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Systematic review: the effects of conservative and surgical treatment for obesity on gastro-oesophageal reflux disease

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SUMMARY

Background
Incidence rates of both obesity and gastro-oesophageal reflux disease (GERD) are increasing, particularly in the Western world. It has been suggested that GERD symptoms may be improved by weight reduction.

Aim
To review the literature on the effect of various weight reducing modalities on manifestations of GERD in obese patients.

Methods
A literature search was performed using PubMed, EMBASE and the Cochrane Library, combining the words obesity and gastro-oesophageal reflux with bariatric surgery, diet, lifestyle intervention and weight loss.

Results
With regard to diet/lifestyle intervention (conservative), four of seven studies reported an improvement of GERD. For Roux-en-Y gastric bypass, a positive effect on GERD was found in all studies, although this was mainly evaluated by questionnaires. In contrast, for vertical banded gastroplasty, no change or even an increase of GERD was noted, whereas the results for laparoscopic adjustable gastric banding were conflicting.

Conclusions
Dietary and lifestyle intervention may improve GERD in obese patients; however, the most favourable effect is likely to be found after bariatric surgery, especially after Roux-en-Y gastric bypass. Future studies need to elucidate for which GERD patients laparoscopic adjustable gastric banding might have a beneficial effect and how they can be identified preoperatively.

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INTRODUCTION

Obesity is a growing epidemiological problem in the Western world. An International Obesity Task Force estimated that at least 1.1 billion people worldwide are overweight [body mass index (BMI) 25–30], with 312 million of them currently being obese (BMI > 30).[1] In the US population, the prevalence of obesity was 30.5% in the period 1999–2000 compared to 22.9% in 1988–1994. The prevalence of overweight increased similarly during this period from 55.9% to 64.5%.[2]

Obesity is therefore becoming an increasingly important medical problem. Common comorbidities because of obesity include diabetes, hypertension and cardiovascular disease. Specific gastroenterological comorbidities are non-alcoholic fatty liver disease, reflux-oesophagitis, Barrett's oesophagus, oesophageal carcinoma and gastro-oesophageal reflux disease (GERD).[3–6] To prevent or treat these disorders, it is important to treat overweight and obesity.

Two meta-analyses have shown a positive correlation between obesity and GERD.[7, 8] Hampel *et al.* showed an association between overweight [Odds Ratios (OR): 1.43] and obesity (OR: 1.94), and GERD. This was based on validated symptom questionnaires and/or endoscopic findings.[7] Corley and Kubo[8] reported an association between GERD, defined on the basis of symptoms, oesophagitis or both, in patients with overweight (OR: 1.57) and obesity (OR: 2.15).

A number of pathophysiological factors are involved in GERD in obesity. The frequency of transient lower esophageal sphincter relaxations (TLESRs) has been reported to be increased,[9] as well as the prevalence of oesophageal motility disorders.[10, 11] In addition, an increased abdominal pressure [12–14] and a high prevalence of hiatal hernias[15, 16] have been reported. These factors all facilitate reflux of gastric juice into the oesophagus.

Several treatment options for GERD are available in obese patients. The first step usually consists of lifestyle and dietary recommendations,[17] often combined with acid inhibiting therapy, such as proton pump inhibitors (PPIs). There is some evidence that GERD may improve by solely reducing weight.[18] If conservative measures are not successful, a surgical approach is an alternative option. A gastric balloon is a solution in between and despite its popularity in the 1990s, the gastric balloon is nowadays only used for a small group of patients who are unfit to undergo surgery (yet) or are not responding to medical therapy.[19] Surgery appears to have better long-term results with regard to weight loss and reduction of comorbidity.[17] The various surgical techniques that are available achieve weight reduction by means of different mechanisms, which can be subdivided into restrictive or malabsorptive techniques or a combination of both (Figure 1).

Restrictive techniques result in weight reduction by reducing stomach volume leading to early satiety. Examples of these are vertical banded gastroplasty (VBG) or (laparoscopic adjustable) gastric banding (LAGB). In VBG, a small proximal pouch is created by stapling the fundus parallel to the lesser curve. The distal exit of this pouch is narrowed by means of a silicone ring. In LAGB, a proximal pouch is created by placing an adjustable silicone band around the proximal part of the stomach. The remaining ostium towards the distal stomach can be adjusted by inflating or deflating the band through a subcutaneous port.

