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Original article

Sleeve gastrectomy and type 2 diabetes mellitus: a systematic review

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Abstract

Background: Existing evidence has suggested that bariatric surgery produces sustainable weight loss and remission or cure of type 2 diabetes mellitus (DM). Laparoscopic sleeve gastrectomy (LSG) has garnered considerable interest as a low morbidity bariatric surgical procedure that leads to effective weight loss and control of co-morbid disease. The objective of the present study was to systematically review the effect of LSG on type 2 DM.

Methods: An electronic data search of MEDLINE, PubMed, Embase, Scopus, Dare, Clinical Evidence, TRIP, Health Technology Database, Conference abstracts, clinical trials, and the Cochrane Library database was completed. The search terms used included LSG, vertical gastrectomy, bariatric surgery, metabolic surgery, and diabetes (DM), type 2 DM, or co-morbidities. All human studies, not limited to those in the English language, that had been reported from 2000 to April 2010 were included.

Results: After an initial screen of 3621 titles, 289 abstracts were reviewed, and 28 studies met the inclusion criteria and the full report was assessed. One study was excluded after a careful assessment because the investigators had combined LSG with ileal interposition. A total of 27 studies and 673 patients were analyzed. The baseline mean body mass index for the 673 patients was 47.4 kg/m^2 (range 31.0–53.5). The mean percentage of excess weight loss was 47.3% (range 6.3–74.6%), with a mean follow-up of 13.1 months (range 3–36). DM had resolved in 66.2% of the patients, improved in 26.9%, and remained stable in 13.1%. The mean decrease in blood glucose and hemoglobin A1c after sleeve gastrectomy was −88.2 mg/dL and −1.7%, respectively.

Conclusion: Most patients with type 2 DM experienced resolution or improvement in DM markers after LSG. LSG might play an important role as a metabolic therapy for patients with type 2 DM. (Surg Obes Relat Dis 2010;xx:xxx.)

Keywords: Sleeve gastrectomy; Type 2 diabetes mellitus; Obesity; Bariatric surgery

Description of obesity

Worldwide, >1.7 billion adults are considered overweight, with ≥300 million considered clinically obese [1]. Obesity is generally defined as a body mass index (BMI) >30 kg/m^2. Co-morbid diseases related to obesity include hypertension, sleep apnea syndrome, and type 2 diabetes mellitus (DM). It has been proposed that in obese patients, a failure might occur of β-cells to secrete adequate levels of insulin to compensate for the insulin resistance in peripheral tissues, which ultimately leads to type 2 DM [2]. People with both obesity and type 2 DM have an increased risk of cardiac events and early death.

Description of intervention

During the past decade, bariatric surgical procedures such as Roux-en-Y gastric bypass and biliopancreatic diversion have demonstrated long-term control of obesity and

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type 2 DM [3,4]. In a recent systematic review, Buchwald et al. [5] demonstrated that 76% of people had resolution of type 2 DM after bariatric surgery. The bariatric surgical procedures included in their review were gastric banding, gastric bypass, gastroplasty, and biliopancreatic diversion with duodenal switch (BPDDS) [5].

Laparoscopic sleeve gastrectomy (LSG) was initially proposed as a staged approach to BPDDS for high-risk, severely obese, surgical candidates [6]. It has been increasingly considered as a definitive surgical procedure for obesity because of early data [7]. LSG involves removing most of the fundus of the stomach, creating a gastric "tube" 60–100 mL in capacity, which in turn limits the capacity for food intake.

How the intervention might work

LSG-associated weight loss is believed to be secondary to restriction of food intake by the small gastric reservoir. However, the mechanism behind LSG and the resolution of type 2 DM has not been clearly defined. Currently, both hormonal changes and a hindgut theory have been postulated to be involved. Karamanakos et al. [8] found a marked reduction of fasting ghrelin levels after LSG surgery. Ghrelin is a hormone produced primarily by the gastric fundus, which inhibits insulin secretion and blocks hepatic insulin signaling [8]. Abbatini et al. [9] stated that by reducing ghrelin levels and its "insulinostatic effect," the islet cells will be able to secrete additional insulin by increasing the maximal capacity of glucose-induced insulin release. The hindgut theory postulates that rapid delivery of undigested nutrients to the distal bowel upregulates the production of L-cell derivates such as glucagon-like peptide 1 (GLP-1) and peptide-YY [10,11]. GLP-1 is secreted by the ileal "L-cells" in response to eating and was shown to be increased in the LSG group in an animal model [12]. GLP-1 acts to stimulate insulin release and might increase the β-cell mass [13]. Peptide-YY is also secreted from L-cells and might ameliorate insulin resistance in mice [14]. The hindgut theory has been supported by Melissas et al. [15], who found that despite preservation of the pylorus in LSG, gastric emptying was accelerated.

