, there was no perception or belief that surgery could affect future pregnancies in a negative manner. However, it is important to note that as a result of improved fertility after bariatric surgery, the risk of an *unintended* pregnancy may increase and unplanned pregnancy within six months of surgery is relatively common[52]. Family planning is often not discussed in sufficient detail before surgery, and there is a need for improved advice around appropriate contraceptive and pregnancy planning in this high-risk group[9,50,52]

Timing of pregnancy after weight loss surgery

For all weight loss surgery patients, there is considerable risk of malnutrition if nutritional aftercare guidelines are not adhered to[10,11]. This risk is more pronounced for those in the preconception or early pregnancy phase. In addition to the routine nutritional supplementation guidance for all post-surgical patients, there are additional considerations around vitamin A, folic acid and more frequent biochemical monitoring for those planning pregnancy or already pregnant[9,10]. It is generally recommended that pregnancy should be delayed for 12–18 months after surgery to reduce the potential for foetal malnutrition[10,53]. International consensus guidance, based on a systematic review, recommends that pregnancy should be postponed until a stable weight is achieved[9]. which is typically achieved one year after SG or RYGB procedures and two years after LAGB. The systematic review identified 14 studies reporting on the surgery-to-conception interval and pregnancy outcomes; however, heterogenous methodology and outcome reporting made comparing results difficult[9]. The UK

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Royal College of Obstetricians and Gynaecologists recommends a more personalised approach, taking into account maternal age and balancing nutritional risk against the risk of delaying pregnancy in older women[54]. Ultimately irrespective of which guidelines are followed, contraceptive counselling should be offered to this population group, with availability of specific preconception clinical services for those who are intending to become pregnant[20].

Micronutrient deficiencies

In women who become pregnant after bariatric surgery, evidence suggests a better overall obstetric outcome in comparison to women with severe obesity managed conservatively; however, there is heightened risk of maternal nutritional deficiencies and infants born small for gestational age (SGA)[8,55–61]. Micronutrient deficiency is very prevalent in the post-bariatric surgery population[62]. This is particularly pronounced in pregnancy, due to the higher nutritional need for certain micronutrients, such as iron, folate and vitamin D[63]. In the general post-bariatric surgery population, deficiency may be due to a combination of general or procedure-specific factors; including the type of surgery and risk of malabsorption, pre-surgical deficiences[37], surgical complications, poor adherence to supplementation, food aversion/intolerance[64], taste disturbances[65] or psychological factors. It is not known whether these factors affect pregnant women disproportionately and whether there is any interaction with pregnancy-related cravings[66] or nausea.

Routine biochemical monitoring of several micronutrients, including zinc and folate, is recommended in each trimester[10]. Depleted maternal concentrations of vitamins A, B_{12}, K, folate and iron post-bariatric surgery were reported in a 2015 systematic review[67]; however, the quality of reporting was not rated highly. A more recent systematic review identified 27 studies, comprising 2056 women with pregnancies after bariatric surgery. Deficiencies were reported in maternal concentrations of vitamins A, B_1, B_6, B_{12}, C, D, K, iron, calcium, selenium and phosphorous[68], indicating vast improvements are required in nutritionally monitoring and care of this group. Of the studies investigating nutrient intake in post-surgical pregnancies most focus on adherence to micronutrient supplementation, with a paucity of data available on food intake during pregnancy and most studies omitting critical information about methods of measuring dietary intake[6,7]. The limited available research suggests dietary patterns can be improved substantially[69,70]; however, qualitative research indicates that most women were given unhelpful or contradictory advice about diet and nutrition whilst pregnant[52]. It is therefore recommended that pregnant women with a history of bariatric surgery are given intensive dietetic support, preferably by dietitians with experience of managing the nutritional complications of bariatric surgery, and closely monitored for nutritional deficiencies[10]. Improved understanding and characterisation of this population group would help to target services towards the women in most need of dietary support.

Specific nutrition recommendations for the preconception and pregnancy phases

Preconception phase. Given that over 50 % of pregnancies in the general population are unplanned, the preconception phase can be difficult to define[20]. Therefore, the need to make nutritional adjustments during the preconception phase should ideally be mentioned to all women of reproductive age who are considering surgery. In those planning pregnancy, the focus should remain on the regular monitoring of diet quality and nutritional status and on encouraging a general healthy dietary pattern and lifestyle. However, dietary needs may differ in terms of the food group proportions from that of the nonsurgical population before (and during pregnancy[9]). This is due to a greater emphasis on lean protein sources, followed by fruit and vegetables, and lastly starchy carbohydrates, as the main component of the post bariatric surgery diet.

