

Abstract

Bariatric surgery is recognised as the most clinically and cost-effective treatment for people with severe and complex obesity. Many people presenting for surgery have pre-existing low vitamin and mineral concentrations. The incidence of these may increase after bariatric surgery as all procedures potentially cause clinically significant micronutrient deficiencies. Therefore, preparation for surgery and long term nutritional monitoring and follow-up are essential components of bariatric surgical care.

These guidelines update the 2014 British Obesity and Metabolic Surgery Society nutritional guidelines. Since the 2014 guidelines the working group has been expanded to include healthcare professionals working in specialist and non-specialist care as well as patient representatives. In addition, in these updated guidelines the current evidence has been systematically reviewed for adults and adolescents undergoing the following procedures: adjustable gastric band, sleeve gastrectomy, Roux-en-y gastric bypass and biliopancreatic diversion/duodenal switch. Using methods based on Scottish Intercollegiate Guidelines Network methodology, the levels of evidence and recommendations have been graded. These guidelines are comprehensive, encompassing preoperative and postoperative biochemical monitoring, vitamin and mineral supplementation and correction of nutrition deficiencies before, and following bariatric surgery, and make recommendations for safe clinical practice in the UK setting.

Potential conflicts of interest

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MO, HP, JP, RW, JM, NW, DT, KC, JD, MS, AB, IM, JB have nothing to disclose.

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Abbreviations

BOMSS, British Obesity and Metabolic Surgery Society;

AGB, adjustable gastric band;

SG, sleeve gastrectomy;

RYGB, Roux-en-y gastric bypass;

BPD/DS, duodenal switch;

OAGB /MGB, One anastomosis gastric bypass /mini gastric bypass;

SADIs, single anastomosis duodenal ileal bypass with sleeve gastrectomy;

SIGN, Scottish Intercollegiate Guidelines Network;

CT, non-randomised controlled trials;

RCT, randomised controlled trial;

EL, Evidence level;

GPP, Good practice point;

PTH, parathyroid hormone;

FPG, Fasting Plasma Glucose;

25OHD, 25-hydroxyvitamin D;

PIVKA-II, Protein Induced by Vitamin K Absence or antagonism;

ROS, Royal Osteoporosis Society;

Introduction

Bariatric surgery is recognised as the most clinically and cost-effective treatment option for people with severe and complex obesity.¹ All bariatric surgery procedures impact on nutrition to varying degrees and can potentially cause clinically significant deficiencies of micronutrients.²⁻⁴

The British Obesity and Metabolic Surgery Society (BOMSS) published its first nutritional guidelines in 2014 following a review of UK clinicians, which showed widespread variation in nutritional monitoring and vitamin and mineral supplementation both pre- and post-surgery.^{5,6} This is an update and review of those guidelines. Since the 2014 guidelines, a number of other nutritional guidelines for the care of people who undergo bariatric surgery have been published.^{3,4,7-11} However, not all have been specifically related to micronutrition, had dietetic involvement and included either primary care or patient representatives. In addition, previous guidance aimed at the management of adolescents undergoing bariatric surgery has only included general nutritional recommendations,¹²⁻¹⁴ despite this vulnerable group being at high risk of developing nutritional deficiencies.¹⁵⁻¹⁹ Until recent guidelines by Shawe et al¹¹, there has been little detail included in previous guidelines on recommendations for the nutritional management of pregnancy post-surgery. In summary, there are no up to date, comprehensive UK guidelines for the peri- and postoperative nutritional care of patients undergoing bariatric surgery.

In this update of BOMSS nutritional guidelines,⁵ we have aimed to systematically review the current evidence for preoperative and postoperative biochemical monitoring and micronutrient replacement for adolescents and adults undergoing bariatric surgery, including pregnancy, and to update the recommendations for safe practice in the UK setting. We have

focussed on the procedures: adjustable gastric band (AGB), sleeve gastrectomy (SG), Roux-en-y gastric bypass (RYGB), duodenal switch (BPD/DS) as these were the most common procedures being undertaken at the time of the literature search. The aim of this work was to produce a set of guidelines that are comprehensive, but remain accessible to healthcare professionals involved in preparation and aftercare of people undergoing bariatric surgery, in particular those working in the UK.

Methods

Members of the original BOMSS nutritional guidelines were involved in the update with additional members selected on the basis of their expertise and experience in supporting people who undergo bariatric surgery. In addition, two patient representatives were included. The membership therefore included six dietitians (MO, GP, NW, DT, KC, JD), two general practitioners (HP, CH), three physicians (JP, RB, JM), two chemical pathologists (JB, MS) two surgeons (RW, KM) and two patient representatives (AB, IM). These guidelines aimed to address four main areas of clinical management for patients undergoing bariatric surgery:

What are the clinical recommendations that are appropriate for:

- Preoperative nutritional screening/or monitoring before bariatric surgery
- Postoperative nutritional screening and/or monitoring after bariatric surgery
- Vitamin and mineral supplementation to prevent nutritional deficiencies following bariatric surgery
- Treatment of nutritional deficiencies before/after bariatric surgery

In order to update the evidence base from the 2014 BOMSS guidelines,⁵ the Cochrane library, NHS Evidence and the HDAS database platform, specifically Medline, PubMed , Cinahl and

Embase databases were searched from 2014 to January 2018 to identify studies and publications related to the nutritional care of adult and/or adolescent patients pre- or post-bariatric surgery. This included studies on the prevention, incidence, prevalence or treatment of nutritional deficiencies pre- and/or post-bariatric surgery. For pragmatic reasons the searches were restricted to publications written in English. A sample search strategy can be found in Supplementary Information Table S1. We also screened any publications suggested by members of the guidelines group based on their knowledge of their own areas of expertise.

Studies were included if they addressed the care of adults or adolescents who were planning or had undergone a bariatric surgical procedure. We focused on: AGB, SG, RYGB and BPD/DS as these were the most common procedures undertaken at the time of the literature search. To be included, papers were required to report data on the nutritional care of people undergoing bariatric surgery. This included both pre- and post-bariatric surgery care and both nutritional monitoring and treatment to manage nutritional deficiencies. We excluded studies in one anastomosis gastric bypass/mini gastric bypass (OAGB/MGB) and single anastomosis duodenal ileal bypass with sleeve gastrectomy (SADIS), due to the scarcity of long-term data at that time, and excluded studies on groups with conditions that in themselves may lead to nutritional problems, such as coeliac disease. We included any study type as well as previous relevant clinical guidelines, but excluded letters, editorials and conference abstracts.

