

Research Article

Early Postoperative Outcomes and Medication Cost Savings after Laparoscopic Sleeve Gastrectomy in Morbidly Obese Patients with Type 2 Diabetes

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Background. We investigated the effect of laparoscopic sleeve gastrectomy (LSG) on morbidly obese diabetics and examined the short-term impact of LSG on diabetic medication cost. **Methods.** A prospective database of consecutive bariatric patients was reviewed. Morbidly obese patients with type 2 diabetes who underwent LSG were included in the study. Age, gender, body mass index (BMI), diabetic medication use, glucose, insulin, and HbA1c levels were documented preoperatively, and at 2 weeks, 2 months, 6 months, and 12 months postoperatively. Insulin resistance was estimated using the homeostatic model assessment (HOMA). Use and cost of diabetic medications were followed. **Results.** Of 178 patients, 22 were diabetics who underwent LSG. Diabetes remission was observed in 62% of patients within 2 months and in 75% of patients within 12 months. HOMA-IR improved after only two weeks following surgery (16.5 versus 6.6, $P < 0.001$). Average number of diabetic medications decreased from 2.2 to <1 , within 2 weeks after surgery; corresponding to a diabetes medication cost savings of 80%, 91%, 99%, and 99.7% after 2 weeks, 2 months, 6 months, and 12 months, respectively. **Conclusion.** Morbidly obese patients with diabetes who undergo LSG have high rates of diabetes remission early after surgery. This translates to a significant medication cost savings.

1. Introduction

The problem of obesity in the United States has reached epidemic proportions. Over the past several decades, the prevalence of obesity has doubled, and it is now estimated that 20–30% of American adults are obese, and nearly two-thirds are either overweight or obese [1, 2]. Obesity-related comorbid conditions include type 2 diabetes, hypertension, and obstructive sleep apnea syndrome, which account for significant morbidity and mortality. The coexistence of obesity and diabetes increases the risk of cardiac disease and death [3]. Bariatric surgery has emerged as the most effective and durable method for weight loss in the morbidly obese, defined as a BMI > 40 kg/m² or BMI > 35 kg/m² with obesity-associated comorbid conditions [4]. In addition, certain bariatric procedures are associated with a significant improvement, and even remission, of comorbidities. The Roux-en-Y gastric bypass (RYGB) and the biliopancreatic

diversion (BPD) have been shown to provide significant long-term improvement or remission of type 2 diabetes in the morbidly obese population [5, 6]. The laparoscopic sleeve gastrectomy (LSG), first described as a modification of the BPD, is emerging as a popular single-stage operation for the treatment of morbid obesity, with acceptable morbidity and long-term weight loss compared to the RYGB and adjustable gastric band (AGB) [7–9]. The advantages of this procedure include lack of an intestinal bypass, thus avoiding metabolic derangements and internal hernias, shorter operating times, and no implantation of a foreign body [10]. In addition to weight loss, studies have suggested a positive effect of LSG on diabetes as well [3, 11, 12].

The costs of obesity and its related conditions were estimated to be \$147 billion in 2008, and they now correspond to more than 9.1% of annual USA medical expenditures compared to 6.5% in 1998. Medication costs, meanwhile, account for as much as 30% of total cost for treating obesity-related

diseases [13, 14]. In this study, we investigated the early postoperative effect of LSG in morbidly obese diabetics and examined the short-term impact of the operation on the diabetic medication costs in these patients.

2. Methods

A prospective database of consecutive patients was reviewed after obtaining institutional review board approval. Morbidly obese patients with type 2 diabetes who underwent LSG as a primary bariatric procedure were included in the study. All patients carried a diagnosis of diabetes in the medical record, were on diabetic medications, had an abnormal fasting glucose, and had an elevated hemoglobin A1c (HbA1c) (greater than 6.2% in our institution). All patients met the National Institutes of Health guidelines [14] for bariatric surgery and had a BMI greater than 35 kg/m². Each patient underwent an extensive, multidisciplinary preoperative workup prior to LSG. All operations were performed by a single surgeon at the Palo Alto VA hospital, and patients were followed by a multidisciplinary team in the postoperative period. Age, gender, BMI, diabetic medication use, fasting glucose, insulin, and HbA1c levels were documented. Insulin resistance was estimated using the calculated Homeostatic Model Assessment (HOMA).