It is recommended that pregnancy should be planned, and that diet quality and nutritional supplementation should be optimised preferably 3–6 months prior to conception[9]. The guidelines of the British Obesity and Metabolic Surgery Society are shown in Table 1[10]. They recommend that following all bariatric procedures, a complete multivitamin and mineral supplement (containing thiamine, iron, zinc, copper and selenium) is taken. Care should be taken to check that the micronutrient supplement contains sufficient amounts of vitamins and minerals to counter the malabsorptive effects of bariatric surgery; however, additional supplements will be needed and should be adjusted according to biochemical monitoring. This applies to those in the preconception and during pregnancy also[10].

All women planning for pregnancy should take folic acid supplements to reduce the risk of foetal neural tube defects. Prior to conception and until the 12th week of pregnancy, 400 µg/d folic acid is recommended. Women with a BMI > 29·9 kg/m^2 or who have diabetes should take a higher dose of folic acid of 4 or 5 mg/d during the periconception period and throughout the first trimester[71,72]. Vitamin B_{12} should be measured during the preconception period before additional folic acid supplements are given. Vitamin B_{12} regimens should be continued at a dose of 1 mg every 3 months via intramuscular depot injection or alternatively, oral supplementation (1 mg/d) can be used to increase compliance in the patient[9]. Vitamin A in the retinol form is teratogenic[73], so it should be replaced with vitamin A in the beta carotene form. This may be achieved by taking a preconception or pregnancy-specific vitamin and mineral supplement[10]; however, the levels of other micronutrients in these preparations should be checked to ensure they are adequate. Regular laboratory surveillance for nutritional deficiencies is recommended and supplementation should be individualised accordingly[9,10]. A more frequent review with the specialist bariatric

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Table 1. Daily dose recommendations for micronutrient supplementation for adults post bariatric surgery, incorporating considerations for (pre) pregnancy supplementation[10]

Nutrient	Dose
Iron	Consider starting with 200-mg ferrous sulphate, 210-mg ferrous fumarate or 300-mg ferrous gluconate daily and twice daily in menstruating women and adjust depending on blood results.
Folic acid	400 μg daily, during preconception and first trimester, 4–5 mg in women with diabetes or obesity.
Calcium	1200–1500 mg in divided doses (includes dietary intake)
Vitamin D	Adjust vitamin D3 supplementation to maintain serum 25-hydroxyvitamin D levels of 75 nmol/L or higher. Maintenance levels of between 2000 and 4000 μg oral vitamin D3 per day may be required following SG and RYGB.
Vitamin A	Take a complete multivitamin and mineral supplement containing U.K. government dietary recommendations for vitamin A, which should be in the beta carotene form.
Vitamin K	Following malabsorptive procedures, daily oral supplementation with additional vitamin K starting with 300-μg is recommended.
Vitamin E	Following malabsorptive procedures, starting daily supplementation with 100-μg oral vitamin E is recommended and adjust as necessary.
Zinc	Recommend a multivitamin and mineral containing at least the government recommended daily allowance for zinc.
Copper	Following RYGB and SG, recommend complete multivitamin and mineral oral supplement containing 2-mg copper
Selenium	Recommend a complete multivitamin and mineral supplement containing selenium.
Thiamine	Consider recommending oral thiamine or vitamin B co strong tablets for first 3- to 4-month post-surgery. Prescribe oral thiamine 200–300 mg daily, vitamin B co strong 1 or 2 tablets, three times a day to people with symptoms such as dysphagia, vomiting, poor dietary intake or fast weight loss.

RYGB: Roux en Y gastric band, SG: Sleeve gastrectomy.
Vitamin and mineral supplements should be reviewed regularly and adjusted accordingly[10].

dietitian may be required during this phase[10] to provide individualised advice.

Pregnancy. There is little or no evidence-based specific dietary (food-based) advice for pregnancies post bariatric surgery[6,8]. Most studies focus on adherence to micronutrient supplementation, with a paucity of data available on food intake during pregnancy[6,7]. Dietary recommendations are based on consensus expert opinion, extrapolated from recommendations for the post-surgical patient and the general pregnant population[9]. Energy requirements should be individualised based on pre-pregnancy BMI, gestational weight gain and physical activity level[9]. In the non-pregnant postsurgical patient, protein intakes of up to 1·5 g/kg ideal body weight/day are proposed (up to a maximum of 2·1 g/kg)[11,53]. How this translates into pregnancy and in particular how ideal body weight should be defined have not been studied. Exposure to abnormal glucose levels during pregnancy, similar to that seen in nonsurgical women with gestational diabetes, warrants dietary intervention. In the case of hyperglycaemia, it is recommended to reduce rapidly absorbed carbohydrates, substituting them with protein and foods of a low glycaemic index[9]. Alcohol and caffeine intake should be minimised, as per general pregnancy dietary guidance. During pregnancy micronutrient supplementation is recommended to continue as per Table 1, with biochemical monitoring and correction as required.