Titles and abstracts were screened for inclusion (MO, HP, CH, JP, RB, JB, JM, EA, RW, KM, MS, GP). Full papers were screened by two independent reviewers (MO and HP). All of the author group, except the patient representatives, were then divided into pairs of independent reviewers and a standardised data extraction form was used to characterise the population, intervention, control groups (where appropriate), study outcomes, and to appraise the

quality of the study. Disagreements were resolved by discussion or by a third reviewer. Study quality was assessed using an established quality assessment tool appropriate for each study type.²⁰⁻²⁷ (See Supplementary Information Table S2 for details of the quality assessment tools).

Data extracted from the studies were initially synthesised by MO with discussion with members of the guidelines group on specific areas of expertise where needed. Early proposed recommendations were circulated amongst the guideline group for iterative discussion and review. Following this the contributing evidence and recommendations were graded based on Scottish Intercollegiate Guidelines Network²⁸ (SIGN) methodology (see Table 1) by two independent reviewers (MO and HP). Draft recommendations together with their grading were then circulated within the guideline group in an iterative process until consensus was achieved on both the recommendations and grading. Although we included previously published guidelines in our literature review, we graded those recommendations as being expert opinion unless we had reviewed the original articles cited by the authors. Just prior to submission, “Clinical practice guidelines for the perioperative nutrition, metabolic, and nonsurgical support of patients undergoing bariatric procedures - 2019 update were published so were included”.⁴

Results

The searches identified 601 studies, 510 of which were identified through database searches and 91 from other sources. One hundred and seventy-one full papers were screened and 139 were included. The main reasons papers were excluded were that no relevant nutritional data were reported or that the study population did not include people who had undergone

bariatric surgery. The 32 full papers removed with reasons for exclusion are listed as Supplementary Information in Table S3.

Summary of the studies

Pre-bariatric surgery studies included seven cross-sectional and two cohort studies. Pre- and post-bariatric surgery studies included one non-randomised controlled trials (CT), one randomised controlled trials (RCTs), 20 cohort studies, one case control study, seven systematic reviews, eight narrative reviews and seven clinical practice guidelines. Post surgery only studies included two CTs, six RCTs, 30 cohort studies, two case control studies, seven cross-sectional studies, one case series, 10 case studies, one survey, nine systematic reviews, seven narrative reviews and ten clinical practice guidelines. Eight studies/reviews included adolescents only and one included both adolescents and adults. The rest of the papers included adults only. There were 45 studies or systematic reviews, which included SG, 74 included RYGB, 29 included BPD/DS and 17 included AGB. Most clinical practice guidelines and narrative reviews focused on a range of procedures including AGB, SG, RYGB and BPD/DS. Studies were conducted in a variety of geographical areas including Australia, Canada, Middle East, South America and Asian countries (23 studies in total), but the majority were conducted in Europe (73 studies) or in the USA (40 studies). Follow-up in the postoperative studies varied between six months and 15 years. The majority reported at one year with smaller numbers reported at five, 10 or 15 years. 49 studies reported on a range of micronutrients, 18 focused on vitamin D, calcium or bone health, 17 focused on anaemia, iron, folate or vitamin B12, eight focused on nutrition issues related to neurological disorders and seven focused on trace minerals.

Overview and rationale for recommendations

There is a high prevalence of nutritional deficiencies in both adults and adolescents with severe and complex obesity. The most common deficiencies include anaemia, ferritin, folate, vitamin B12 and vitamin D.^{15,29-50} Less frequently, lower levels of thiamine,^{36,43} vitamin A,⁵⁰ and zinc and copper³³ have been reported. Following surgery, the risk of nutritional deficiencies increases due to the impact of bariatric surgery on both oral intake and absorption.

1. Preoperative care

All people should have a comprehensive nutritional assessment prior to bariatric surgery. Detailed preoperative care recommendations are listed in Table 2. A specialist dietitian, skilled in bariatric nutrition, should undertake a detailed dietary and nutritional assessment.^{1-5,13,51} Essential preoperative blood tests include screening for nutritional deficiencies, diabetes, dyslipidaemia and renal function.^{2-4,9,10,12-14,52-54} Additional discretionary tests should be considered if clinically indicated; for instance, vitamin A, zinc, copper and selenium serum levels before malabsorptive procedures such as BPD/DS,^{3,4} because of the higher levels of postoperative deficiencies. (See sections 2.4, 2.5).

Nutritional deficiencies should be investigated and corrected as clinically indicated before surgery.³ The dietitian should continue to give support and education as part of preoperative preparation.^{3,14,51,54}

Many centres recommend that people follow a low calorie/low carbohydrate diet immediately prior to surgery to reduce the size of the liver.⁵⁵ As these diets are not always nutritionally complete, a multivitamin and mineral supplement is needed.⁵⁶

1.1 Haematinics

Prevalences of iron deficiency and low haemoglobin levels ranging from 0 to 47% have been reported in people going forward for bariatric surgery.^{15,30-33,35-37,41,43,46,49,57-59} Reports of folate deficiency before bariatric surgery have ranged between 0 and 63% ,^{15,30,34,36,50,60} and between 0 to 23% for vitamin B12 deficiency.^{29,30,32-34,36,40,41,43,47,50,58}

1.2 Vitamin D, calcium and parathyroid hormone

Vitamin D deficiency is common in people with severe and complex obesity^{19,29,30,32,34,38,40,42-48,50,58,61-65} with reports as high as 99% of participants in one study conducted by Ben-Porat et al.⁴⁰ A raised albumin-adjusted serum calcium in the presence of raised parathyroid hormone (PTH) may indicate primary hyperparathyroidism, and so both PTH and calcium should be measured preoperatively.⁶⁶ If primary hyperparathyroidism is suspected, advice should be sought from a specialist in this area.⁶⁶

1.3 Vitamin A, zinc, copper, selenium and malabsorptive procedures

The reported prevalence of vitamin A deficiency where tested is low.^{29,38,39,43,50} Zinc, copper and selenium deficiencies are not commonly reported prior to surgery,^{30,36,37,67} although De Luis et al.³³ reported prevalences of 73.9% and 63.8% deficiency, respectively for zinc and copper. We did not consider that there was strong evidence for routine checking of vitamin A, zinc, copper and selenium levels prior to bariatric surgery unless there is suspicion of deficiency.