Use and cost of diabetic medications were followed throughout the postoperative course. The cost of medications to treat diabetes was calculated before and after sleeve gastrectomy, based on the current VA pharmacy-subsidized cost for each medication. Patient data was obtained preoperatively and at regular intervals in the postoperative periods: at 2 weeks, 2 months, 6 months, and 12 months after LSG. Remission of diabetes was defined as discontinuation of diabetic medications, concurrent with normalization of fasting glucose and HbA1c.

2.1. Surgical Procedure. All operations were performed laparoscopically under general anesthesia, with the patient in supine position. We used a 5-port technique with the table in reverse-Trendelenburg position. The division of the vascular supply to the greater curvature of the stomach was begun 6-cm proximal to the pylorus and continued to the angle of His using the Ligasure device (Covidien, Norwalk, CT). The sleeve gastrectomy was performed using an Echelon Flex stapler (Ethicon, Somerville, NJ). The green staple load (4.1/60 mm) was used for the first 3 staple firings, followed by gold staple loads (3.8/60 mm) to complete the sleeve. Bovine pericardial Peristrips (Synovis, Surgical Innovations, St. Paul, MN) were used to buttress the staple line in the first 13 operations; SeamGuard (W.L. Gore, Flagstaff, AZ) buttressing strips were used in the subsequent cases. The sleeve volume was calibrated to an intraluminal 36 Fr endoscope. The proximal resection line was performed 1-2 cm lateral to the angle of His to complete the sleeve. An endoscopic airleak test was routinely used at the conclusion of the operation to confirm an intact staple line, and an upper gastrointestinal contrast study was performed on the first postoperative day before introduction of oral liquid diet.

TABLE 1: Patient demographic data.

	Preoperative morbidly obese diabetic patients
<i>N</i>	22
% male/female	79/21
Mean age	55.3 years
Mean initial BMI	46 kg/m ²
Mean initial HbA1c	7.4%
Taking >1 diabetes med	77%
Using injectable insulin	55%
Avg. number of obesity co-morbidities (other than diabetes)	2.9

2.2. Statistical Analysis. Comparisons of means were performed using a Student's *t*-test, and $P < 0.05$ was considered statistically significant.

3. Results

Of 178 patients in our bariatric surgery database, 22 were diabetics who underwent LSG. The majority of the patients were male, with a mean age of 55.3 years and a mean preoperative BMI of 46 kg/m² (Table 1). The average preoperative HbA1c level was 7.4%, all patients were taking at least 1 medication to treat diabetes, and 77% were taking more than one (mean of 2.2 medications). Injectable insulin was used by 55% of the patients before surgery. In addition to type 2 diabetes, the patients had an average of 2.9 additional obesity-related comorbid conditions, including hypertension, hyperlipidemia, obstructive sleep apnea, and osteoarthritis.

The mean duration of followup after surgery was 7 months, and the average percent excess weight loss (EWL) in each time interval was 20% at 2 weeks postoperatively, 31% at 2 months, 47% at 6 months, and 56% at 12 months (Figure 1). This was not significantly different from our predominantly male, nondiabetic patients who underwent LSG (56% versus 60%, $P = 0.33$).

The number of diabetic medications decreased from a mean of 2.2 before surgery to less than one medication at 2 weeks after surgery ($P < 0.001$). This trend continued throughout the postoperative period through 12 months (2.2 versus 0.25, $P < 0.001$) (Figure 2). The decrease in medication use corresponded to an improvement or remission of diabetes (as demonstrated by normalization of fasting glucose and HbA1c over the same time interval). Overall, mean HbA1c decreased from 7.4% preoperatively to 6.1% after 12 months postoperatively ($P < 0.05$) (Figure 3). Insulin resistance, as estimated by the calculated HOMA, showed dramatic improvement even after only two weeks following surgery (16.5 versus 6.6, $P < 0.001$) (Table 2); it decreased by 80% after 12 months. Overall, 100% of the patients had improvement of diabetes, and 75% had complete remission at 12 months. Of those with complete remission after 1 year, 61% of the patients discontinued all diabetic medications within 2 weeks, and 83% were off all diabetic medications within 2 months after surgery. Seventy-five

