

## REVIEW

# Surgical treatment of obesity

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## Abstract

More than half of the European population are overweight (body mass index (BMI)  $>25$  and  $<30$  kg/m<sup>2</sup>) and up to 30% are obese (BMI  $\geq 30$  kg/m<sup>2</sup>). Being overweight and obesity are becoming endemic, particularly because of increasing nourishment and a decrease in physical exercise. Insulin resistance, type 2 diabetes, dyslipidemia, hypertension, cholelithiasis, certain forms of cancer, steatosis hepatis, gastroesophageal reflux, obstructive sleep apnea, degenerative joint disease, gout, lower back pain, and polycystic ovary syndrome are all associated with overweight and obesity. The endemic extent of overweight and obesity with its associated comorbidities has led to the development of therapies aimed at weight loss. The long-term effects of diet, exercise, and medical therapy on weight are relatively poor. With respect to durable weight reduction, bariatric surgery is the most effective long-term treatment for obesity with the greatest chances for amelioration and even resolution of obesity-associated complications. Recent evidence shows that bariatric surgery for severe obesity is associated with decreased overall mortality. However, serious complications can occur and therefore a careful selection of patients is of utmost importance. Bariatric surgery should at least be considered for all patients with a BMI of more than 40 kg/m<sup>2</sup> and for those with a BMI of more than 35 kg/m<sup>2</sup> with concomitant obesity-related conditions after failure of conventional treatment. The importance of weight loss and results of conventional treatment will be discussed first. Currently used operative treatments for obesity and their effectiveness and complications are described. Proposed criteria for bariatric surgery are given. Also, some attention is devoted to more basic insights that bariatric surgery has provided. Finally we deal with unsolved questions and future directions for research.

*European Journal of Endocrinology* 158 135–145

## Introduction

More than half of the European population are overweight (body mass index (BMI)  $>25$  and  $<30$  kg/m<sup>2</sup>) and up to 30% are obese (BMI  $\geq 30$  kg/m<sup>2</sup>) (1, 2). Being overweight and obesity are created by a positive energy balance (when energy intake exceeds energy consumption) in which case the surplus of energy is stored as adipose tissue (3, 4). Approximately 50% of the inter-individual variation in BMI is genetically determined via the influence on various complex neuroendocrine systems; ultimately it is the interaction between genetic predisposition and environment that finally determines the attained body weight (3). Overweight and obesity are becoming endemic, particularly because of increasing nourishment and a decrease in physical exercise (3–5).

Overweight and obesity are associated with insulin resistance, type 2 diabetes, dyslipidemia, hypertension, cholelithiasis, certain forms of cancer, steatosis hepatis, gastroesophageal reflux, obstructive sleep apnea, degenerative joint disease, gout, lower back pain, and polycystic ovary syndrome (3, 4). Being overweight or

obese at the age of 40 reduces life expectancy by at least 3 or 6 years (6). In the Netherlands, 5% of deaths are indirectly caused by being overweight and obesity, the estimated costs on a yearly basis are half a billion euros due to direct medical expenses and three billion euros as a result of economical losses (loss of production, benefits, and other social premiums) (7).

The endemic extent of overweight individuals and obesity with their associated comorbidities has led to the development of therapies aimed at weight loss. The rates of bariatric surgery procedures are increasing sharply and to date it is the only option resulting in substantial and durable long-term weight loss (8, 9).

In this review, the importance of weight loss and results of conventional treatment will be discussed first. Then we will describe currently used operative treatments for obesity and their effectiveness and complications. Proposed criteria for bariatric surgery are given. Also, some attention is devoted to some more basic insights that bariatric surgery has provided. The final part deals with unsolved questions and future directions for research.

## Importance of weight loss

Weight reduction in the short term (1–3 years) leads to a decline in insulin resistance, a better metabolic regulation of patients with diabetes mellitus, lower blood pressure, and a less atherogenic lipid profile (10–12). In the Diabetes Prevention Program, it became clear that in subjects with a BMI > 24 modest weight loss of only 5.6 kg on average reduced the incidence of diabetes by 58% (12). The 'Swedish obese subjects' (SOS) study has shown that long-term weight reduction – achieved by bariatric surgery – substantially improves the cardiovascular risk profile (Table 1) (13), ultimately resulting in a decrease in overall mortality (14).

## Conventional treatment of overweight and obesity

In the SOS study, the effect of conventional measures on metabolic and cardiovascular risk profiles was compared with the effect of bariatric surgery (10). The study involved 4047 obese subjects of which 641 underwent surgical treatment and 627 patients had an average age of  $47.3 \pm 6.1$  years and a BMI of  $40.5 \pm 4.2$  kg/m<sup>2</sup> and were conventionally treated and followed for 10 years (13). After 10 years of conventional treatment – which was not standardized and varied from intensive lifestyle

advice and guidance to no treatment at all – the weight had increased by 1.6% (13).