Malabsorptive procedures such as BPD/DS are associated with an increased incidence of vitamin A, zinc, copper and selenium deficiencies,⁶⁸⁻⁷⁴ and so consideration may be given to checking these preoperatively before these procedures.

1.4 Thiamine

Few studies measure thiamine levels preoperatively. However, low levels have been reported in some people.^{36,43} We did not consider there was strong evidence for routine checking of thiamine levels.

1.5 Magnesium

Few studies have measured magnesium prior to surgery.^{36,58} Low prevalence of magnesium deficiency is reported.^{36,58}

1.6 HbA1c, lipids, liver and renal function

These guidelines do not specifically address the preoperative medical assessment of people with type 2 diabetes. However, biochemical monitoring is an important part of pre- and post-operative care, since bariatric surgery is used to manage type 2 diabetes and its associated comorbidities^{1,10,75,76} Therefore, a brief summary of these important aspects of care is included here.

1.6.1 Preoperative and perioperative management of diabetes

People with known type 2 diabetes should have an up to date preoperative evaluation of current glycaemic control including measurement of HbA1c, and glycaemic control should be optimised before surgery.¹⁰ Insulin and other diabetes medications should be reviewed and adjusted as appropriate.¹⁰ The European Association for the Study of Obesity taskforce

has made detailed suggestions for perioperative management of diabetes.¹⁰ The preoperative HbA1c is also a baseline from which the impact of bariatric surgery and subsequent medication adjustments are assessed. This assessment is essential in planning postoperative diabetes management, especially if withdrawal of insulin is planned.¹⁰

Preoperative consideration of diabetes aetiology is important if this is not already known, because the expected impact of bariatric surgery on glycaemic control differs between type 1 and type 2 diabetes. People with type 1 diabetes have absolute insulin deficiency, and while people with obesity and type 1 diabetes may achieve improved glycaemic control following bariatric surgery,⁷⁷ they will not be expected to achieve glycaemic remission and insulin withdrawal. Furthermore, in one single centre observational study the postoperative occurrence of both diabetic ketoacidosis and hypoglycaemia was observed in people with type 1 diabetes undergoing bariatric surgery.⁷⁸ Therefore, people with type 1 diabetes require careful blood glucose monitoring to detect reducing insulin requirements.

The presence and extent of diabetes complications should also be noted preoperatively because long term monitoring of existing microvascular complications may still be required. There is also some evidence in one small case series that the abrupt glycaemic improvement following bariatric surgery can exacerbate proliferative diabetic retinopathy.⁷⁹

Finally, people without known diabetes should routinely undergo preoperative screening for diabetes. Appropriate tests include HbA1c and Fasting Plasma Glucose (FPG) and/or a discretionary oral glucose tolerance test. Diabetes should be diagnosed according to established criteria.⁸⁰

1.6.2 Dyslipidaemia, liver and renal function

People with pre-existing treated dyslipidaemia should undergo a preoperative fasting lipid profile, as a baseline from which to assess the subsequent effect of bariatric surgery on dyslipidaemia during follow-up.^{4,81}

The most common liver abnormality in this patient group is non-alcoholic fatty liver disease (NAFLD), and bariatric surgery results in pronounced improvements.⁸² Therefore, it is appropriate routinely to check liver function preoperatively to assess for the presence of NAFLD, and as a baseline for any long term monitoring.

1.7 Correction of nutritional deficiencies preoperatively

As bariatric surgery impacts on oral intake and absorption, we recommend treatment and correction of deficiencies preoperatively.³ See section 4.

2. Postoperative care and biochemical monitoring

People should have access to life-long monitoring following bariatric surgery to ensure that nutritional requirements are met and risks of developing post-bariatric surgery related nutritional deficiencies reduced.^{1-4,8,10,12-14,83} The type and frequency of nutritional monitoring should reflect the bariatric procedure and may need to be individualised. The follow-up care should remain with the bariatric surgery centre for the first two years.^{1,8,83} Following discharge, people should be offered lifelong monitoring of nutritional status at least annually as part of shared-care management.^{1,8,83} Detailed recommendations are listed in Table 3.

2.1 Urea and electrolytes, renal and liver function tests

Renal function should be monitored for all procedures. Initially following surgery, people may have difficulty in maintaining an adequate fluid intake and become dehydrated.⁵¹ Routine

postoperative monitoring of liver function is also appropriate,^{2,84} to document changes in NAFLD, as well as part of general safety monitoring for hypoalbuminaemia which may indicate underlying infection and inflammation.

2.2 Haematinics

There is a high incidence of iron deficiency anaemia following bariatric surgery due to low dietary iron intake, reduced intestinal absorption, and for some women, menstruation.^{15,18,19,35-37,41,57-60,72-74,85-94}

Vitamin B12 absorption is adversely affected by SG, RYGB and BPD/DS as it requires an acidic environment and presence of intrinsic factor produced by the gastric parietal cells.⁹⁵ Many people have about two years' stores of vitamin B12, therefore deficiency may present several years after surgery.^{15,18,19,40,41,47,57-59,65,73,86-89,92,93,96} Vitamin B12 deficiency impacts adversely on the haematopoietic and nervous systems and may result in megaloblastic anaemia and irreversible neuropathies.⁹⁵ Vitamin B12 levels are not a good predictor of deficiency since methodological problems affect sensitivity and specificity.⁹⁷ In view of this, methylmalonic acid (MMA) has been proposed as a better indicator, but this requires a sensitive plasma assay not routinely available in the UK.^{98,99} If there is doubt about vitamin B12 deficiency, it is better to treat.⁹⁷

Since folic acid is absorbed in the small bowel,⁹⁵ absorption may be affected by RYGB or BPD/DS, but deficiency is also observed following SG so is more likely to be due to low dietary intake or non-adherence with vitamin and mineral supplementation.^{15,18,19,32,34,40,41,47,87,100,101}

It should be noted that megaloblastic and macrocytic anaemia, associated with vitamin B12 deficiency, can be masked by folic acid supplementation, high folate levels or iron

deficiency.⁹⁵ It is essential to assess all haematinics before recommending additional folic acid supplements.^{97,102}