Malabsorptive techniques result in weight reduction by functional shortening of the digestive tract and/or by diverting digestive juices. Examples of these are a jejuno-ileal bypass, biliopancreatic diversion and biliopancreatic diversion with duodenal switch. These types of operations are not commonly performed nowadays and almost no study has evaluated their effect on GERD.

A Roux-en-Y gastric bypass (RYGB) has both restrictive and malabsorptive properties, in that the proximal stomach is completely divided from the residual stomach and transformed into a pouch. Then, the pouch is anastomosed with a Roux-en-Y limb that bypasses the duodenum and proximal jejunum.

It is not completely clear, whether lifestyle and dietary advice on the one hand or a surgical procedure on the other hand are indeed effective in reducing symptoms of GERD, and if so, which technique is preferable to establish this. We therefore systematically reviewed the literature on the effect of weight reducing measures, either conservative or surgical (VBG, LAGB and RYGB) on manifestations of GERD in obese patients.

METHODS

Search strategy

A literature search was performed using three databases: PubMed, the Cochrane Library and EMBASE. The following medical subject headings or keywords were used: obesity and gastro-oesophageal reflux combined

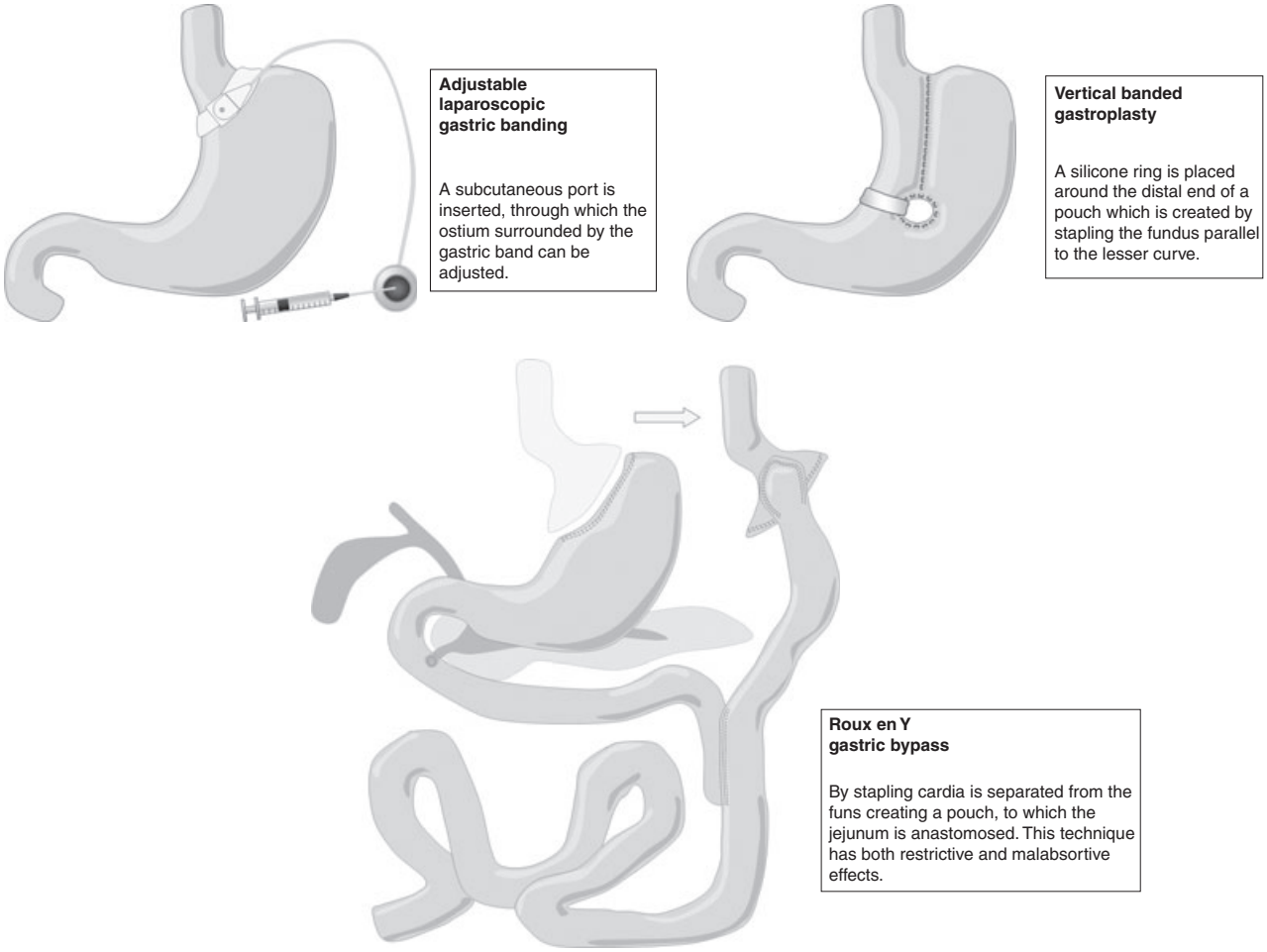

Figure 1. The various surgical techniques mentioned in this review.