The development of other cardiovascular risk factors is shown in Table 1. It should be noted that the SOS study was not a randomized trial but a well-matched surgical intervention cohort study with a non-operative comparison arm (13, 15).

Even an intensive program of lifestyle modification only leads to a modest weight loss. In the Diabetes Prevention Program, 1079 subjects with an average BMI of 33.9 kg/m<sup>2</sup> were submitted to an intensive program aimed at weight reduction through diet and physical exercise (12). Despite very intensive individualized guidance, the average weight loss after 2.8 years was 5.6 kg (12). This is comparable with the mean weight loss of 3.0 kg achieved in 1637 patients during 4 years of treatment with placebo and lifestyle measures in the Swedish xendos trial (16).

Very low calorie diets contain <800 kcal/day. Programs using very low caloric diets generally result in a weight reduction of 15–25% after 3–6 months (17). However, long-term results are modest: 9% weight reduction after 1 year and 5% after 4 years (17).

Recently, pharmacologic treatment of obesity has evolved (18–22). Drugs prescribed for weight loss can be divided into two categories: appetite suppressants and substances that inhibit the absorption of nutrients. By and large, pharmacological support can generate an extra weight loss of about 5 kg in the first year (18–21). The xendos trial treatment with orlistat and lifestyle measures over 4 years resulted in a mean weight loss of 5.8 kg (16). Unfortunately, longer-term data regarding weight, cardiovascular events, incidence and prevalence of diabetes as well as side effects of these drugs are lacking (18–21).

In contrast to these relatively poor long-term results of conservative measures, there is a growing body of evidence to suggest that surgical treatment of obesity may lead to a more sustained weight loss.

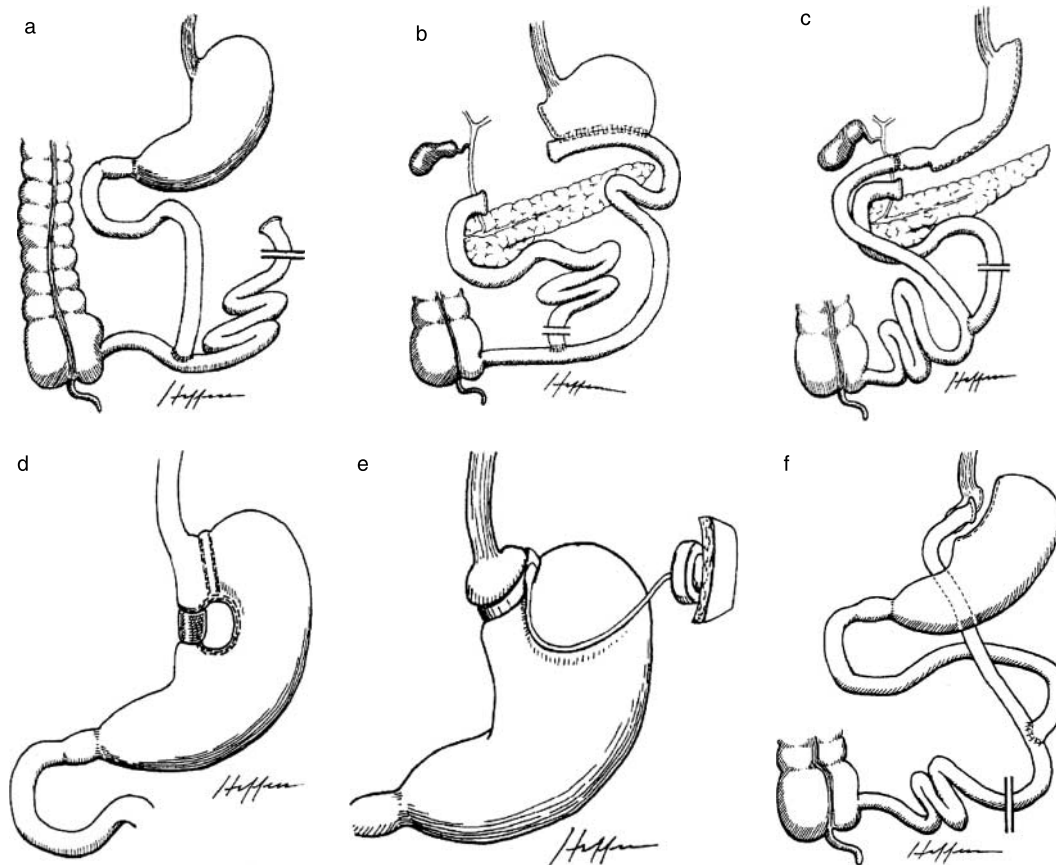
## Surgical treatment of obesity: bariatric surgery

Bariatric surgical techniques are divided into two groups: malabsorptive and restrictive procedures (Fig. 1) (23).