2.3 Vitamin D, calcium and parathyroid hormone

Vitamin D plays an important part in musculoskeletal health and is essential for calcium absorption and bone mineralisation.^{44,48,64,103,104} Following bariatric surgery, the desirable serum 25-hydroxyvitamin D (25OHD) levels to optimise bone health, prevent secondary hyperparathyroidism, improve bone mineral density and calcium balance, and decrease fracture risk are not known.^{44,48} Many guidelines recommend 25OHD levels of >75nmol/L.^{2-4,52} However, Chaktoura suggested that these were based on expert opinion rather than robust evidence, and proposed serum 25OHD levels of 50nmol/L with a call for further research.⁴⁸

Normal 25OHD levels accompanied by persistently elevated PTH and high serum calcium levels may be an indication of primary hyperparathyroidism hence the need to check PTH levels at baseline.¹⁰ All people are at risk of developing vitamin D deficiency following bariatric surgery,⁴⁴ but those who have more malabsorptive procedures are at greater risk.^{68-73,89,94} Therefore, serum calcium and 25OHD levels should be monitored following bariatric surgery. If vitamin D supplementation is adjusted, serum calcium and 25OHD levels should be rechecked.¹⁰⁵

2.4 Fat soluble vitamins A, E and K

Vitamin A deficiency has been reported after RYGB and in adolescents.^{15,93,106-108} Although clinical problems rarely occur consideration should be given to monitoring serum vitamin A levels if there are concerns such as deterioration in night vision, dry eyes or protein-energy

malnutrition.^{3,4,53} Vitamin A deficiency is more common following BPD/DS.⁶⁸⁻⁷⁴ Consequently, after malabsorptive procedures such as BPD/DS procedures, there should be routine monitoring of serum vitamin A levels. Many primary and secondary care providers are unable to request vitamin A monitoring and interpretation of levels should be treated with caution as they do not directly reflect the body's vitamin A pool.¹⁰⁹

Vitamins E and K deficiencies have been reported following BPD/DS,^{69,70,72,73,94} but we found no reports after AGB, SG³² or RYGB.⁹³ Vitamin E is normally assessed by serum α -tocopherol, which is transported non-specifically in lipoproteins. When considering vitamin E nutritional status, adjustment should therefore be made for serum lipid levels.¹¹⁰ Vitamin K levels should be monitored by measuring serum vitamin K1 and Protein Induced by Vitamin K Absence or antagonism (PIVKA-II).¹¹¹ This creates a dilemma as many centres are unable to request measurement of vitamin K and coagulation screens are not a reliable indication of vitamin K status.¹¹¹ Consequently, we recommend that postoperative care of people following malabsorptive procedures (BPD/DS) should remain with specialist centres lifelong with routine monitoring of serum vitamin E and K levels.

Following AGB, SG or RYGB routine monitoring of serum vitamin E and K levels is not recommended but may be measured in people presenting with unexplained anaemia, neuropathy, bruising or uncontrolled bleeding.^{2-4,51}

2.5 Trace minerals: zinc, copper, selenium and magnesium

Zinc deficiency occasionally occurs following SG or RYGB and more commonly following BPD/DS.^{31,36,37,53,58,67,69,72-74,89,94,101,112,113} Factors may include length of time after surgery and limb length.^{112,113} Zinc deficiency may present as poor wound healing, taste changes, glossitis

and hair loss.⁵³ Serum/plasma zinc levels should be monitored if there are unexplained symptoms including anaemia or changes in taste acuity and at least annually following SG, RYGB and BPD/DS.²⁻⁴

Copper deficiency may present following RYGB,^{37,67,114-117} and more commonly following BPD/DS.^{72,89,112} Symptoms include anaemia, leucopenia, thrombocytopenia and neuromuscular abnormalities.^{114,115,118-120} Elhag et al.¹⁹ reported a fall in copper levels in adolescents who had SG. In addition, high dose zinc supplementation over time can cause copper deficiency and vice versa.¹¹⁸⁻¹²⁰ Serum copper should be monitored following SG, RYGB and BPD/DS; in people who are on high doses of zinc, and in people who present with unexplained anaemia and myeloneuropathy.²⁻⁴

Serum selenium levels are not commonly measured, but deficiency has been reported after SG, RYGB and BPD/DS.^{67,69,73,89,107} Given that there are reports of selenium deficiency we recommend routine monitoring of serum selenium levels after SG, RYGB and BPD/DS or if there is chronic diarrhoea, metabolic bone disease, unexplained anaemia or unexplained cardiomyopathy.^{2,4}

There was insufficient evidence to recommend routine monitoring of magnesium, however people with hypocalcaemia should be investigated for hypomagnesaemia and treated prior to calcium supplementation.¹²¹

2.6 Thiamine

People are at risk of developing thiamine deficiency if they experience prolonged vomiting, rapid weight loss, poor dietary intake, alcohol abuse, oedema or symptoms of neuropathy.^{34,122-128} All healthcare professionals involved in the aftercare of bariatric surgery

patients should be aware of the potential risk for severe thiamine deficiency (see Sections 3.9 and 4.6).

Symptoms of thiamine deficiency include ataxia, confusion and coma (Cerebral Beri Beri and Wernicke's encephalopathy), neuropathy and neuritis especially in lower limbs (Dry Beri Beri) or cardiac insufficiency with tachycardia, and respiratory symptom (Wet Beri Beri).^{95,124,125} If thiamine deficiency is suspected, either because of risk factors or clinical symptoms, oral or intravenous treatment should be initiated immediately and not delayed pending tests results.

2.7 Dyslipidaemia

Treatment needs for dyslipidaemia should be reassessed after achievement of weight loss.¹⁰

3. Vitamin and mineral supplementation

Since peoples' requirements and adherence may vary over time, we recommend that supplements should be reviewed regularly and adjusted accordingly. Details of the recommended vitamin and mineral supplements are shown in Table 4.

3.1 Complete multivitamin and mineral supplements

Following all bariatric procedures, a complete multivitamin and mineral supplement (containing thiamine, iron, zinc, copper and selenium) is recommended.²⁻⁴ A minimum of 2mg of copper and 15mg zinc per day is advised following SG, RYGB and BPD/DS (see section 3.7). Care should be taken to check that the multivitamin and mineral supplement contains sufficient amounts of vitamins and minerals to counter the malabsorptive effects of bariatric surgery, however additional supplements will be needed.