with bariatric surgery, diet, lifestyle-intervention and weight loss. In addition, bibliographies of retrieved articles were manually searched, and reviews were evaluated. To limit and focus the review, papers with GERD as a secondary outcome parameter were not selected.

Study selection

Studies were included when the following inclusion criteria were met: (i) Patients with obesity (BMI > 30) or overweight (BMI > 25). (ii) Data on gastro-oesophageal reflux symptoms and/or an established diagnosis of GERD. When typical symptoms such as heartburn, regurgitation, epigastric pain or retrosternal pain were recorded, sometimes in combination with the atypical symptoms dysphagia and/or postprandial and/or nocturnal cough, these were also regarded as indicative of GERD and these patients were eligible for this study. An established diagnosis was defined as GERD being the outcome of one or more of the following tests: endoscopy (oesophagitis, Barrett's oesophagus) and/or ambulatory oesophageal pH monitoring (positive 24 h recordings). (iii) Treatment modalities included a type of bariatric surgery (gastric banding, VBG or RYGB), diet and/or diet/lifestyle intervention. All studies were divided according to the level of evidence (Table 1). Retrospective studies, prospective studies and randomized controlled trials (RCTs) were included, whereas case reports and expert opinions were excluded.

Intervention definition

Diet/lifestyle. The studies that were included used the following definitions for diet and lifestyle interventions. A very low-calorie diet was defined as a diet

Table 1. Level of evidence

Level	Method
1	Meta-analysis of randomized controlled trials
2	Randomized controlled trials
3	Prospective cohort/follow-up, patient-control
4	Retrospective studies
5	Case reports
6	Expert opinions

containing 420 kcal/day and a low calorie diet as a diet containing 1000–1500 kcal/day. A very low-carbohydrate diet had a daily carbohydrate intake of <20 gm/day. Lifestyle interventions included weight loss programmes aimed at energy restriction, enhancing physical exercise and behavioural modification.

Bariatric surgery. Bariatric surgical procedures included restrictive procedures, either VBG or LAGB, or RYGB. Laparotomic and non-adjustable gastric banding techniques were only used in two of fourteen studies.

Outcome definition

Primary outcomes were defined as the effect on GERD, measured by 24-h pH monitoring, manometry, endoscopy and/or radiological techniques, whereas the reduction in reflux symptoms was evaluated by questionnaires. A secondary outcome was weight reduction. Weight reduction was measured in kilograms, in percentages of original weight or in decreased BMI. A commonly used measure in the evaluated studies was the percentage of excess weight loss.

Quality assessment and data analysis

The quality of studies was assessed according to the Cochrane library definitions.[20]

Assessment items included population, selection bias, intervention, outcome, follow-up, lost-to-follow-up, confounders, results and conclusion(s). Two authors assessed all studies on methodological quality without consideration of the results. Disagreements were resolved until consensus was established. The selected studies were pooled into four groups: lifestyle/diet intervention, RYGB, restrictive procedures (LAGB, VBG) or studies with two or more techniques used. Table 2 shows characteristics of the four groups.

RESULTS

The initial literature search revealed 78 citations (Figure 2). Twenty-two studies met the inclusion criteria. After further screening of bibliographies and references, 10 additional studies were identified. In total, 32 studies were included in the review. The results are shown in Tables 2 and 3.