Malabsorptive procedures induce decreased absorption of nutrients by shortening the functional length of the small intestine (23). The created short-bowel syndrome leads to a negative energy balance and weight loss. The jejunoileal bypass (Fig. 1a) was one of the first bariatric operations. It is associated with substantial long-term complications including liver failure, malnutrition, electrolyte imbalances, vitamin deficiencies, renal (oxalate) stones, and death. This procedure is therefore no longer performed (9, 23). Currently used malabsorptive techniques are the biliopancreatic

**Table 1** Changes at 10 years in the Swedish obese subjects (SOS) study (13).

|                                     | Control group<br>(n=627) | Surgery group<br>(n=641) | P value | Odds ratio |
|-------------------------------------|--------------------------|--------------------------|---------|------------|
| Weight (%)                          | 1.6                      | –16.1                    | <0.001  | –          |
| Blood pressure (%)                  |                          |                          |         |            |
| Systolic                            | 4.4                      | 0.5                      |         | –          |
| Diastolic                           | –2.0                     | –2.6                     | <0.001  | –          |
| Glucose (%)                         | 18.7                     | –2.5                     | <0.001  | –          |
| Triglycerides (%)                   | 2.2                      | –16.3                    | <0.001  | –          |
| HDL cholesterol (%)                 | 10.8                     | 24.0                     | <0.001  | –          |
| Incidence over 10 years             |                          |                          |         |            |
| Diabetes mellitus                   | 24%                      | 7%                       | <0.001  | 0.25       |
| Hypertension                        | 49%                      | 41%                      | 0.13    | 0.75       |
| Triglycerides<br>(≥ 1.7 mmol/l)     | 27%                      | 17%                      | 0.03    | 0.61       |
| Total cholesterol<br>(≥ 5.2 mmol/l) | 27%                      | 30%                      | 0.57    | 1.16       |
| HDL cholesterol<br>(< 1.0 mmol/l)   | 6%                       | 3%                       | 0.12    | 0.57       |
| Recovery over 10 years              |                          |                          |         |            |
| Diabetes mellitus                   | 13%                      | 36%                      | 0.001   | 3.45       |
| Hypertension                        | 11%                      | 19%                      | 0.02    | 1.68       |
| Triglycerides<br>(≥ 1.7 mmol/l)     | 24%                      | 46%                      | <0.001  | 2.57       |
| Total cholesterol<br>(≥ 5.2 mmol/l) | 17%                      | 21%                      | 0.14    | 1.30       |
| HDL cholesterol<br>(< 1.0 mmol/l)   | 53%                      | 73%                      | 0.001   | 2.35       |



**Figure 1** Bariatric procedures. (a) Jejunioileal bypass; (b) biliopancreatic diversion; (c) biliopancreatic diversion with duodenal switch; (d) vertical banded gastroplasty; (e) laparoscopic adjustable gastric band; and (f) Roux-en-Y gastric bypass. With permission from Ref. (129).

diversion and the biliopancreatic diversion with duodenal switch (Fig. 1b and c) (9, 23, 24). In both procedures, a partial gastrectomy is performed, creating a 100–150 ml gastric pouch. The biliopancreatic diversion (Fig. 1b) consists of a horizontal distal gastrectomy with a gastro-jejunostomy or gastro-ileostomy; this long (food) limb is anastomosed to the biliopancreatic (bile, a pancreatic juice) limb (23, 24). In a biliopancreatic diversion with duodenal switch (Fig. 1c), a pylorus-sparing sleeve gastrectomy with duodeno-ileostomy is performed (23, 24). It is generally accepted that biliopancreatic diversion with duodenal switch results in less cases of dumping and marginal ulcers than a classical biliopancreatic diversion (25, 26). In both procedures, the length of the common limb – i.e., the time during which digestion and nutrient absorption can occur – determines the degree of malabsorption (23, 24).