Objectives of present review

The primary goal of bariatric surgery is to produce long-term, sustainable weight loss, with improvement of comorbid disease such as type 2 DM. Despite the efficacy of both gastric bypass and BPDDS, these remain complex surgical procedures with significant postoperative morbidity. LSG is a technically less-complex surgical procedure that has been reported to improve weight loss and type 2 DM remission rates. However, existing studies have consisted of small heterogeneous patient populations. The published data on LSG has not yet been systematically reviewed or subjected to a meta-analysis.

In the present study, we systematically reviewed the published data regarding the efficacy of LSG for weight loss and the resolution of type 2 DM in obese patients.

Methods

The criteria for considering studies for the present review included the study type, participants, interventions, and outcome measures used.

The types of studies we considered included human retrospective and prospective case series (both with >5 patients), nonrandomized controlled trials, and randomized controlled trials.

We considered studies with a target population of adult (>18 years old) male or female patients with type 2 DM who had undergone LSG. Patients considered clinically obese with a BMI >30 kg/m^2 were included.

The intervention under study was LSG as a solitary procedure or as a first-stage procedure in a staged bariatric procedure.

The types of outcome measures included primary and secondary outcomes. The primary outcome was resolution of type 2 DM. The resolution of type 2 DM was defined as discontinuation of all hypoglycemic medications and/or insulin and a normal fasting plasma glucose level, normal postprandial glucose excursions, and normal hemoglobin A1c (HbA1c).

The secondary outcomes included the percentage of excess weight loss, change in BMI, and change in glucose levels, HbA1c levels, mortality, and postoperative complications.

The search method for the identification of studies was primarily electronic. We considered unpublished and/or non-English language studies for review inclusion. A comprehensive search of electronic databases (i.e., MEDLINE, PubMed, Embase, Scopus, Dare, Clinical Evidence, BIOSIS Previews, TRIP, Health Technology Database, Conference abstracts, clinical trials, and the Cochrane Library database) using broad search terms was completed. All human studies reported from 2000 to April 2010 were considered.

In addition, we used other resources to search for studies. The reference lists of all included studies were examined to identify additional potentially relevant publications. "Gray literature," including conference abstracts, registered clinical trials, and Web sites were searched. These included the conference papers Index and OCLC Papers First. Ongoing trials were identified using controlled trial registration Web sites, including the International Clinical Trials Registry Platform Search Portal for the World Health Organization. The Google search engine was also used to search for clinical practice guidelines and government documents.

Data collection and analysis

Studies of any design that involved LSG for adult obese patients with type 2 DM from 2000 to 2010 were considered. A trained librarian conducted the electronic searches, and one of us conducted a prescreen to identify the clearly irrelevant reports by title, abstract, and Keywords of the publication. Two independent reviewers then assessed the studies for relevance; inclusion; and methodologic quality. The studies were classified as relevant (meeting all specified inclusion criteria); possibly relevant (meeting some; but not all; inclusion criteria); and rejected (not relevant to our review).

Two reviewers independently reviewed the full-text versions of all studies classified as relevant or possibly relevant. Any disagreements were resolved by repeat extraction.

Data extraction and management

Two reviewers independently extracted the data from the full versions of the reports. The extracted information included details of the methods (e.g., retrospective case series, clinically controlled trial), demographics (e.g., age, gender), clinical characteristics, study inclusion and exclusion criteria, number of patients excluded and lost to follow-up, details of the intervention (e.g., solitary LSG, staged bariatric procedure), baseline and postintervention outcomes (e.g., glucose levels, HbA1c, BMI), and methods of analysis.

Measures of treatment effect

Weight loss is reported as a mean percentage of excess weight loss, currently considered standard in bariatric surgery. It is calculated as follows: percentage of excess weight loss = (weight loss/excess weight) × 100, where excess weight is the total preoperative weight minus the ideal weight [5]. We have also reported the BMI when appropriate.

The resolution of type 2 DM was calculated as the percentage with DM resolution according to the number of patients in whom type 2 DM had disappeared or no longer required therapy. We extracted the number of patients evaluated as the denominator.