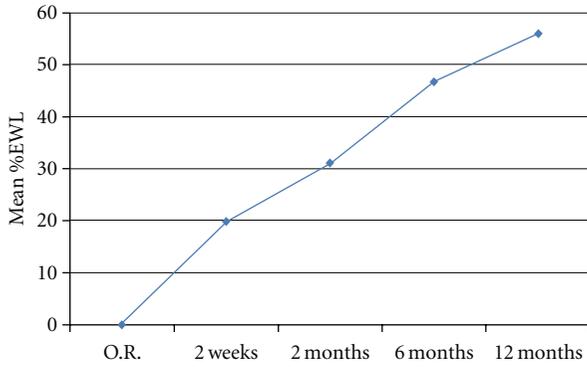


FIGURE 1: Postoperative percent excess weight loss. %EWL: percent excess weight loss.

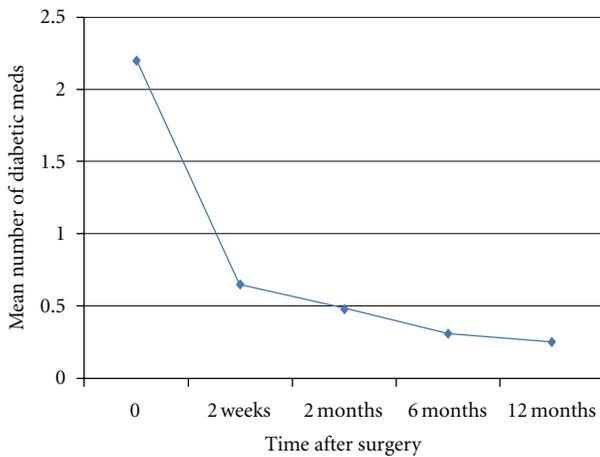


FIGURE 2: Reduction in the mean number of diabetic medications being taken.

percent remained off diabetic medications at 1 year. Of the 25% still taking diabetic medications, half were on insulin, and all of them had decreased dose requirements compared to preoperative doses.

The cost of medications to treat diabetes was calculated before and after sleeve gastrectomy, based on the current VA pharmacy-subsidized cost for each medication. Decreased use of medications corresponded to a progressive decrease in diabetic medication costs throughout the postoperative period. After 2 weeks, individual diabetic medication costs decreased by 80% compared to preoperative costs. This further decreased by 91% after 2 months and 99% after 6 months. This trend continued with >99% diabetic medication cost savings after 12 months ($P < 0.001$) (Table 3).

Postoperative complications included a delayed presentation (8 months after surgery) of a distal staple line leak in 1 patient, postoperative nausea beyond the first 24 hours that resolved within 48 hours in 3 patients, and intractable hiccups for 72 hours after surgery in 1 patient.

4. Discussion

The prevalence of obesity has been increasing worldwide, along with a concurrent increase in morbidity due to

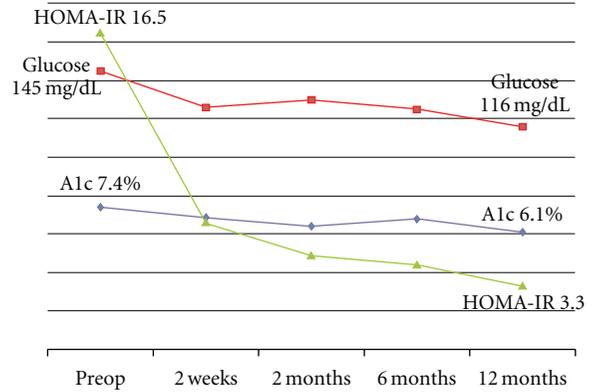


FIGURE 3: Mean change in diabetes markers. HbA1c: Hemoglobin A1c, HOMA-IR: Homeostatic Model Assessment for Insulin Resistance, and Glucose: Fasting glucose.

TABLE 2: Postoperative changes in markers of diabetes and insulin resistance. HbA1c: Hemoglobin A1c, HOMA-IR: Homeostatic Model Assessment for Insulin Resistance.