Diet/lifestyle

The effect of a lifestyle or diet intervention on GERD in overweight and obese patients was evaluated in seven studies.[18, 21–26] Two studies used a very low-calorie liquid diet, one a low-calorie diet, one a very low-carbohydrate diet and three, lifestyle interventions. Most studies provided level 2 and three studies, level 3 evidence (Table 2). In three studies, the effect of a gastric balloon was compared with sham balloon treatment.[22, 23, 26] In two of these, an improvement in pH-metry was noted after lifestyle intervention and sham balloon treatment. Fraser-Moodie *et al.*[18] also found a positive correlation between life style intervention and a reduction in GERD symptoms, which was substantiated by improvement in pH-metry outcomes. Austin *et al.* [21] showed an improvement in reflux symptoms and a reduction in acid exposure to the oesophagus with a low-carbohydrate diet, but no significant weight loss was achieved. On the other hand, Frederiksen *et al.*,[24] Mathus-Vliegen *et al.*[26] and Kjellin *et al.*[25] found no improvement in reflux symptoms and pH-metry outcomes following dietary and lifestyle interventions.

Gastric bypass

The effect of RYGB on GERD was evaluated in eight studies.[27–34] Additionally, three studies compared RYGB with other techniques for weight reduction.[35–37] All studies provided at most level 3 or level 4 evidence (Table 3). In all reported studies, a reduction in weight was reported. In the majority, the weight reduction was expressed as percentage of excess weight loss, with a mean of 72% (range 68.8–76%). RYGB resulted in more weight loss than LAGB in the comparative studies.[35–37] Almost all studies showed an improvement of GERD symptoms except the study of Korenkov *et al.*[35] in

Table 2. Design and baseline characteristics of the selected studies

Authors	Level of evidence	No. patients	Mean BMI at start	Reflux evaluation	Intervention	Follow-up (weeks)
Diet						
Kjellin *et al.*[25]	2	20	31.4	Quest, 24-h pH, manometry, endoscopy	VLCalD	24
Mathus-Vliegen and Tytgat[26]	2	17	54.2	24-h pH, endoscopy	Life style	16
Fraser-Moodie[18]	3	34	23.5	Quest	Life style	26
Mathus-Vliegen and Tytgat[22]	2	43	43.4	24-h pH, endoscopy	LCalD	26
Mathus-Vliegen *et al.*[23]	2	32	44.3	24-h pH, endoscopy	Life style	26
Austin *et al.*[21]	3	8	43.5	Quest, 24-h pH	VLCD	1
Gastric bypass						
Jones *et al.*[29]	3	100	Not stated	Quest, endoscopy	RYGB	80
Smith *et al.*[33]	3	188	44.1	Quest	RYGB	208
Jones[30]	4	44	33	Quest	RYGB	Not stated
Frezza *et al.*[28]	3	152	48	Quest	RYGB	52
Clements *et al.*[27]	3	43	47.8	Quest	RYGB	24
Patterson *et al.*[34]	4	12	55	Quest, 24-h pH, manometry	RYGB	52
Perry *et al.*[32]	3	57	43	Quest	RYGB	74
Nelson *et al.*[31]	3	227	51	Quest	RYGB	36
Restrictive procedures						
Deitel *et al.*[39]	3	31	45.1	Quest, barium, endoscopy, manometry, acid perf.	VBG	24
Naslund *et al.*[42]	3	21	42.5	24-h pH, manometry, endoscopy	VBG	152
Lundell *et al.*[43]	3	50	42.5	Quest, 24-h pH, endoscopy	VBG or GB	52
Ovrebo *et al.*[41]	3	43	GB 44/VBG 46	Quest, 24-h pH, endoscopy	VBG or GB	156
Angrisani *et al.*[44]	3	40	44.7	Quest	LAGB	Not stated
Dixon *et al.*[45]	4	48	Not stated	Quest	LAGB	>16
Weiss *et al.*[50]	3	43	42.5	Quest, 24-h pH, manometry, endoscopy, barium	LAGB	24
Iovino *et al.*[46]	3	43	44.7	Quest, 24-h pH, manometry	LAGB	74
Weiss *et al.*[51]	3	57	42.5	Quest, 24-h pH, manometry, endoscopy, barium	LAGB	102
De Jong *et al.*[48]	3	26	47	Quest, 24-h pH, endoscopy,barium	LAGB	24
Di Francesco *et al.*[38]	3	14	46	24-h pH, manometry	VBG	52
Papravramidis *et al.*[40]	3	23	56	24-h pH	VBG	74
Suter *et al.*[53]	3	43	42.2	Quest, 24-h pH, manometry, endoscopy	LAGB	74
De Jong *et al.*[47]	3	29	46.1	Quest, manometry, barium	LAGB	24

Table 2. (Continued)