3.2 Iron

Following insertion of AGB, people should be able to meet their iron requirements by oral diet and a complete multivitamin and mineral supplement containing the recommended daily allowance of iron. A dietetic review may be needed to check nutritional adequacy of their diet.¹²⁹

Following SG, RYGB and malabsorptive procedures such as BPD/DS, a complete multivitamin and mineral supplement may not prevent iron deficiency and additional elemental iron is required.^{2-4,19,34,35,74,92,130} We suggest adding 200mg ferrous sulphate, 210mg ferrous fumarate or 300mg ferrous gluconate daily. However, this may not be sufficient to prevent anaemia.^{35,47,74,88,89} Women, of reproductive age and who are menstruating, have additional requirements of 50 to 100mg elemental iron daily (i.e. two 200mg ferrous sulphate or 210mg ferrous fumarate tablets daily).^{53,130} Taking iron supplements alongside citrus fruits/drinks or vitamin C may aid absorption. Iron and calcium supplements should be taken one to two hours apart to avoid affecting absorption of each.^{3,53}

3.3 Folic acid

Folic acid requirements for people who have undergone bariatric surgery are unknown. Complete multivitamin and minerals that contain less than 400 micrograms daily, may not be sufficient to prevent deficiencies.³ There are increased requirements for preconceptual care, pregnancy and lactation (see section 4.8).^{11,131}

3.4 Vitamin B12

Given the risk of developing vitamin B12 deficiency following SG, RYGB and BPD/DS (see section 2.2), additional vitamin B12 supplementation is required for prevention. Untreated

vitamin B12 deficiency may result in irreversible neuropathy or subacute combined degeneration of spinal cord, which may occur in the absence of megaloblastic anaemia.^{95,132} Discussion continues as to the optimal dosage and route of supplementation.¹³³⁻¹³⁵ Some studies suggest that supplementation with high doses of oral vitamin B12 may prevent or reduce the development of deficiency.^{34,135} Further research is needed, as deficiency may still occur in the presence of high oral doses.^{34,92,136} Adherence to oral supplementation is more difficult to determine.^{34,96,133-135} Given the serious consequences of vitamin B12 deficiency, we recommend routine supplementation with three monthly intramuscular vitamin B12 injections for SG, RYGB and malabsorptive procedures such as BPD/DS.¹³⁴

3.5 Calcium and vitamin D

Vitamin D3 supplementation requirements to maintain optimal serum 25OHD levels greater than 75nmol/L post-bariatric surgery are higher than for a non-bariatric surgery population.^{3,4,10,44,48,52,62,137} Starting regimens of 2000 to 4000IU of vitamin D3 per day are recommended to maintain serum 25OHD levels after surgery with adjustments being made dependent on results.^{3,48,62} With malabsorptive procedures such as BPD/DS, higher doses of vitamin D3 supplementation are likely to be needed.^{52,69,70,74} Dietary intake of vitamin D and weight bearing activity should also be encouraged.⁵¹

Calcium absorption is adversely affected by bariatric surgery.^{70,138} Several guidelines recommend additional calcium supplementation.^{2-4,9,51} However, the optimal calcium intake for people who have had bariatric surgery, is not known. Dietary sources of calcium should be encouraged as it is more bioavailable than supplemental calcium and may have a protective role in the formation of kidney stones.¹³⁹ Parrott et al. recommend 1200-1500mg

calcium/day from food and supplements following AGB, SG and RYGB and 1800-2400mg/day following BPD/DS.³

Discussion continues as to whether calcium citrate should be favoured over calcium carbonate. However, there have been no large RCTs comparing the two supplements for all bariatric procedures.^{51,103,140} Although calcium citrate may be more bioavailable and the preferred option for people at risk of kidney stones,¹⁴¹ calcium carbonate may be better tolerated.³ Parrott et al. advise taking calcium in divided doses, taking calcium carbonate with meals and calcium citrate with or without meals.³ Care should be taken to ensure that there is not excess calcium intake and healthcare professionals should be mindful of the risk of kidney stones. Good hydration should be encouraged.⁴⁸

3.6 Vitamins A, E and K

Following AGB and SG, people should be able to meet requirements for vitamins A, E and K through their oral diet and a complete multivitamin and mineral supplement. Given that lower levels of vitamin A or deficiency has been reported after RYGB,^{93,107,108} some people may require additional vitamin A supplementation. Whilst we did not find sufficient evidence to recommend routine additional supplementation beyond the complete multivitamin and mineral supplement, this may be identified through monitoring (see section 2.4).

The optimum level of supplementation to prevent vitamin A deficiency following BPD/DS is not known. There are reports of vitamin A deficiencies developing despite supplementation of 5000 to 25000IU/day.^{71,89,94} For BPD/DS with 100cm common channel, Homan et al.⁷⁴ recommended starting vitamin A supplementation with 50,000IU/week, checking blood levels after 3 months and adjusting the dosage if necessary. Homan et al.⁷⁴ also estimated

that an oral dose of 7500 -15000IU/day (solubilised vitamin A) is needed to prevent vitamin A deficiency after BPD/DS, while Topart et al.⁸⁹ suggested that vitamin A 50,000IU/day in tablet form was needed to prevent deficiency. Homan et al. noted that this difference may be due to differences in formulation, as solubilised forms may be better absorbed.⁷⁴ We recommend starting with 10000IU/day vitamin A and adjusting depending on blood results to avoid over-supplementation.⁵¹

For prevention of vitamin E deficiency has been found post BPD/DS, Slater et al. supplemented with 60IU vitamin E/day although a small number of participants still presented with vitamin E deficiency at 4 years.⁷⁰ We suggest starting with 100IU vitamin E/day following BPD/DS and adjusting as required.

The optimal level of vitamin K supplementation to prevent deficiencies after malabsorptive procedures is not known. Although, Aills et al. suggest 300 micrograms vitamin K daily.⁵¹

Water-miscible forms of fat-soluble vitamins may improve absorption especially after malabsorptive procedures.^{2-4,51}

3.7 Zinc and copper

The complete multivitamin and mineral supplement may not contain sufficient zinc to prevent deficiency following SG, RYGB or BPD/DS (see section 2.5). Although the optimum level of zinc supplementation is not known, we suggest starting with 15mg/day zinc which may be contained within the multivitamin and mineral supplement. After BPD/DS, Topart et al.⁸⁹ suggested starting with 30mg/day zinc whilst Homan et al.⁷⁴ suggested 100mg/day zinc is needed to prevent deficiency. Given that zinc and copper have an inverse relationship for absorption, we recommend starting with 30mg/day zinc after BPD/DS.