Assessment of risk of bias in included studies

All included trials were assessed independently by 2 reviewers for methodologic quality using the Cochrane (concealment of allocation) and risk of bias tools [16].

Statistical analysis

We performed an analysis of the data from the included studies. Descriptive statistics (simple counts and mean values) were used to report the study-, patient-, and treatment-level data. The number of patients enrolled was used in the calculation of the study and patient demographics. Efficacy outcomes of interest were synthesized by pooling the data from the LSG patients. Because of the high heterogeneity among the studies and the lack of randomized controlled trials, a meta-analysis was not deemed appropriate. All calculations were performed using Stata, version 10 (StataCorp, College Station, TX), statistical software.

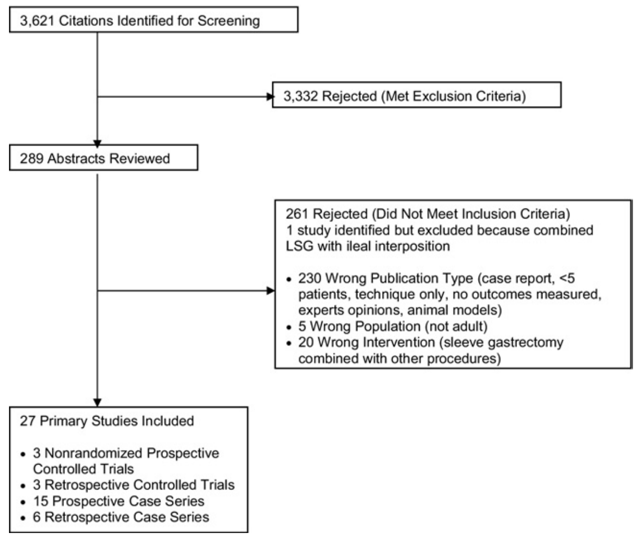

Fig. 1. Flow chart showing systematic review search results.

Results

Search results

A total of 3621 studies were identified using our search criteria for screening (Fig. 1). After an assessment according to our exclusion criteria, 3332 were rejected and 289 studies remained for abstract review. Of the 289 studies, 28 were identified; 1 was excluded because they had combined LSG with ileal interposition [17]. Thus, a total of 27 primary studies meeting the inclusion criteria were identified after a careful screening. These included 3 nonrandomized prospective controlled trials [18–20], 3 retrospective controlled trials [21–23], 15 prospective case series [7,24–37], and 6 retrospective case series [38–43].

Included studies

All 27 studies reported LSG-associated outcomes data on BMI, excess weight loss, and type 2 DM-related measurements. The baseline patient characteristics in the included studies are listed in Table 1. A total of 673 patients were assessed in the 27 studies, and numbers of patients ranged from 7 to 75. The average patient age was 46.6 ± 3.8 years (range 42–51); approximately 66% of the patients were women. The mean preoperative BMI was 47.4 ± 7.9 kg/m^2 (range 31–53.5) based on 13 included studies. The patients had a mean follow-up of 13.1 ±8.1 months (range 3–36).

The primary outcome of type 2 DM resolution was assessed by 26 of the included studies. LSG resulted in a DM resolution rate of 66.2% (Table 2). Within the studies,