Restrictive operations reduce the storage capacity of the stomach and as a result early satiety arises, leading to a decreased caloric intake (23). In general, restrictive procedures are simpler to perform and are accompanied by less procedural complications than malabsorptive procedures. The vertical banded gastroplasty and the laparoscopic adjustable gastric band

represent the current most frequently performed restrictive procedures (9) (Fig. 1d and e). During a vertical banded gastroplasty (Fig. 1d), the fundus of the stomach is stapled parallel to the lesser curve using a surgical stapling device (23, 24). The distal exit of the created pouch is narrowed with a band. A food-receiving reservoir of ~50 ml remains and the banding provides an outlet diameter of 10–12 mm (23, 24). The laparoscopic adjustable gastric band technique (Fig. 1e) involves placing a silicon inflatable gastric band horizontally around the proximal part of the stomach. By inflating the gastric band via a s.c. port, a pouch is created. Moreover, the diameter of the band can be adjusted to the individual needs of the patient (23, 24). The advantage of the latter technique is that in the case of excessive vomiting or reflux following the operation (i.e., when the exit of the pouch is too narrow) the tension of the gastric band can be reduced (23, 24).

An intragastric balloon is a smooth saline-filled balloon that is endoscopically placed in the gastric cavity. It can be used as temporary method to aid in weight reduction, for example, as a first-stage treatment of high-risk super-obese patients in need of surgical intervention or in patients who refuse bariatric surgery (27, 28).

At this moment, the Roux-en-Y gastric bypass (Fig. 1f) is (at least in the United States) the most frequently performed bariatric procedure (9). It has both restrictive and malabsorptive aspects (9) (Fig. 1c). A (restrictive) gastric pouch is created and separated from the remainder of the stomach (23, 24). The continuity is then restored by a Roux-Y-limb, which is connected to the jejunum (23, 24). During a meal, the gastric pouch quickly fills creating a sensation of satiety. Food in the gastric pouch enters the jejunum via the Roux-Y-limb. The length of the common limb – which is inversely related to the length of the Roux-Y-limb – determines the degree of malabsorption. Roux-en-Y gastric bypass is being performed laparoscopically on a growing scale (23, 24).

## Effectiveness of bariatric surgery

### Weight

The effectiveness of bariatric surgery has recently been studied in two meta-analyses (29, 30). On average surgical treatment of obesity results in 20–40 kg of weight loss and a 10–15 kg/m<sup>2</sup> reduction in BMI (29, 30). In the SOS study, the average 10-year weight loss was well over 19 kg (13). This result was achieved despite the fact that vertical banded gastroplasty was the dominant procedure and only 5% of those who had a follow-up of 10 years had a Roux-en-Y gastric bypass (which is superior to vertical banded gastroplasty regarding weight loss) (13). After a period of 15 years, patients who had undergone laparoscopic gastric banding had lost 13 ± 14% compared with the baseline weight. Corresponding weight losses 15 years after vertical banded gastroplasty and Roux-en-Y gastric bypass were 18 ± 11% and 27 ± 12% respectively (14).

Few studies have compared weight loss between surgical procedures. In two randomized clinical trials collectively enrolling 231 patients, Roux-en-Y gastric bypass was compared with vertical banded gastroplasty (29, 31, 32). Pooled results showed that at 12 and 36 months patients assigned to Roux-en-Y gastric bypass lost substantially more weight than those assigned to vertical banded gastroplasty (42.43 kg versus 34.45 kg and 39.73 kg versus 30.65 kg at 12 and 36 months respectively) (29, 31, 32). On the basis of these and other studies (33–35), it can be concluded that in regard to weight loss, Roux-en-Y gastric bypass is superior to vertical banded gastroplasty. Recently, laparoscopic adjustable gastric banding was compared with laparoscopic vertical banded gastroplasty in a randomized trial involving 100 patients (36). In this study, excess weight loss was 58.9% 3 years after laparoscopic vertical banded gastroplasty and 39% 3 years after laparoscopic adjustable gastric banding (36). Biliopancreatic diversion resulted in an excess weight loss of 74 ± 12% at 2 years and 72 ± 10% at 8 years after surgery (37).

In biliopancreatic diversion with duodenal switch, a mean weight loss of 46 ± 20 kg was reported in 252 patients followed for a mean of 8.3 years (26).

Placement of an intragastric balloon for 6 months resulted in an excess weight loss of 33.9 ± 18.7% (38). In well-selected patients, it seems possible to extend the treatment period to 1 year (39). However, only about half of the patients maintain a weight loss of over 50% in the year after removal of the balloon (39).

Taken together it can be concluded that long-term weight loss after Roux-en-Y gastric bypass is less than after biliopancreatic diversion, but more than when compared with restrictive surgical procedures including intragastric balloon (29). Mean weight loss is maximal after 1–2 years and slowly increases until year 8–10 after which body weight stabilizes (14).