	2 weeks	2 months	6 months	12 months	Total
Δ HbA1c (%)	-0.6	-0.4	0	-0.3	-1.3
Δ Fasting glucose (mg/dL)	-19.0	+5.0	-5.5	-9.0	-28.5
Δ fasting insulin (mU/L)	-24.0	-5.1	-1.7	-3.4	-34.2
Δ HOMA-IR	-9.9	-1.7	-0.5	-1.1	-13.2

TABLE 3: Postoperative diabetic medication cost savings.

	Preoperative	2 weeks	2 months	6 months	12 months
\$/day	6.00	1.19	0.53	0.03	0.02
% change	—	-80%	-91%	-99%	-99.7%

obesity-related co-morbid conditions, including type 2 diabetes [15]. This has been shown to result in a significant increase in healthcare costs [16]. The surgical treatment of morbid obesity is known to produce significant and durable weight loss, along with improvement in its comorbidities [17]. More recently, the laparoscopic sleeve gastrectomy has emerged as a stand-alone procedure for the treatment of morbid obesity, and unlike the Roux-en-Y gastric bypass, the LSG does not bypass the foregut [18, 19].

Percent excess weight loss following LSG varies from 33 to 90% up to four years after surgery [10, 18]. In this study, we report %EWL of 56% at 12 months, which is within the lower half of this range. It is possible that total weight loss in older males is more modest than in the general population. In addition, it is also likely that diabetics experience lesser weight loss after bariatric surgery compared to nondiabetics [20]. Dietary, behavioral, and medication treatments for obesity are often unsuccessful, and higher failure rates in

diabetics are associated with the use of antidiabetic agents [21, 22].

Fewer than half of all patients with type 2 diabetes achieve American Diabetes Association recommendations for HbA1c [23]. Meanwhile, significant improvement or remission of diabetic markers is commonly observed after bariatric surgery [3, 17, 24]. Improvement of comorbid conditions was observed after LSG. Vidal et al. reported a remission of type 2 diabetes after LSG in 51% of patients after 4 months and 84% after 12 months [25, 26]. A recent 3-year study of diabetic patients after LSG demonstrated an improvement in all comorbidities in 70% of patients [21]. Our results are consistent with these findings, and further suggest that the improvements in diabetes occur early in the postoperative course. Together with the results of Todkar et al., it additionally appears that while these changes occur early, they are also durable [21]. Our results are also compared favorably with a recent review of 27 studies of sleeve gastrectomy that found a 66% resolution of diabetes with a mean followup of 13 months [3]. We found improvement of diabetes in all our patients and discontinuation of diabetic medications in the large majority of patients, already within 2 months after surgery.

The mechanism responsible for remission of type 2 diabetes after LSG has not yet been elucidated and necessarily excludes the bypass of the foregut theory, as has been suggested for the gastric bypass [27]. As has been reported by others and supported by the results in this study, a significant reduction in diabetes markers and diabetic medications precedes maximal weight loss [28]. In fact, we found that significant improvements are seen 2 weeks after surgery, and the majority of improvements occur within two months and are largely sustained throughout the 12 month postoperative period. Without foregut bypass, attention has focused on gastric hormones, including ghrelin and peptide YY. Ghrelin, an orexigenic hormone largely produced in the resected gastric fundus, has been found to be significantly reduced after LSG compared to gastric bypass [29]. Further studies are needed to better define the effect of gastric hormone reduction on pancreatic endocrine function and systemic insulin resistance. In addition, it is possible that the LSG changes the milieu of other gut hormones, producing a positive metabolic effect.

The national cost of obesity is high. Recent reports suggest that the individual annual cost of obesity is \$8,365 and \$6,518 for women and men, respectively. These costs are 15 times higher for an obese individual, compared to a person with BMI < 30 [30]. Furthermore, medication costs account for as much as 30% of the total cost of treating obesity-related diseases [13, 14]. Our study results suggest that an improvement in diabetes in the early postoperative period translates into a significant medication costs savings, that is sustained for 12 months after laparoscopic sleeve gastrectomy. Over a large population, this may translate to a significant impact on total healthcare expenditures. Future studies to include costs of clinic visits and the treatment of diabetes complications may suggest an even greater economic impact of bariatric surgery in general and the LSG specifically.

5. Conclusion

The laparoscopic sleeve gastrectomy produces significant weight loss and remission of type 2 diabetes in the early postoperative period. This translates to a significant medication cost savings.

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