Table 1
Baseline characteristics within included studies for systematic review

Investigator	Study design	Patients (n)	Mean age (y)	Gender (% female)	Mean BMI (kg/m^2)	Surgery	Follow-up period (mo)
Lakdawala et al. [21], 2010	RCS	7				LSG	12
Lirosi et al. [24], 2010	PCS	34		68	53 ± 8	LSG	3
Nienhuijs et al. [25], 2010	PCS	20	42		51	LSG	12
Sammour et al. [26], 2010	PCS	25				LSG	12
Shah et al. [27], 2010	PCS	53	46.5 ± 8.7	55	45.2 ± 9.3	LSG	12
Todkar et al. [38], 2010	RCS	23	44.6 ± 11.9	74	40.7 ± 6.6	LSG	36
Basso et al. [22], 2009	RCS	20	46.6 ± 4.2	60	51.6 ± 16	LSG	36
Berry et al. [28], 2009	PCS	14	50.6 ± 12.7	64	38.3 ± 6.7	LSG	6
Chowbey et al. [39], 2009	RCS	23				LSG	6
Frezza et al. [23], 2009	RCS	53	51	79	53.5	LSG	18
Jacobs et al. [29], 2009	PCS	39				LSG	12
Keidar [40], 2009	RCS	18				LSG	3
Letessier et al. [30], 2009	PCS	18				LSG	14
Magee et al. [31], 2009	PCS					LSG	12
Nocca [18], 2009	Non-RCT	33			50.6	LSG	12
Rosenthal et al. [41], 2009	RCS	30	42.3	70	46.1 ± 11	LSG	6
Cottam et al. [32], 2006	PCS	75				LSG	12
Gan et al. [20], 2007	Non-RCT	21		62	52.8 ± 8.2	LSG	11.4
Kasalicky et al. [33], 2008	PCS	17				LSG	18
Lee et al. [34], 2008	PCS	20	46.3	70	31 ± 2.9	LSG	12
Ou Yang et al. [35], 2008	PCS	33			50.6 ± 11	LSG	24
Tagaya et al. [36], 2008	PCS	6				LSG	12
Vidal et al. [19], 2008	Non-RCT	39	49.9 ± 1.5	59	51.9 ± 1.2	LSG	12
Wheeler et al. [37], 2008	PCS	13				LSG	3.4
Weiner et al. [42], 2007	RCS	14				LSG	12
Moon Han et al. [43], 2005	RCS	8				LSG	6
Silecchia et al. [7], 2005	PCS	17				LSG	18
Total/mean		673	46.6	66	47.4		13.1

RCS = retrospective clinical study; LSG = laparoscopic sleeve gastrectomy; PCS = prospective clinical study; BMI = body mass index; RCT = randomized clinical trial.

16 reported both resolution and improvement of type 2 DM, and 97.1% of the patients had experienced DM resolution or improvement. Four studies reported DM resolution, improvement, or stable disease in 94.8% of their patients.

The secondary outcomes included the percentage of excess weight loss, postoperative BMI, and changes in glucose and HbA1c levels. A substantial percentage of excess weight loss of 47.3% ± 19.1% (range 6.3–74.5%) was seen in patients included in 11 studies with a mean follow-up of 13 ± 8.1 months (range 3–36). The postoperative BMI had decreased to 35.9 ± 6.6 kg/m^2 (range 24.6–44.7) based on 8 included studies. Within the 7 studies that reported the plasma glucose levels, the levels had decreased from a baseline of 181.2 mg/dL to 119.2 mg/dL. The HbA1c levels had also decreased from a baseline of 7.9% to a postoperative level 6.2%, based on 11 studies.

The operative mortality at ≤30 days was .36% for all LSG (not only DM patients) procedures (4 deaths of 1117 patients) based on 16 studies [7,20,21,23,25,26,28,29,32,33,35–37,39,42,43]. Postoperative complications such as bleeding occurred in 1.79% (20 of 1117 patients). Postoperative abscess or infection occurred in .27% (3 of 1117 patients). Postoperative leaks occurred in 22 of 1117 patients (1.97%).

Discussion

A systematic review of the existing evidence has suggested that LSG for morbid obesity results in resolution or improvement of type 2DM in most patients. Although approximately two thirds of the patients experienced complete DM resolution, the remaining 30% of patients had significant improvement.

A systematic review by Buchwald et al. [5] demonstrated similar improvement in type 2 DM resolution after other bariatric surgical procedures. Gastric banding, gastric bypass, and BPDDS resulted in resolution of type 2 DM in 48%, 84%, and 98% of patients, respectively [5]. In our analysis of LSG, the overall DM resolution and improvement rate was 97.1%. Similarly, the Swedish Obesity Subjects study demonstrated that the 2-year recovery rate from DM in the group treated with bariatric surgery was significantly greater [44]. Furthermore they demonstrated an 80% reduction in annual mortality in the surgically treated group compared with the control group [44]. Similarly, MacDonald et al. [45] found that gastric bypass reduced the progression of type 2 DM within the surgically treated patients. The mortality rate in the bypass group was 9% compared with 28% in the medically treated controls. The reduction was