### Diabetes mellitus

Recovery from type 2 diabetes was established in 76.8% of the patients who underwent bariatric surgery (30). In the surgically treated group of the SOS study, type 2 diabetes had disappeared in 72% after 2 years. Unfortunately, 'only' 36% of those who had diabetes at entry remained free of the disorder at 10 years (13). In the conventionally treated group, these percentages were 21 and 13% respectively (13). Similar recovery rates are described in other studies as well (40–42). Moreover, these percentages seem related to the operative procedure that is used, with vertical banded gastroplasty, laparoscopic adjustable gastric banding, and Roux-en-Y gastric bypass resulting in resolution of diabetes in about 40, 60, and 80% of patients respectively (for an overview see Table 5 in reference (41)) (40–42). Several studies using homeostatic model assessment have reported improvements in insulin sensitivity and  $\beta$ -cell function (43, 44). These data are substantiated by studies that have used euglycemic-hyperinsulinemic clamp and i.v. glucose tolerance testing (45, 46).

Interestingly, many patients become euglycemic well before the weight loss occurs. Those procedures that expedite nutrient supply to the lower gastrointestinal tract appear to be especially promising in this respect (41, 47, 48). Indeed, in surgically treated obese (albeit nondiabetic) subjects studied with the insulin clamp technique, gastric bypass improves insulin sensitivity in proportion to weight loss whereas insulin resistance is completely restored long before normalization of body weight after biliopancreatic diversion (49).

### Lipids

Hypercholesterolemia and hypertriglyceridemia improve after surgical treatment of obesity irrespective of the technique used (30). Total and low density lipoprotein (LDL) cholesterol concentrations decreased with an average of 0.86 mmol/l (95% confidence



interval (CI) 0.60–1.13 mmol/l) and 0.76 mmol/l (95% CI 0.46–1.06 mmol/l) respectively (30). While triglyceride concentrations decrease with an average of 0.90 mmol/l (95% CI 0.73–1.08 mmol/l), high density lipoprotein (HDL) cholesterol concentration showed no difference in a combined analysis of all surgical procedures (30). However, patients who underwent vertical banded gastroplasty ( $n=253$ ) or gastric banding ( $n=623$ ) showed an increase in concentration of HDL cholesterol of 0.13 mmol/l (95% CI 0.02–0.24 mmol/l) and 0.12 mmol/l (95% CI 0.04–0.20 mmol/l) respectively (30).

### ***Hypertension, obstructive sleep apnea, and polycystic ovary syndrome***

A benefit of surgery in reducing the prevalence of hypertension and obstructive sleep apnea has also been shown (30). Of the surgically treated patients, 62% of those with hypertension and 86% of those with obstructive sleep apnea recovered (30). In patients with polycystic ovary syndrome treated with bariatric surgery (either laparoscopic gastric bypass or biliopancreatic diversion), hirsutism, hyperandrogenemia, insulin resistance, and ovulation and/or restoration of menstrual cycle significantly improved in all (50).

### ***Quality of life***

The SOS study found a dramatic improvement in the quality of life at 2 years among patients who had had surgical treatment for obesity, particularly concerning psychological performance (51). Unsurprisingly, there is a strong positive correlation between the degree of improvement in quality of life and the degree of weight loss (51). In another study, 95% of 275 patients who underwent laparoscopic Roux-en-Y gastric bypass surgery reported improvement in quality of life (52). Similar results have been reported for laparoscopic adjustable gastric banding (53).

### ***Mortality***

Retrospective cohort studies have suggested that bariatric surgery leads to a decrease in mortality; two published studies have shown that for obese patients with diabetes mellitus, bariatric surgery reduces mortality considerably (54, 55). Moreover, in nondiabetic patients mortality reduction after bariatric surgery has also been demonstrated: in a cohort of 1035 patients with an average BMI of 50 kg/m<sup>2</sup> undergoing bariatric surgery, mortality declined by 89% when compared with a control group which did not receive surgical treatment for obesity (0.68% vs 6.17%; relative risk 0.11, 95% CI 0.04–0.27) (56). Long-term mortality data for gastric bypass surgery were very recently reported. In a large retrospective cohort study (9949 gastric bypass

procedures versus 9628 severely obese controls), long-term mortality from any cause (mean follow-up of 7.1 years) decreased by 40% compared with that in the control group (57). Prospective mortality data are provided by the 'SOS' study; during an average of 10.9 years follow-up subjects who underwent bariatric surgery had an overall mortality hazard ratio of 0.76 when compared with control subjects (14).

In conclusion, bariatric surgery is an effective treatment option for long-term reduction of body weight and amelioration of obesity-related comorbid conditions. Importantly, evidence shows that for obese patients – with or without diabetes mellitus – surgical treatment of obesity leads to a reduction in mortality.