We recommend that all people have a complete vitamin and mineral supplement that provides 2mg/day copper.^{67,117} People who have had long limbed gastric bypass or BPD/DS may have additional requirements.^{74,89,112}

If additional zinc supplements are given, monitor both zinc and copper levels as normally a ratio of 8-15mg of zinc for each 1 mg copper should be maintained to avoid zinc induced copper deficiency.^{3,4} The current complete multivitamin and mineral available on prescription (Forceval) in the UK contains 2mg copper and 15mg zinc and doubling up on the dosage may be sufficient in some cases to meet the additional requirements.¹¹²

3.8 Selenium

Although the evidence is limited, a complete multivitamin and mineral supplement, which contains selenium should be recommended after bariatric surgery. Additional selenium may be needed by some people following RYGB and especially following BPD/DS.^{69,73,89,107} Over the counter preparations or Brazil nuts may also be used to supplement selenium.

3.9 Thiamine

People are at high risk of developing thiamine deficiency post-bariatric surgery (see Section 2.6). Garg et al. reported that people who saw a dietitian had more favourable thiamine levels at three months post-surgery.¹²⁶

The complete multivitamin and mineral supplement containing thiamine, may not be sufficient to prevent deficiency. Parrott et al. recommend that all people take 12mg/day thiamine and preferably 50mg dose of thiamine once or twice/day from a vitamin B-complex supplement.³ We were unable to find sufficient evidence to support this, however we recognise that further research and evidence are needed in this important area. For people

in which there is concern that a complete multivitamin and mineral supplement containing thiamine is not sufficient, consideration should be given to prescribing additional thiamine or a vitamin B-complex supplement for the first three to four post-operative months.

If people present with prolonged vomiting, dysphagia, poor nutritional intake, inability to tolerate vitamin and mineral supplements, high alcohol intake or fast weight loss, additional thiamine supplementation should be administered immediately to prevent the development of Wernicke's encephalopathy.^{122,124-128} Consideration should be given to admission and immediate parenteral replacement with thiamine in people where thiamine deficiency is suspected, see sections 2.6 and 4.6.

Given the severe consequences that arise from untreated or late treatment of thiamine deficiency, we recommend that people are educated about potential risks of thiamine deficiency and to seek early advice. Clinicians in both primary and secondary care need education on the factors that may predispose to thiamine deficiency and the importance of initiating immediate treatment.

4. Abnormal test results and clinical problems

Detailed recommendations are listed in Table 5.

4.1 Protein malnutrition / protein energy malnutrition / oedema

This can present several years following bariatric surgery. Causes include poor dietary protein intake as well as malabsorption. People who have difficulty progressing their diet because of a stricture, overtight band or food intolerances, are at risk in addition to those with protein malabsorption.^{69,71,89,94,142}

Oedema is an important indicator of protein energy malnutrition, and may mask muscle wasting and weight loss. Whilst it is necessary to exclude the many other causes of oedema, people should also be referred back to the bariatric centre for further investigation.

4.2 Anaemia

4.2.1 Iron deficiency anaemia

Iron deficiency anaemia may be dietary in origin, with oral diet and iron supplements being insufficient to meet the needs of people following bariatric surgery (see section 2.2). Sources of blood loss, both related and unrelated to bariatric surgery should also be considered, investigated and excluded.¹⁴³

If there is a low haemoglobin and low mean cell volume (MCV), serum ferritin levels should be measured. Levels of serum ferritin less than 15 micrograms/L confirm iron deficiency anaemia.¹⁴³ Acute and chronic inflammatory conditions, liver disease and malignant disease may result in increased ferritin levels independent of iron status, therefore people, with chronic inflammation and a ferritin concentration of 50 micrograms/L or higher could still be iron deficient. If inflammation is thought to be affecting the ferritin levels, other markers of inflammation such as C-reactive protein or measures of iron status such as total iron binding capacity should be considered. If there is doubt about the tests to be requested or interpretation of results, specialist advice should be sought.¹⁴³

4.2.2 Vitamin B12 and folate

The most common causes of megaloblastic, macrocytic anaemia are vitamin B12 and folate deficiency¹³² and folate supplementation may mask severe vitamin B12 depletion (see

section 2.2). It is essential that vitamin B12 deficiency is treated immediately before initiating additional folic acid (see section 2.2).

In vitamin B12 deficiency with possible neurological involvement, such as unexplained sensory and/or motor and gait symptoms, vitamin B12 deficiency should be treated immediately and urgent specialist advice sought from a neurologist and haematologist.¹³² Hydroxocobalamin 1mg intramuscularly should be administered on alternate days until there is no further improvement, then hydroxocobalamin 1mg intramuscularly administered every 2 months.¹³² For people with vitamin B12 deficiency and no neurological involvement, hydroxocobalamin 1mg intramuscularly should be administered three times a week for 2 weeks, followed by maintenance treatment with 1mg intramuscularly every 2 to 3 months for life.¹³²

Folic acid deficiency may indicate non-adherence with the daily multivitamin and mineral supplement or malabsorption. Some medications, such as anticonvulsants, sulfasalazine and methotrexate may affect folic acid levels.¹⁰² For treatment of folic acid deficiency (after excluding vitamin B12 deficiency), oral folic acid 5mg daily should be given for a minimum of 4 months.¹³²

4.2.3 Unexplained anaemia

Unexplained anaemia or fatigue, may be a symptom of other nutritional deficiencies including protein, zinc, copper and selenium so levels of these should all be checked.^{2-4,114,115,117,144}

4.3 Low vitamin D levels

Although low serum 25OHD levels are not a barrier to bariatric surgery, vitamin D insufficiency or deficiency should be treated preoperatively especially where the surgical procedure is

likely to result in reductions in serum 25OHD levels.^{3,44,48,52} Following surgery, if people present with vitamin D insufficiency/deficiency, adherence with the recommended supplements should be checked. However, for many people, despite good adherence, additional supplementation with vitamin D and higher maintenance doses may be required.^{3,44,48,62,63}

Vitamin D deficiency requires correction with loading doses of vitamin D.^{3,48} Many healthcare professionals have access to local guidelines/protocols for treatment of vitamin D deficiency. In the absence of these, the Royal Osteoporosis Society (ROS) gives recommendations for replacement.¹⁰⁵ For adolescents, refer to ROS paediatric guidelines.¹⁴⁵ For those people who remain vitamin D deficient or need a more aggressive approach, a referral to a secondary care specialist is recommended.