Table 2
Laparoscopic sleeve gastrectomy outcomes—systematic review

Investigator	Glucose level (mg/dL)		HbA1c (%)			EWL (%)	Type 2 DM (%)		
	Pre	Post	Pre	Post	Change (%)		Resolved	Improved	Stable
Lakdawala et al. [21], 2010							98	2	
Lirosi et al. [24], 2010						6.3	85	15	
Nienhuijs et al. [25], 2010						49.6	50	40	10
Sammour et al. [26], 2010							48	24	7
Shah et al. [27], 2010			8.4	6.1	−2.3		96.2	3.8	
Todkar et al. [38], 2010	157.4	97	9.1	6.4	−2.7	74.6	69.6		30.4
Basso et al. [22], 2009			7.7	5.9	−1.8	36.3	80.9		
Berry et al. [28], 2009	132	96.7	7.1	5.5	−1.6		85.7	14.3	
Chowbey et al. [39], 2009			6.46	5.2	−1.26		82.6	17.4	
Frezza et al. [23], 2009		118				59.2			
Jacobs et al. [29], 2009							82	18	
Keidar [40], 2009							77		
Letessier et al. [30], 2009							41.2	47.1	
Magee et al. [31], 2009							23		
Nocca [18], 2009						60.1	75.8	15.2	
Rosenthal et al. [41], 2009	158.9	128.3	6.4	5.9	−.5	35.4	63.3	36.7	
Cottam et al. [32], 2006						46	81	11	
Gan et al. [20], 2007	145.8	104.4	8	6.6	−1.4	35.9	14	81	5
Kasalicky et al. [33], 2008							71	29	
Lee et al. [34], 2008	240.1	132.9	10.1	7.1	−3	70.4	50		
Ou Yang et al. [35], 2008			7.91	6.47	−1.44	46.1	39	49	
Tagaya et al. [36], 2008							67	33	
Vidal et al. [19], 2008	252.8	157.2	7.4	6.9	−.5		84.6		
Wheeler et al. [37], 2008					−2.2		61.5		
Weiner et al. [42], 2007							14	86	
Moon Han et al. [43], 2005							100		
Silecchia et al. [7], 2005							79.6	15.4	
Mean	181.2	119.2	7.9	6.2	−1.7	47.3	66.2	26.9	13.1

HbA1c = hemoglobin A1c; EWL = excess weight loss; Pre = preoperatively; Post = postoperatively; DM = diabetes mellitus.

attributed to a decrease in cardiovascular-related death [45]. It remains to be seen whether the LSG-related resolution or improvement in type 2 DM will translate into a long-term decrease in patient mortality.

In 705 morbidly obese patients, LSG reduced excess weight by 47.3%. Buchwald et al. [5] found gastric banding, gastric bypass, and BPDDS to reduce excess weight in patients by 47%, 62%, and 70%, respectively. A prospective observation study by Williamson et al. [46] found intentional weight loss by overweight women with obesity-related health conditions was associated with a 20% reduction in total mortality. Bariatric surgery, other than LSG, has previously been shown to result in substantially greater weight loss than that with medical treatment [47].

Compared with the review by Buchwald et al. [5], our findings have demonstrated that patients undergoing LSG had a greater degree of excess weight loss and resolution of type 2 DM than with gastric banding. Abbatini et al. [9] reached a similar conclusion when comparing LSG and gastric banding in 60 morbidly obese patients. They reported a type 2 DM resolution rate of 80.9% for LSG compared with 60.8% after gastric banding, as well as greater improvements in insulin resistance in the LSG-treated group. Additional benefits for the patients undergoing LSG included the lack of a need for adjustments to a gastric band and the avoidance of needles. LSG restricts the size of the stomach by removing the gastric fundus. Furthermore, the pylorus functions as a natural band, facilitating additional restriction. The removal of the gastric fundus reduces ghrelin levels [8], a stimulator of food intake in humans [48]. Karamanakos et al. [8] found significantly decreased levels of ghrelin in 16 patients after LSG surgery, which might be associated with greater appetite suppression. A hormonal mechanism has also been suggested by Abbinti et al. [9], who found a similar type 2 DM resolution rate with LSG and laparoscopic gastric bypass surgery.

LSG was initially proposed as a staged approach to BPDDS for superobese patients [6]. The finding by Melissas et al. [15] that LSG results in increased transit of stomach contents and absent or very mild vomiting after eating is uncharacteristic of a restrictive procedure. However, it might have added benefits similar to that of gastric bypass or BPDDS according to the hindgut theory. With the rapid transit of undigested nutrients, the distal bowel upregulates the production of GLP-1 and peptide YY. Both derivatives of L-cells, GLP-1 stimulate insulin secretion and has an antiapoptotic effect on β-cells in the pancreas [49]. Peptide YY might ameliorate insulin resistance in mice [14]. If the hindgut theory holds true, it could explain the additive improvement of type 2 DM after LSG compared with other restrictive procedures. Although the excess weight loss and type 2 DM resolution has been lower after LSG compared with after both gastric bypass and BPDDS, benefits exist. LSG remains a less technically complex procedure and might have wider applicability to general surgeons. The risks of surgery such as malabsorption and internal hernias postoperatively are minimal. Dumping syndrome has not been reported as a postoperative issue.