Authors	Level of evidence	No. patients	Mean BMI at start	Reflux evaluation	Intervention	Follow-up (weeks)
Klaus *et al.*[49]	3	587	46.7	Quest, 24-h pH, manometry, endoscopy	LAGB	104
Tolonen *et al.*[52]	3	31	46	Quest, 24-h pH, manometry, endoscopy	LAGB	28–128
Restrictive procedures vs. gastric bypass						
Korenkov *et al.*[35]	3	53	LAGB 46.4 RYGB 54	Quest, manometry	LAGB or RYGB	88
Ortega *et al.*[37]	3	50	VBG 42	Quest, 24-h pH, manometry	VBG or RYGB	52
Merrouche *et al.*[36]	3	100	LAGB 42 RYGB 48.6	Quest, 24-h pH, manometry	LAGB or RYGB	124
Diet vs. banding						
Frederiksen *et al.*[24]	3	25	43	24-h pH	Liquid VLCalD and VBG	3

Acid perf., acid perfusion test; barium: barium swallow; GB, gastric banding; LAGB, laparoscopic adjustable gastric band; LCalD, low calory diet; Quest, symptom questionnaires; RYGB, Roux-en-Y gastric bypass; VBG, vertical banded gastroplasty; VLCD, very low carbohydrate diet; 24-h pH, twenty-four hour pH-monitoring.

which two patients with preoperative GERD symptoms improved post-operatively, but two other patients developed GERD symptoms after surgery. Merrouche *et al.*[36] and Ortega *et al.*[37] showed that RYGB yielded better results than gastric banding with regard to gastro-oesophageal reflux reduction.

Restrictive procedures

The effect of gastric banding on GERD was evaluated in 20 studies; LAGB in 12[35, 36, 44–53] and VBG in eight studies[24, 37–43] (two studies compared VBG with gastric banding). Four studies compared gastric banding with RYGB[35–37] or a diet.[24] All studies provided level 3 or level 4 evidence. Weight loss was mainly documented as a decrease in BMI. During follow-up (7 weeks–48 months), mean BMI decreased from 39.8 (range 23.5–56) kg/m^2 to 31.5 (range 21.8–42.0) kg/m^2. All studies reported weight reduction but the effects on GERD were conflicting.

Vertical banded gastroplasty. Of the eight studies included,[24, 37–43] one study reported that VBG resulted in a significant improvement of GERD.[39] Ortega *et al.*[37] showed an initial improvement at 3 months post-operatively, but 30% of the operated patients still had symptomatic GERD and 60% had pH-metric reflux at 1 year. Another five studies[40–43] reported no significant change, whereas Di Francesco *et al.*[38] even found increased gastro-oesophageal reflux, as measured with pH-metry.

Laparoscopic adjustable gastric banding. Four studies showed a positive effect after LAGB on GERD.[44–47] In two other studies, an improvement was found, provided that no pouch dilatation occurred and/or preoperative determined oesophageal body motility was not ineffective.[48, 49] Four studies showed conflicting results with improvements and worsening in different domains of the diagnostic tests.[36, 50–52] Two other studies found an increase of GERD symptoms and worsening in pH-metry, manometry and/or endoscopy findings.[41, 53] Finally, two studies showed that LAGB had no effect on GERD.[35, 43]

DISCUSSION

The objective of this review was to compare the effect of various modalities for treating obesity on GERD. The published studies showed important methodologi-