## **Mortality, complications, and side effects of surgical treatment of obesity**

### ***Mortality***

The early mortality rate of bariatric surgery (i.e., death < 30 days) is 0.1–2.0%, depending on procedure and patient characteristics (8, 29, 30, 58). Mortality after 30 days varies between 0.1 and 4.6% (29, 58). For all 60,077 patients who underwent Roux-en-Y gastric bypass in California in the period 1995–2004, the overall in-hospital mortality rate was 0.18%, 30-day mortality was 0.33%, and 1-year mortality was 0.91% (59). These results are similar to those found in a recent audit of 1144 cases from 29 academic centers in the United States in which the 30-day mortality rate for gastric bypass was 0.4% (60). The 30-day mortality rate for restrictive procedures in this study was 0% (60); again comparable with that found in a number of other studies (36, 61, 62). Important determinants of mortality are: age, sex, cardiorespiratory fitness, and surgeon experience. For patients over 65 years of age, the mortality rate at 30 days is 4.8% and 11.1% at 1 year; for patients under age 65, the mortality rate is 1.7 and 3.8% respectively (58). The risk of death after bariatric surgery is higher for men than for women: at 30 days and at 1 year, 3.7% vs 1.5% and 7.5% vs 3.7% respectively (58, 63). Reduced cardiorespiratory fitness levels – defined as peak oxygen consumption < 15.8 ml/kg per min – were associated with a six times higher risk of short-term (cardiovascular) complications and death (64). Within the surgeon's first 19 procedures the odds of death within 30 days were 4.7 times higher (95% CI, 1.2–18.2) than at later points in a surgeon's case order (65). Considering the causes of death it seems that pulmonary embolism is one of the leading causes at least after gastric bypass (63, 66). In an autopsy study of 10 patients who died after surgery, pulmonary embolism was found in 8 (66).

Taken together the mortality after 30 days varies in diverse studies between 0.1 and 4.6% and mainly

occurs following a malabsorptive procedure. Restrictive procedures appear to have a much lower mortality rate.

### **Postoperative complications and difficulties**

As a result of the selection of overweight and obese patients, the risk of postoperative complications increases (67). In obese patients, the course of postoperative complications and side effects is often atypical and a high level of clinical suspicion is therefore warranted.

Of particular concern are venous thromboembolism (66, 68–70) and sepsis. The latter occurs especially as a result of infection of the gastric band, anastomotic leak, and wound infection (52, 70–72). The incidence of venous thromboembolism is reported to be between 0.4 and 3.1% (52, 71, 73). It is therefore imperative to use adequate multimodal thromboprophylaxis. With a protocol consisting of early ambulation, compression stockings, intermittent compression stockings, and enoxaparin, a low rate of postoperative venous thromboembolism was described (74). In patients at especially high risk for venous thromboembolism (e.g., patients: older than 65 years, BMI > 50, a previous venous thromboembolism, venous insufficiency, sleep apnea), placement of a vena cava filter as well as a prolonged course of oral anticoagulants should be seriously considered (75–78).

Anastomotic leaks are another cause of morbidity and mortality occurring in ~0.5–3% (52, 63, 71, 75, 79–84). Leaks are difficult to diagnose, a heart rate above 120 beats/min and respiratory distress/failure are the most common manifestations of anastomotic leak (68, 70, 85). It should be noted that anastomotic leaks after bariatric surgery frequently become clinically apparent after discharge (86). Radiological studies are often falsely negative and anastomotic leak can therefore not be excluded on the basis of a negative water-soluble gastrointestinal contrast study alone (85, 87). So, if the clinical picture is compatible with the presence of anastomotic leak, then an exploratory laparotomy is strongly advised (70).

Intubation and mechanical ventilation can be difficult and direct postoperative extubation is often not possible (70, 88). Nursing (e.g., lifting, turning, and washing the patient, helping the patient to go to the toilet) and monitoring (e.g., measuring the blood pressure and assessing X-rays) are often troublesome (70).

Thus, a high degree of clinical suspicion in considering postoperative complications is mandatory. Pulmonary embolism and anastomotic leaks are the most fearsome, i.e. deadly, complications that should always be considered whenever the postoperative course takes an unexpected turn.

### **Procedure-specific perioperative complications**

A substantial proportion of patients vomit during the first postoperative months because of the decreased volume of

the stomach (89). Vomiting may also be a symptom of anastomotic stenosis occurring in 20–33% of all cases; as a result upper gastrointestinal endoscopy is warranted in all the cases of persistent vomiting. If in the first postoperative weeks, food is insufficiently chewed it can cause upper gastrointestinal obstruction at the level of the gastrojejunal anastomosis. In such instance, endoscopic removal will provide immediate relief. Anastomotic stricture after laparoscopic gastric bypass occurs more frequently when a 21 mm circular stapler instead of a 25 mm stapler is used (90).