Buchwald et al. [5] reported a mortality rate of .1% for purely restrictive procedures (3000 patients), .5% for gastric bypass (5644 patients), and 1.1% for BPDDS (3030 patients). From 16 studies, the estimated mortality rate for LSG is .35% (4 deaths in 1117 patients). Postoperative complications such as bleeding (1.79%) and staple line leak (1.97%) compared favorably with the rates reported for gastric bypass and BPDDS [40].

Study limitations

To our knowledge, no randomized controlled studies comparing LSG and medical therapy or other bariatric surgical procedures assessing the resolution of type 2 DM in obese patients have been published. The primary studies included in the present review, therefore, consisted largely of nonrandomized controlled trials or case series, which are inherently biased. Thus, in most available studies, a single bariatric surgical procedure was assessed without comparison with a control group. Furthermore, because of the considerable heterogeneity among the studies, a meta-analysis was not feasible. In addition, a potential source of heterogeneity (e.g., age, gender) could not be addressed in our review because of the lack of consistent outcome reporting. Other possible sources of heterogeneity (e.g., study design, population, and interventions) were sufficiently similar to support the decision to pool the data.

Given the potential sources of bias inherent in nonrandomized studies, the results of our systematic review should be interpreted with caution. Missing demographic data and limited outcome data could have produced misleading results. This situation, however, appears inherent to a vast proportion of bariatric surgical data and has led to calls for standardized reporting in future studies. Despite these limitations, our review supports the idea that LSG is associated with the resolution and improvement of type 2 DM and could thus serve as a basis for the development of high-level randomized clinical trial evidence on this important issue.

Conclusion

Our findings have shown that LSG has a substantial effect on type 2 DM, producing resolution or improvement in most cases. With the potential to be revised to a gastric bypass or BPDDS procedure, LSG is a promising surgical procedure for the treatment of morbid obesity and type 2 DM.

Disclosures

The authors have no commercial associations that might be a conflict of interest in relation to this article.

References

[1] Deitel M. Overweight and obesity worldwide now estimated to involve 1.7 billion people. Obes Surg 2003;13:329–30.

[2] American Diabetes Association. Prevention or delay of type 2 diabetes. Diabetes Care 2004;27:S47–53.

[3] Greenway SE, Greenway FL III, Klein S. Effects of obesity surgery on non-insulin-dependent diabetes mellitus Arch Surg 2002;137:1109–17.

[4] Hickey MS, Pories WJ, MacDonald KG, et al. A new paradigm for type 2 diabetes mellitus: could it be a disease of the foregut? Ann Surg 1998;227:637–44.

[5] Buchwald H, Avidor Y, Braunwald E, et al. Bariatric surgery: a systematic review and meta-analysis. JAMA 2004;292:1724–37.

[6] Hess DS, Hess DW. Biliopancreatic diversion with a duodenal switch. Obes Surg 1998;8:267–82.

[7] Silecchia G, Boru C, Pecchia A, et al. Effectiveness of laparoscopic sleeve gastrectomy (first stage of biliopancreatic diversion with duodenal switch) on co-morbidities in super-obese high-risk patients. Obes Surg 2006;16:1138–44.

[8] Karamanakos SN, Vagenas K, Kalfarentzos F, Alexandrides TK. Weight loss, appetite suppression, and changes in fasting and postprandial ghrelin and peptide-YY levels after Roux-en-Y gastric bypass and sleeve gastrectomy: a prospective, double blind study. Ann-.Surg 2008;247:401–7.

[9] Abbatini F, Rizzello M, Casella G, et al. Long-term effects of laparoscopic sleeve gastrectomy, gastric bypass, and adjustable gastric banding on type 2 diabetes. Surg Endosc 2010;24:1005–10.

[10] Mason EE. The mechanisms of surgical treatment of type 2 diabetes. Obes Surg 2005;15:459–61.

[11] Rubino F, Forgione A, Cummings DE, et al. The mechanism of diabetes control after gastrointestinal bypass surgery reveals a role of the proximal small intestine in the pathophysiology of type 2 diabetes. Ann Surg 2006;244:741–9.