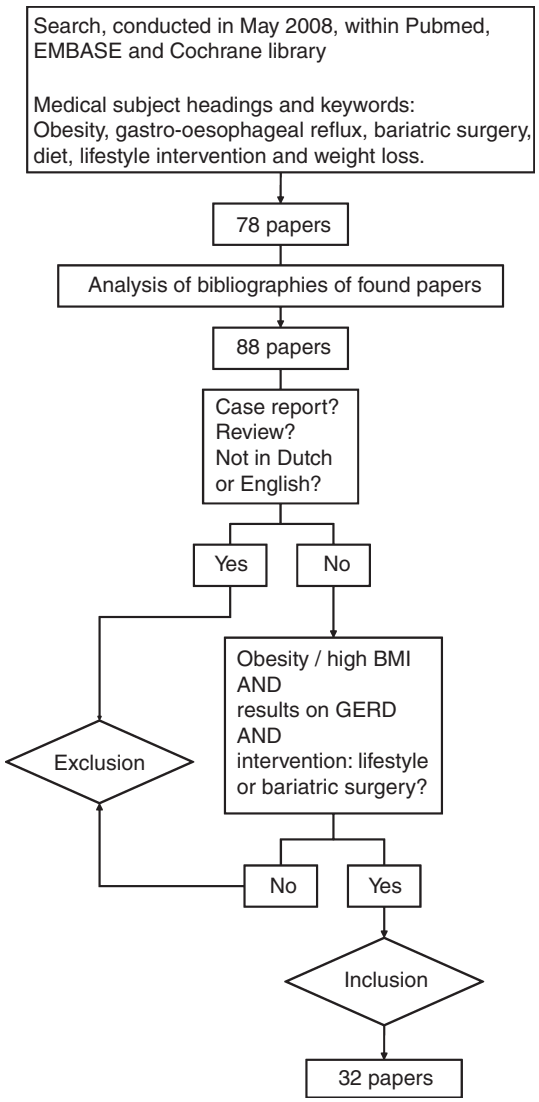

Figure 2. Flowchart of the literature search.

cal differences, which makes it difficult or even impossible to compare the results. Particularly, definitions of obesity, GERD and weight loss differed among studies. Only a few randomized trials were available; however, evidence levels were generally low and studied populations often small. GERD was evaluated in different ways, often with questionnaires and in only a minority of studies with 24-h pH-metry and/or endoscopy. It is well known that GERD symptoms poorly predict the presence of excessive oesophageal acid exposure or oesophagitis.[54]

Confounding factors were the different types of advice regarding PPI use, dietary and lifestyle habits, which may, for instance, in case a diet with reduced fat consumption was advised, account for some of the reported beneficial effects on GERD symptoms.[55–58] Only five of 27 studies that dealt with bariatric surgery reported whether patients took a diet after surgery, making it difficult to interpret the role of the diet on post-operative GERD. In addition, an effect on GERD symptoms cannot simply be attributed to weight loss as the anatomical and physiological condition of the subjects changed dramatically. For example, in RYGB-treated patients, almost the entire acid-producing part of the stomach is divided from the remaining pouch. One can hypothesize that gastric banding creates a mechanical barrier against gastric reflux.

In spite of these limitations, some conclusions can be drawn from this systematic review that specifically addresses the effects of dietary/lifestyle and surgical obesity treatment on GERD. The results of diet and lifestyle intervention as treatment of obesity-related GERD were mainly positive. Two methodologically sound RCTs by Mathus-Vliegen[22, 23] showed a positive effect of weight reduction on GERD symptoms. Fraser-Moodie *et al.*[18] showed a positive effect of a nonsurgical intervention on GERD; however, in this study, the population had a mean BMI of 23, which means that no clear overweight or obese individuals were included. It should be noted that there were also three studies that did not show any improvement.[24–26] In the RCT of Kjellin *et al.*,[25] weight reduction with a very low-caloric diet did not improve subjective or objective manifestations of GERD. He only studied patients with endoscopic evidence of reflux oesophagitis. It is presumable that weight reduction was not able to correct this and therefore the symptoms continued.

Roux-en-Y gastric bypass was found to have a favourable effect on GERD. However, one may argue that mainly questionnaires were used to evaluate the effect on GERD. Therefore, the results on RYGB could theoretically be different if objective measurements had been performed. In contrast to dieting and lifestyle intervention in which it is more difficult to achieve and maintain significant weight loss, bariatric surgery, i.e. RYGB, provides a more permanent anatomical and physiological change, which aids in maintaining the positive effect of weight reduction on weight and GERD.

The included studies did not show a clear beneficial effect of VBG on GERD in obese patients, although a weight reduction was achieved in the majority. This may mean that the weight loss because of VBG had no beneficial effect on GERD, or, more likely, the positive effect of weight loss was counteracted by a negative

Table 3. Results of the different treatment modalities on reflux symptoms, 24-pH, manometry and gastro-oesophageal reflux disease in general