Vertical banded gastroplasty has a high incidence of persistent (>10 years) postoperative vomiting (20%) and heartburn (16%) (91, 92). In exceptionally severe cases, symptoms can be reversed by converting to gastric bypass (93).

Dumping syndrome occurs in about half of patients after gastric bypass surgery (29). Treatment consists of avoiding provoking food products. A newly described complication after gastric bypass surgery is endogenous hyperinsulinemic hypoglycemia with nesidioblastosis (94). The exact factor that causes the nesidioblastosis is unknown but might be related to a change in concentrations and/or activity of gut hormones due to the change in the upper gastrointestinal tract (94).

Typical complications after laparoscopic adjustable gastric band are erosion of the band into the gastric wall, prolapse of the band leading to gastric outlet obstruction, disconnection of the band from the s.c. reservoir, and esophageal dilation (95–98).

Finally, as a consequence of the altered anatomy after bypass surgery internal hernias are not uncommon (23, 24).

In summary, vomiting is a relatively frequent occurrence in the first postoperative weeks. Due to the creation of a small gastric pouch upper gastrointestinal obstruction can occur. Dumping syndrome initially occurs in about half of patients after gastric bypass surgery; more recently endogenous hyperinsulinemic hypoglycemia with nesidioblastosis has been described.

## **Metabolic side effects**

### **Immediate postoperative period**

In the first six postoperative weeks, the diet can be gradually expanded from clear liquids to small meals only. As vomiting is quite common in this period, special care should be taken to prevent dehydration, hypokalemia, and hypomagnesemia (89). Also, as thiamine deficiency can ensue as a result of frequent vomiting, thiamine supplementation can become necessary.

### **Six weeks postoperative**

Even after the patient has adequately adopted new eating habits, nutritional deficiencies can develop as a

result of changes in the anatomy of the gastrointestinal tract (89). Deficiencies of vitamin B12 and iron are highest in prevalence especially after gastric bypass (89, 99). Prevalence of vitamin B12 deficiency tends to increase yearly and can be difficult to treat, often high doses of an oral or parenteral supplement are needed (89, 99, 100). Since bypassing the distal part of the stomach hampers the absorption of iron, iron deficiency can easily ensue, especially in menstruating women (89, 101). In such cases, oral supplementation is indicated; however, parenteral administration of iron may be necessary in selected cases (89, 101). Anastomotic ulceration is another frequent cause of iron deficiency after bariatric surgery (89).

Three months after gastric bypass, bone resorption markers are already increased and 9 months post-operatively loss of bone mineral at the spine, hip, and total body has been described (102). Gastroenterostomy is also a known cause for vitamin D deficiency (103). Indeed, 3–5 years after gastric bypass 25-hydroxyvitamin D levels are lower than normal (104). Thus, in the case of secondary hyperparathyroidism, supplemental vitamin D and calcium should be given (105–110).

Weight loss is related to the development of cholelithiasis (111). The incidence of gallstones after bariatric surgery varies between 22 and 71% (112, 113). Of those who formed stones 7–41% had symptomatic cholelithiasis (112, 113). In the case of concomitant cholelithiasis at the time of the bariatric operation, it is advisable to perform a cholecystectomy prior to or during the bariatric procedure (112, 114). In all patients on whom an open – as opposed to a laparoscopic – procedure is performed it seems reasonable to perform a cholecystectomy.

Thus, due to the specific anatomical and physiological changes after bariatric surgery and in order to prevent development of serious complications, long-term follow-up and monitoring of all patients is indicated. Table 2 provides some guidance (please note: this table is not based upon evidence based guidelines and cannot replace clinical judgment).

# Which patients are eligible for bariatric surgery?

Overall it can be concluded that bariatric surgery is the most effective long-term treatment for obesity. However, serious complications can occur and therefore a careful selection of patients is of utmost importance to ensure that those with the greatest predicted benefit undergo these procedures. We, and others (8), feel that bariatric surgery should at least be considered for all patients with a BMI of more than 40 kg/m<sup>2</sup> and for those with a BMI of more than 35 kg/m<sup>2</sup> with concomitant obesity-related conditions. Table 3 shows commonly accepted criteria for bariatric surgery (23). Clearly, these criteria are not absolute.