[12] Li F, Zhang G, Liang J, Ding X, Cheng Z, Hu S. Sleeve gastrectomy provides a better control of diabetes by decreasing ghrelin in the diabetic Goto-Kakizaki rats. J Gastrointest Surg 2009;13:2302–8.

[13] Wynne K, Stanley S, Bloom S. The gut and regulation of body weight. J Clin Endocrinol Metab 2004;89:2576–82.

[14] Murphy KG, Bloom SR. Gut hormones and the regulation of energy homeostasis. Nature 2006;444:854–9.

[15] Melissas J, Koukouraki S, Askoxylakis J, et al. Sleeve gastrectomy: a restrictive procedure? Obes Surg 2007;17:57–62.

[16] Higgins JP, Green S, editors. *Cochrane handbook for systematic reviews of interventions.* London: Wiley; 2008.

[17] DePaula AL, Macedo AL, Rassi N, et al. Laparoscopic treatment of metabolic syndrome in patients with type 2 diabetes mellitus. Surg Endosc 2008;22:2670–8.

[18] Nocca D. Laparoscopic adjustable gastric banding and laparoscopic sleeve gastrectomy: which has a place in the treatment of diabetes in morbidly obese patients? Diabetes Metab 2009;35:524–7.

[19] Vidal J, Ibarzabal A, Romero F, et al. Type 2 diabetes mellitus and the metabolic syndrome following sleeve gastrectomy in severely obese subjects. Obes Surg 2008;18:1077–82.

[20] Gan SS, Talbot ML, Jorgensen JO. Efficacy of surgery in the management of obesity-related type 2 diabetes mellitus. ANZ J Surg 2007;77:958–62.

[21] Lakdawala MA, Bhasker A, Mulchandani D, Goel S, Jain S. Comparison between the results of laparoscopic sleeve gastrectomy and laparoscopic Roux-en-Y gastric bypass in the Indian population: a retrospective 1 year study. Obes Surg 2010;20:1–6.

[22] Basso N, Leonetti F, Mariani PP, et al. Early hormonal changes after sleeve gastrectomy in diabetic obese patients. Obes Surg IFSO 2009 Abstract P-064. Online: http://sites.google.com/a/clos.net/mini/ifso-2009-abstr. (Accessed May 2010).

[23] Frezza EE, Wozniak SE, Gee L, Wacthel M. Is there any role of resecting the stomach to ameliorate weight loss and sugar control in morbidly obese diabetic patients? Obes Surg 2009;19:1139–42.

[24] Lirosi F, El Kallaawi M, Batterham RL, Adamo M. Do we need bypass surgery to cure diabetes? Prompt remission of diabetes after laparoscopic sleeve gastrectomy—a UK experience. Surg Obes Relat Dis 2010;6:229–30.

[25] Nienhuijs SW, de Zoete JP, Berende CAS, de Hingh IHJT, Smulders JF. Evaluation of laparoscopic sleeve gastrectomy on weight loss and co-morbidity. Int J Surg 2010;8:302–4.

[26] Sammour T, Hill AG, Singh P, Ranasinghe A, Babor R, Rahman H. Laparoscopic sleeve gastrectomy as a single-stage bariatric procedure. Obes Surg 2010;20:271–5.

[27] Shah S, Todkar J, Shah P. Effect of laparoscopic sleeve gastrectomy (LSG) on HbA1c levels in T2DM patients: results at one year. Obes Surg IFSO 2009 Abstract P-071. Online: http://sites.google.com/a/clos.net/mini/ifso-2009-abstr. (Accessed May 2010).

[28] Berry M, Villagran R, Lamoza P, Urrutia L, Conoman H. Laparoscopic sleeve gastrectomy (LSG) impact in diabetic (T2DM) obese patients. Obes Surg IFSO 2009 Abstract P-084. Online: http://sites.google.com/a/clos.net/mini/ifso-2009-abstr. (Accessed May 2010).

[29] Jacobs M, Bisland W, Gomez E, et al. Laparoscopic sleeve gastrectomy: a retrospective review of 1- and 2-year results. Surg Endosc 2010;24:781–5.

[30] Letessier E, Dariel A, Avallone S, Wyart V, Le Cam G. Improvement of type 2 diabetes mellitus in morbid obesity with laparoscopic sleeve gastrectomy. Obes Surg IFSO 2009 Abstract P-079. Online: http://sites.google.com/a/clos.net/mini/ifso-2009-abstr. (Accessed May 2010).