Authors	Symptom score	24-h pH	Manometry	Conclusions of outcome on GERD
Diet				
Kjellin *et al.*[25]	Same	Same	Same	Weight reduction does not improve subjective or objective manifestations
Mathus-Vliegen and Tytgat[26]	Not stated	Same	Not stated	No significant change in 24-h pH, although significant weight loss was achieved
Fraser-Moodie[18]	Better	Not stated	Not stated	Significant correlation weight loss and symptom reduction
Mathus-Vliegen and Tytgat[22]	Not stated	Better	Not stated	Body weight loss and visceral fat loss resulted in improved reflux parameters
Mathus-Vliegen *et al.*[23]	Not stated	Better	Better	Weight loss led to decreased acid exposure (upright, meal-related and postprandial) and to significantly increased LOS length
Austin *et al.*[21]	Better	Better	Not stated	VLCD improves reflux symptoms and reduce acid exposure significantly in obese patients
Gastric bypass				
Jones *et al.*[29]	Better	Not stated	Not stated	RYGB is a very effective antireflux procedure in obese patients
Smith *et al.*[33]	Better	Not stated	Not stated	RYGB with or without antireflux procedure can improve reflux symptoms
Jones[30]	Better	Not stated	Not stated	RYGB is efficient also for the less than morbid obese with reflux oesophagitis
Frezza *et al.*[28]	Better	Not stated	Not stated	Significant decrease in GERD-related symptoms and decrease of medication
Clements *et al.*[27]	Better	Not stated	Not stated	Morbidly obese patients experience more GI-symptoms than controls and all symptoms except dysphagia return to control level after 6 months after surgery
Patterson *et al.*[34]	Better	Better	Not stated	Both RYGB as LN where effective for reflux symptoms, RYGB operation of choice for morbidly obese patients
Perry *et al.*[32]	Better	Not stated	Not stated	All patients reported improvement or no symptoms of GERD
Nelson *et al.*[31]	Better	Not stated	Not stated	Symptoms of GERD improved significantly after RYGB
Restrictive procedures				
Deitel *et al.*[39]	Better	Not stated	Better	Significant improvement of reflux symptoms, decrease of oesophagitis, increase of sphincter pressure
Naslund *et al.*[42]	Not stated	Same	Same	No effect of VBG on reflux. Also no significant improvement
Lundell *et al.*[43]	Better	Same	Not stated	Gastric restriction operations do not seem to increase the incidence of reflux in patients with normal antireflux barriers, no difference between VBG and GB
Ovrebo *et al.*[41]	GB worse VBG same	GB worse VBG same	Not stated	Prevalence of GER was unchanged by VBG, no antireflux properties. Incidence of GER increased after GB
Angrisani *et al.*[44]	Better	Not stated	Not stated	GER with or without hiatal hernia is not a contraindication for a LAGB
Dixon *et al.*[45]	Better	Not stated	Not stated	Lap-band prevents and improves symptoms of gastro-oesophageal reflux, also after a very short time

Table 3. (Continued)

Authors	Symptom score	24-h pH	Manometry	Conclusions of outcome on GERD
Weiss *et al.*[50]	Better	Better	Better*	Reflux symptoms, 24-h pH and oesophagitis improved significantly. LAGB leads to a higher LES pressure but impairs relaxation of LES
Iovino *et al.*[46]	Better*	Better	Better	Significant reduction of heart burn and regurgitation, significant increased dysphagia. Reduction of abnormal oesophageal acid exposure.
Weiss *et al.*[51]	Better	LAGB better OGB better	LAGB worse OGB worse	Both LAGB as OGB strengthening the antireflux barriers but impair LES relaxations that can cause oesophageal dilatation and stasis LAGB < OGB
De Jong *et al.*[48]	Better*	Better*	Not stated	LAGB reduces gastro-oesophageal reflux if there is no pouch formation during follow-up. If a pouch develops an increase of reflux and reflux symptoms will be found
Di Francesco *et al.*[38]	Not stated	Worse	Worse	VBG was not able to reduce gastro-oesophageal acid reflux, only when accompanied by fundoplication
Papravramidis *et al.*[40]	Not stated	Better	Not stated	VBG does not affect the pH levels in the oesophagus or in the antrum. But there is acidification in the antrum, which could lead to pH-related diseases
Suter *et al.*[53]	Same	Better	Worse	Low amplitude of contraction in the lower oesophagus and increased oesophageal acid exposure should be regarded as contraindication to LAGB
De Jong *et al.*[47]	Better*	Not stated	Better	LAGB cause increase of LES pressure, it decreases reflux symptoms. Pouch formation increases heartburn and regurgitation
Klaus *et al.*[49]	Better	Better	Better*	LAGB provides sufficient antireflux barrier except in patients with defective oesophageal body motility preoperatively
Tolonen *et al.*[52]	Better	Better	Worse	Correctly placed gastric band is an effective antireflux barrier in short term
Restrictive procedures vs. gastric bypass				
Korenkov *et al.*[35]	LAGB same RYGB same	Not stated	LAGB same RYGB same	No effect of LAGB or RYGB on reflux or oesophageal function
Ortega *et al.*[37]	VBG same RYGB better	VBG better RYGB better	Not stated	RYGB is significantly better than VBG for antireflux and weight loss
Merrouche *et al.*[36]	LAGB better RYGB better	LAGB worse RYGB better	Not stated	GERD-symptoms improved after RYGB en LAGB, but there was a worsening pH-metric data after LAGB
Diet vs. banding				
Frederiksen *et al.*[24]	Not stated	VLCD same VBG same	Not stated	Nor liquid diet nor VBG had appreciable effect on gastro-oesophageal reflux