4.4 Vitamin A deficiency

Vitamin A deficiency can lead to visual problems such as xerophthalmia and loss of night vision,^{106,108} reduced male fertility and may also result in foetal abnormalities.^{95,146} Vitamin A levels should be measured if there are clinical concerns and if appropriate, a referral to an ophthalmologist should be considered. For treatment of vitamin A deficiency in adults, oral supplementation with vitamin A, 10000 to 25000IU/day for one to two weeks for clinical improvement is recommended.^{3,72,84} Higher doses, including intramuscular injections may be needed if the person is experiencing night blindness.^{3,4,147} The levels should be rechecked at three months.⁷² For vitamin A deficiency that does not respond to oral supplementation, an onward referral to a specialist is needed as intramuscular injections may be required.

Silva et al. highlight that there are no guidelines for vitamin A replacement in adolescents.¹⁶

We recommend seeking specialist advice.

4.5 Vitamin E and vitamin K deficiency

Symptoms of vitamin E deficiency include peripheral neuropathy, muscle weakness and ataxia.⁸⁴ Oral vitamin E 100 to 400IU/day has been recommended for maintenance of vitamin E levels recognising more may be needed for repletion.^{3,51}, while Bays et al. suggested 400 to 800IU vitamin E.⁵³ Serum levels should be monitored and treatment continued until serum levels reach normal range.^{3,53,84} For vitamin E deficiency that does not respond to oral supplementation, refer onto a specialist as intramuscular injections may be needed.

Large vitamin E doses can result in over-replacement and exacerbate vitamin K deficiency and therefore affect blood coagulation, so care should be taken.⁹⁵ Furthermore, assessment of vitamin K should be performed when there is established fat-soluble vitamin deficiency with hepatopathy, coagulopathy or osteoporosis.^{2,4,148} For vitamin K deficiency, Ketovite tablets contain acetomenaphthone (vitamin K) 500 micrograms per tablet and may be used to treat vitamin K deficiency although menadiol sodium phosphate or phytomenadione may be taken orally.¹⁴⁹ An oral dose of 1 to 2mg/day is recommended.³ Seek further advice from a haematologist if people are taking anti-coagulants such as warfarin. Onward referral is needed if vitamin K deficiency does not respond to treatment.

4.6 Deficiencies associated with neurological symptoms/Wernicke's encephalopathy

Myeloneuropathy may have a number of causes including deficiencies of vitamin B12, thiamine, copper or vitamin E. Beri Beri and Wernicke's encephalopathy are severe

complications caused by thiamine deficiency.⁹⁵ All these conditions may occur after bariatric surgery.^{122,124,125,127,128,150}

In people at risk of thiamine deficiency or with clinical suspicion of acute deficiency (see sections 2.6 and 3.9), additional thiamine and vitamin B compound strong should be given immediately i.e. oral thiamine 200–300mg/day and vitamin B compound strong 1 or 2 tablets three times/day, or full dose daily intravenous vitamin B preparation, if necessary for those unable to tolerate thiamine orally.^{125,151,152} Oral or intravenous glucose must not be given to people at risk of or with suspected thiamine deficiency as it can precipitate Wernicke-Korsakoff syndrome.^{122,150} All healthcare professionals, including emergency department staff, need to be aware of this preventable complication and its management. Note that prolonged vomiting or dysphagia is not normal and should always be investigated. A referral back to the bariatric centre is recommended.

Vitamin B12, copper and vitamin E levels should be assessed and any deficiencies corrected (see sections 4.2.2, 4.5 and 4.7). People with neurological symptoms should be referred to a neurologist.

4.7 Zinc and copper deficiency

For borderline low zinc or copper levels, blood tests should be repeated at three months as levels may fluctuate. In these cases, levels may respond to two capsules/day of complete multivitamin and mineral supplement available on prescription (Forceval). Although normally zinc/copper ratio should be maintained when giving additional supplements, in the case of deficiency of one of these micronutrients and a normal level of the other, high doses of either

one may be given providing the levels of both continue to be monitored. Where there is doubt, seek specialist advice.

4.9 Pregnancy

Women are often advised to avoid pregnancy for the first 12-18 months following bariatric surgery.^{2,4,11,131} The evidence base for this recommendation is limited, however this helps to ensure that the woman has reached weight stability, is able to eat a varied nutritious diet and enables appropriate planning of pregnancy and associated care.¹¹

Preconception care should be discussed with women who plan to become pregnant. All women, planning for pregnancy, should take additional folic acid to reduce the risk of foetal neural tube defects. Prior to conception and until the 12th week of pregnancy, 400 micrograms/day folic acid is recommended. However, in women with obesity or diabetes, the recommendation is 5mg/day folic acid.^{11,131,153,154} Vitamin B12 should be measured during the preconception period before additional folic acid supplements are given.

A systematic review by Jans et al. concluded that the evidence on micronutrient deficiencies in pregnant and postpartum women after bariatric surgery and subsequent adverse neonatal outcomes was weak and inconclusive, and called for larger prospective cohort studies to be undertaken.¹⁴⁶ In a retrospective study of 73 pregnancies in a single centre, Yau et al. did not find an increase in nutritional deficiencies in women post-bariatric surgery who had a shorter time from surgery to conception.¹⁵⁵ In other studies, the incidence of vitamin A deficiency has been seen to increase over pregnancy.^{146,156,157} The incidence of vitamin K deficiency has also been found to increase with the long-limbed gastric bypass and BPD/DS during pregnancy.¹⁵⁸ Vitamin K deficiency may be related to neonatal intracranial bleedings and birth

defects. The frequency of nutritional monitoring should therefore be increased during pregnancy.^{11,131} Reference values for levels may change over pregnancy and it is useful to check results against sources such as those provided by Perinatology.¹⁵⁹

Women, as part of preconception care, are advised to avoid vitamin and mineral preparations which contain vitamin A in the retinol form, in the first twelve weeks of pregnancy.¹⁶⁰ however this may leave them at risk of developing vitamin A deficiency.^{146,156} Supplements containing retinol may increase the teratogenic risk especially in the first trimester.⁹⁵ There are a number of vitamin and mineral supplements containing no vitamin A which are specifically aimed at preconception and pregnancy. Supplements containing vitamin A in the beta carotene and not retinol form may be continued in pregnancy. It is important to check this, for example, the capsule form of the multivitamin and mineral supplement available on prescription is appropriate, but the soluble form is not.