Biochemical monitoring during pregnancy. Routine biochemical monitoring of several micronutrients, including zinc and folate is recommended to occur in each trimester[9–11] as listed in Table 2. Vitamin E, zinc, copper and selenium should be monitored during the first trimester. During pregnancy, serum levels of many micronutrients and macronutrients will decrease because of the expanding maternal blood volume and increasing demands of the growing foetus. Accordingly, reference values for serum micronutrient levels may change during pregnancy, and it is useful to check results against pregnancy-specific reference ranges[10].

Post bariatric patients with prolonged vomiting are at risk of thiamine deficiency; this may occur in pregnant women with severe pregnancy sickness. Clinicians should be aware of the signs of thiamine deficiency and prescribe 300 mg daily with vitamin B complex. Furthermore, intravenous thiamine should be given at a minimum dose of 100 mg daily with intravenous vitamin B complex if oral supplementation with a B vitamin-complex is not possible due to the severity of vomiting[9].

Gestational weight gain. There are no formal, evidence-based guidelines from the UK government or professional bodies on appropriate GWG[74]. However, the Institute of Medicine guidelines[16], based on pre-gestational BMI, are informally used in the United Kingdom. Additionally, the Royal College of Obstetricians and Gynaecologists suggest a pragmatic approach for women with obesity, recommending that a focus on a healthy diet may be more applicable than a prescribed weight target[71]. Little is known about GWG in women post weight loss surgery, either in terms of recommendations or outcomes[29]. In a recent study of 337 post-surgery pregnancies conducted in France, GWG was categorised as appropriate in 26·7 %, insufficient in 35 % and excessive in 38·3 % of pregnancies[75]. Gestational age at birth was significantly lower when GWG was insufficient. Overall, the study concluded that adequate GWG was associated with better obstetrical outcomes and that the Institute of Medicine recommendations can be applied to pregnant women who have undergone bariatric surgery, a finding supported by a later systematic review[59]. A multisite study from Belgium had similar findings, noting that excessive weight gain increased weight retention after delivery and could precipitate weight regain[76]. Overall, the extent to

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Table 2. Recommended biochemical monitoring during each trimester of pregnancy[10]

- Ferritin
- Vitamin B12
- Folate
- Iron studies including transferrin saturation and full blood count
- Serum vitamin D with calcium, phosphate, magnesium and parathyroid hormone
- Vitamin A
- Serum vitamin K1 concentration level
- Serum protein and albumin
- Renal function and liver function tests

which GWG affects the long-term weight outcomes of bariatric surgery is unclear[59,77,78], a factor which could be investigated with longer term follow-up.

Current developments in obesity management and future research needs

With women making up the majority of people having bariatric surgery[42], there is need for many evidence gaps surrounding pregnancy to be filled. Consensus European expert guidelines on periconception, antenatal and postnatal care written in 2019[9] highlighted many gaps in relation to bariatric surgery; namely how best to meet nutritional needs with food, optimal screening and supplementation strategy for micronutrient deficiencies before and during pregnancy, how to ensure safe and acceptable gestational weight gain, in addition to how best to communicate advice around pregnancy planning. However, since then, the onset of the COVID-19 pandemic has further limited the number of surgeries being conducted, with demand and eligibility far outstripping supply[41]. Simultaneously, new pharmaceutical weight loss therapies, Glucagon Like Peptide-1 Receptor Agonists (GLP-1RA), have been licenced for use in the UK[79,80], which have been evaluated for use both prior[81] to and after bariatric surgery[82]. Although GLP-1RAs are contraindicated during pregnancy[83,84] and there are concerns about inhibition of absorption of oral contraceptives[85], there is evidence for their use in improving fertility in those with PCOS[27]. Ultimately more research about the effect of GLP-1RAs on reproductive health outcomes in women is needed[86], especially as they may be accessed without a prescription and potentially may be sought by those who are seeking improvements in fertility whilst facing a prolonged wait for surgery. With the recent publication of the women's health strategy for England[87] and pledge to improve funding and research into women's reproductive health from its current low level[88], it is hoped that both the research and the implementation of novel research findings around maternal weight loss and pregnancy outcomes will accelerate in the coming years.

Conclusion

Pregnancy after weight loss surgery represents a time of increased nutritional risk, as there is a potential for multiple micronutrient deficiencies, co-existing alongside overweight or obesity, potentially during a phase of rapid weight loss. With individualised advice and monitoring from a multidisciplinary team, the risk and effects of the DBM and increased risk of unintended pregnancies can be addressed. This includes emphasis on pregnancy planning, waiting until weight stabilisation has occurred, prevention of nutritional deficiencies by providing timely nutritional monitoring and optimising GWG with individualised dietary advice. Many gaps remain in the care and management of this population group, with further research required, especially in the context of new pharmacotherapy and the increasing trend of seeking surgery abroad. Specifically prospective research studies recruiting participants before surgery with long term follow-up are required to investigate research gaps comprehensively.

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Conflict of interests

The authors have no conflict of interest.

Authorship

Initial draft of article was written by K.M. and critically reviewed and revised by all authors.

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