[31] Magee C, Barry J, Arumagasamy M, et al. Laparoscopic sleeve gastrectomy as a bridge to surgery—comorbidity and risk reduction in a UK specialist unit. Obes Surg IFSO 2009 Abstract O-040. Online: http://sites.google.com/a/clos.net/mini/ifso-2009-abstr. (Accessed May 2010).

[32] Cottam D, Qureshi FG, Mattar SG, et al. Laparoscopic sleeve gastrectomy as an initial weight-loss procedure for high-risk patients with morbid obesity. Surg Endosc 2006;20:859–63.

[33] Kasalicky M, Michalsky D, Housova J, et al. Laparoscopic sleeve gastrectomy without an over-sewing of the staple line. Obes Surg 2008;18:1257–62.

[34] Lee WJ, Ser KH, Chong K, et al. Laparoscopic sleeve gastrectomy for diabetes treatment in nonmorbidly obese patients: efficacy and change of insulin secretion. Surgery 2010;147:664–9.

[35] Ou Yang O, Loi K, Liew V, Talbot M, Jorgensen J. Staged laparoscopic sleeve gastrectomy followed by Roux-en-Y gastric bypass for morbidly obese patients: a risk reduction strategy. Obes Surg 2008; 18:1575–80.

[36] Tagaya N, Kasama K, Kikkawa R, et al. Experience with laparoscopic sleeve gastrectomy for morbid versus super morbid obesity. Obes Surg 2009;19:1371–6.

[37] Wheeler AA, Morales M, Fearing N, Scott JS, de la Torre R, Ramanswamy A. Laparoscopic sleeve gastrectomy in the super morbidly obese is effective treatment for diabetes mellitus and obstructive sleep apnea. Surg Obes Relat Dis 2008;4:351–2.

[38] Todkar JS, Shah SS, Shah PS, Gangwani J. Long-term effects of laparoscopic sleeve gastrectomy in morbidly obese subjects with type 2 diabetes mellitus. Surg Obes Relat Dis 2010;6:142–5.

[39] Chowbey PK, Dhawan K, Khullar R, et al. Laparoscopic sleeve gastrectomy: an Indian experience—surgical technique and early results. Obes Surg Epub 2009.

[40] Keidar A. Rates of metabolic improvement after sleeve gastrectomy. Obes Surg IFSO 2009 Abstract O-021. Online: http://sites.google.com/a/clos.net/mini/ifso-2009-abstr. (Accessed May 2010).

[41] Rosenthal R, Li X, Samuel S, Martinez P, Zheng C. Effect of sleeve gastrectomy on patients with diabetes mellitus. Surg Obes Relat Dis 2009;5:429–34.

[42] Weiner RA, Weiner S, Pomhoff I, Jacobi C, Makarewicz W, Weigand G. Laparoscopic sleeve gastrectomy—influence of sleeve size and resected gastric volume. Obes Surg 2007;17:1297–305.

[43] Moon Han S, Kim WW, Oh JH. Results of laparoscopic sleeve gastrectomy (LSG) at 1 year in morbidly obese Korean patients. Obes Surg 2005;15:1469–75.

[44] Sjostrom CD, Lissner L, Wedel H, Sjostrom L. Reduction in incidence of diabetes, hypertension and lipid disturbances after intentional weight loss induced by bariatric surgery: the SOS Intervention Study. Obes Res 1999;7:477–84.

[45] MacDonald KG Jr, Long SD, Swanson MS, et al. The gastric bypass operation reduces the progression and mortality of non-insulin-dependent diabetes mellitus. J Gastrointest Surg 1997;1:213–20.

[46] Williamson DF, Pamuk E, Thun M, Flanders D, Byers T, Heath C. Prospective study of intentional weight loss and mortality in never-smoking overweight US white women aged 40–64 years. Am J Epidemiol 1995;141:1128–41.

[47] Maggard MA, Shugarman LR, Suttorp M, et al. Meta-analysis: surgical treatment of obesity. Ann Intern Med 2005;142:547–59.

[48] Wren AM, Seal LJ, Cohen MA, et al. Ghrelin enhances appetite and increases food intake in humans. J Clin Endocrinol Metab 2001;86: 5992–5.

[49] Drucker DJ. Glucagon-like peptide-1 and the islet beta-cell: augmentation of cell proliferation and inhibition of apoptosis. Endocrinology 2003;144:5145–8.