GERD, gastro-oesophageal reflux disease; GB, gastric banding; VBG, vertical banded gastroplasty; LAGB, laparoscopic adjustable gastric band; VLCD, very low carbohydrate diet; RYGB, Roux-en-Y gastric bypass; OGB, oesophageal gastric banding.
*See explanation in 'Conclusions of outcome on GERD' in Table 3.

effect of the operation itself. It has been suggested that this negative effect might be related to acid accumulation in the VBG pouch.[38]

The effect of gastric banding on GERD remains unclear because of conflicting study results. This may well be explained by the use of different study designs. Angrisani *et al.*[44] and Dixon and O'Brien[45] only used questionnaires to evaluate the effect of gastric banding on GERD symptoms. The negative results of gastric banding on GERD were mainly documented in studies with more objective tests, such as 24-h pH-metry, manometry and endoscopy. Some of the conflicting results may be related to the use of different inclusion and exclusion criteria in various studies. Suter *et al.*[53] excluded patients with large hiatal hernias, whereas Ovrebo *et al.*[41] excluded patients with severe GERD.

It is not clear which factors are most commonly associated with an increase or decrease of GERD (symptoms) over time after gastric banding. The mechanism through which gastric banding may lead to an increase of GERD is similar to that in VBG, i.e. a reduced volume of the gastric cardia with an increased intragastric pressure and/or a change in the anatomy at the gastro-oesophageal junction. On the other hand, one can also postulate that the reported decrease in GERD symptoms after gastric banding can be explained by an increased length and/or increased pressure of the LES.[45, 46, 50]

An interesting topic in relation to gastric banding is the screening of patients with GERD symptoms prior to the procedure. Klaus *et al.*[49] retrospectively compared two groups of obese GERD patients treated with LAGB. One group had merely preoperative GERD, while the other group had persisting GERD post-operatively. They found that patients in the latter group more often had oesophageal dysmotility preoperatively. Greenstein *et al.*[59] also identified oesophageal dysmotility as a negative factor for post-operative GERD after gastric banding; however, they also found an association between post-operative GERD and gastric band slippage. The effect of the presence of a hiatal hernia was investigated by de Jong *et al.*[48] and Angrisani *et al.*[44] Both these studies found no association between a preoperative diagnosis of hiatal hernia and post-operative GERD. Nonetheless, an association between the presence of a hiatal hernia and GERD has extensively been documented in both obese and non-obese patients.[15, 16, 46] Some authors have therefore suggested that the presence of a hiatal hernia should be a contraindication for gastric banding.[59] This is derived from studies that have shown that patients with a hiatal hernia have a higher risk of developing a gastric prolaps, pouch dilatation and band slippage and in that way more reflux symptoms. Another issue is that in these patients also more often a re-operation is required. A recent study by Gulkarov *et al.*[60] demonstrated that a hiatal hernia repair added to a LAGB, significantly reduced the number of re-operations.

It can be concluded that diet and lifestyle intervention, leading to weight reduction, appears to be beneficial with respect to GERD. Of all surgical techniques evaluated in this review, RYGB seems to be the most promising in reducing GERD, whereas VBG appears to be ineffective. Gastric banding may improve or worsen GERD for reasons that are currently not fully understood. Clearly, more studies are needed to identify the factors that are able to predict the course of GERD after gastric banding. For future research on anti-obesity measures (either diet/lifestyle or surgery) on GERD, it is important that standard definitions are being used to make a comparison between different studies meaningful. For the outcome definition for weight loss, we suggest that excess weight loss in percentages should be used and not the pre- and post-operative differences of the BMI or body weight. It is also recommended to use standardized and validated questionnaires and to include 24-h pH-metry measurements at different time points to quantify objectively the effect of weight reduction on GERD.[61]

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