Women, who become pregnant post-bariatric surgery, should be treated as a specialist obstetric population with specific needs.^{11,131} This includes access to specialist dietetic support and close monitoring of nutrition. They should undergo nutritional screening every trimester.^{11,131} This should include ferritin, folate, vitamin B12, calcium, vitamin D and vitamin A.¹¹ Those who have had long limbed bypass or BPD/DS procedures, may be at risk of low vitamins A, E and K levels and so these should be monitored if clinically indicated.¹⁴⁶ A more frequent review with the specialist bariatric dietitian may be required.^{11,131} It should be noted that for women, who have had a gastric band, decisions around band management should be made in clinical context as there are no randomised control trials to define optimum management of the gastric band inflation during pregnancy.^{4,161}

4.9 Adolescents

A number of studies, whilst giving favourable outcomes in adolescents undergoing bariatric surgery, reported both preoperative and postoperative nutritional deficiencies.^{15-19,162} Adherence to nutritional supplements and engagement with postoperative follow-up is a challenge in all age groups however adolescents are a vulnerable group and need regular monitoring and support through growth and sexual development.¹²⁻¹⁹

4.10 Nutritional care of people who have had malabsorptive procedures

Malabsorptive procedures such as BPD/DS are associated with higher prevalence of post-surgery nutritional deficiencies including fat soluble vitamins and trace minerals. The management of these including prevention and correction of deficiencies can be difficult. Healthcare professionals, especially in primary care, may be unable to request specific blood tests. In addition, people may not be able to access a full range of supplements. Unlicensed products may be needed for the correction of deficiencies. We recommend that individuals who have malabsorptive procedures remain under the care of specialist centres.

4.11 Newer procedures (OAGB/MGB and SADIs)

It is recognised that there is a growing interest in OAGB/MGB and SADIs and that, as yet, these are not covered robustly by clinical practice guidelines. Until such data emerges, it may be hypothesised that requirements for nutritional supplements in people undergoing OAGB/MGB with BP limb of 150cm would be at least that of people undergoing RYGB, if not more, and that nutritional requirements for people undergoing OAGB/MGB with BP limb greater than 150cm and SADIS would be at least that of people undergoing the traditional BPD/DS.¹⁶³⁻¹⁶⁶ We therefore recommend that healthcare professionals follow RYGB nutritional recommendations for postoperative care after OAGB/MGB with BP limb length

of 150cm and BPD/DS recommendations for people after OAGB/MGB with BP limb length of greater than 150cm or SADIs.

Discussion

Clinical guidelines can make a vitally important contribution to patient safety and a number of guidelines for the nutritional care of people undergoing bariatric surgery have been published over the last few years.^{1,3,4,8-11} However, not all have been specifically related to micronutrition, had dietetic involvement or detail on recommendations for the nutritional management of pregnancy post-surgery. No previous nutritional guidelines for people undergoing bariatric surgery have included either primary care or patient representatives. Previous guidance aimed at the management of adolescents undergoing bariatric surgery has only included general nutritional recommendations,¹²⁻¹⁴ despite this vulnerable group being at high risk of developing nutritional deficiencies.¹⁵⁻¹⁹

Here comprehensive, up to date guidelines have been developed using robust methodology, that include graded recommendations for preoperative and postoperative nutritional monitoring, vitamin and mineral supplementation and correction of deficiencies for people undergoing bariatric surgery. Importantly, nutritional guidance for the care of adolescents and pregnancy post-surgery has also been included and the guidance development group was comprised of a multidisciplinary team from primary and secondary care as well as patient representation. Thus ensuring that all professions involved in preparing people for surgery and providing aftercare, as well as patient views and needs, were properly considered. Although these guidelines are aimed at improving practice in the UK setting and take account of the current model of healthcare in the UK, they are likely to be applicable to other healthcare settings. However, we have addressed issues specifically related to the UK

healthcare system where possible, for example both specialist and non-specialist care providers may not always be able to access all the suggested nutritional blood tests such as vitamin A and vitamin K. Correction of some nutritional deficiencies, especially fat soluble vitamins, can be a challenge as the use of off license medications may be required. In addition, it is of concern that in some parts of the UK, people are not given access to prescribed vitamin and mineral supplements, particularly for those undergoing malabsorptive procedures. These people will have higher requirements, but there is no easy access to supplements containing larger amounts of vitamins A, E and K. This is a potentially serious issue that must be addressed. Accessibility and affordability were amongst the factors affecting adherence to vitamin and mineral supplements after bariatric surgery in the UK.¹⁶⁷

The main limitations of these guidelines are related to the current evidence base. There have been a very limited number of RCTs undertaken in bariatric surgery and nutrition.^{34,68,101,130,135,168} There is also a lack of evidence for optimal nutritional supplementation after bariatric surgery, which is complicated by the fact that requirements will vary according to the surgical procedure, size of gastric pouch and length of common channel. Due to this lack of good quality evidence and robust studies in the area, the guidelines group were required to make a number of recommendations based on good practice and the expert opinion of the group (good practice points).

Conclusion

Preoperative dietetic assessment and biochemical monitoring is vital to ensure that people are able to meet nutritional needs after bariatric surgery and any nutritional deficiencies are identified and corrected.³ Long-term biochemical monitoring is important for the detection

and treatment of emergent post-operative nutritional deficiencies.^{1-4,8-11,83} Annual reviews enable nutritional supplements to be reviewed and adjusted. We have systematically reviewed the current evidence base for the nutritional care of patients undergoing bariatric surgery and report our consensus guidelines with graded recommendations. These guidelines have the potential to improve clinical practice and safety for people undergoing bariatric surgery and should be considered for adoption by healthcare organisations. They will be updated regularly as new evidence emerges.

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Table Legend

Table 1 Levels of evidence, grades of recommendations and good practice points (SIGN 50²⁸)

Table 2 Preoperative nutritional assessment

Table 3 Postoperative care and biochemical monitoring

Table 4 Postoperative vitamin and mineral supplementation

Table 5 Abnormal test results, clinical problems, pregnancy and adolescents