Research concerning age and BMI criteria is ongoing. In a recent review, it was concluded that ‘it is reasonable to propose that bariatric surgery performed in the adolescent period may be a more effective treatment for childhood-onset extreme obesity than delaying surgery for extremely obese youth until adulthood’ (115). In a small trial in patients with a BMI ranging from 30 to 35 surgical treatments using laparoscopic adjustable gastric banding were statistically significantly more effective than non-surgical therapy in reducing weight, resolving the metabolic syndrome, and improving quality of life during a 24-month treatment program (62). Thus, by taking comorbidities and other patient characteristics into account, it will be possible to better identify those who will benefit the most from bariatric surgery without using absolute age and/or BMI criteria (62, 115–117). Moreover, it should be noted that comorbid conditions caused by obesity are an argument in favor of bariatric surgery. The majority of patients operated upon in experienced centers are in American Society of Anesthesiology class III (52).

In a recent report, recommendations considering preoperative management of patients about to undergo weight loss surgery are given (118). Several aspects deserve special attention. Obstructive sleep apnea is associated with an increased perioperative risk, notably difficult intubation and postoperative respiratory

**Table 2** Suggested follow-up after bariatric surgery (after Ref. (89)).

|                           | 1 month | 3 months | 6 months | 12 months | 18 months | 24 months | Annually |
|---------------------------|---------|----------|----------|-----------|-----------|-----------|----------|
| Chemistry <sup>a</sup>    | X       | X        | X        | X         | X         | X         | X        |
| Complete blood count      | X       | X        | X        | X         | X         | X         | X        |
| Magnesium                 | X       | X        | X        | X         | (X)       | X         | X        |
| Iron studies <sup>b</sup> | X       | X        | X        | X         | (X)       | X         | X        |
| Vitamin D                 |         | X        |          | X         | (X)       | X         | X        |
| PTH                       |         | X        |          | X         | (X)       | X         | X        |
| Vitamin B12               | X       |          | X        | X         | (X)       | X         | X        |
| Bone densitometry         |         |          |          | X         |           |           |          |

Dependent on the pace of weight loss, type of procedure (purely restrictive versus malabsorptive), and previous test results this scheme should be adapted.

<sup>a</sup>Electrolytes, glucose, BUN, creatinin, albumin, liver enzymes, and alkaline phosphate.

<sup>b</sup>Ferritin, iron, and transferrin (transferrin saturation).



**Table 3** Criteria for bariatric surgery (Ref. 23).

|   |
|---|
| BMI $\geq 40$ kg/m <sup>2</sup> or BMI $\geq 35$ kg/m <sup>2</sup> with significant obesity-related comorbidities |
| Age between 16 and 65 years   |
| Acceptable operative risks  |
| Documented failure at nonsurgical approaches to long-term weight loss   |
| A psychologically stable patient with realistic expectations  |
| A well-informed and motivated patient   |
| Commitment to prolonged lifestyle changes   |
| Supportive family/social environment  |
| Resolution of alcohol or substance abuse  |
| Absence of active psychosis and untreated severe depression   |

problems (118–120). However, it is unknown if preoperative evaluation has added value, but it might be considered in high-risk patients (118–120). Pre-operative management is otherwise dictated by the presence of comorbidities (121).

### Where should bariatric surgery be performed?

Due to the inverse relationship between patient volume and mortality and morbidity, bariatric surgery should only be performed in experienced centers. Bariatric surgery requires a multidisciplinary approach by an internist, a surgeon, an anesthesiologist, a dietician, and other specialists if necessary (24). Furthermore, the hospital infrastructure should be adequately equipped: operating tables which can handle extremely obese patients, extra long laparoscopic instruments, special staplers, and extra large beds. Also, the Radiology Department must be able to accommodate extremely heavy patients (24).

### Basic insights derived from bariatric surgery

The gastrointestinal tract is an important source of peptides regulating food intake and energy homeostasis (122). We have already referred to the impression that those procedures that expedite nutrient supply to the lower gastrointestinal tract appear to be especially successful in the 'cure' of diabetes (41, 47, 48). Moreover, it is very likely that changes in gut peptides following specific bariatric procedures are related to, or even responsible for, improvement in comorbid conditions (123–126). Indeed, two of the most effective bariatric procedures (Roux-en-Y gastric bypass and biliopancreatic diversion with duodenal switch) are associated with markedly suppressed ghrelin levels whereas diet or gastric restrictive surgery lead to increased ghrelin levels (127, 128). Further development of such insights will hopefully lead way to development of more effective pharmacotherapy of obesity and its associated conditions.

### Conclusion

Bariatric surgery is the most effective treatment for long-term reduction of body weight. Bariatric surgery should at least be considered for all patients with a BMI of more than 40 kg/m<sup>2</sup> and for those patients with a BMI of more than 35 kg/m<sup>2</sup> with important obesity-related comorbid conditions. Recent evidence shows that bariatric surgery for severe obesity is associated with decreased overall mortality.

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Received 20 October 2007

Accepted 8 November 2007