Factors Associated With Weight Loss After Gastric Bypass

Guilherme M. Campos, MD; Charlotte Rabl, MD; Kathleen Mulligan, PhD; Andrew Posselt, MD, PhD; Stanley J. Rogers, MD; Antonio C. Westphalen, MD; Feng Lin, MS; Eric Vittinghoff, PhD

Background: Gastric bypass (GBP) is the most common operation performed in the United States for morbid obesity. However, weight loss is poor in 10% to 15% of patients. We sought to determine the independent factors associated with poor weight loss after GBP.

Design: Prospective cohort study. We examined demographic, operative, and follow-up data by means of multivariate analysis. Variables investigated were age, sex, race, marital and insurance status, initial weight and body mass index (BMI) (calculated as weight in kilograms divided by height in meters squared), comorbidities (diabetes mellitus, hypertension, joint disease, sleep apnea, hyperlipidemia, and psychiatric disease), laparoscopic vs open surgery, gastrointestinal pouch area, gastrojejunostomy technique, and alimentary limb length.

Setting: University tertiary referral center.

Patients: All patients at our institution who underwent GBP from January 1, 2003, through July 30, 2006.

Main Outcome Measures: Weight loss at 12 months defined as poor (≤40% excess weight loss) or good (>40% excess weight loss).

Results: Follow-up data at 12 months were available for 310 of the 361 patients (85.9%) undergoing GBP during the study period. Mean preoperative BMI was 52 (range, 36-108). Mean BMI and excess weight loss at follow-up were 34 (range, 17-74) and 60% (range, 8%-117%), respectively. Thirty-eight patients (12.3%) had poor weight loss. Of the 4 variables associated with poor weight loss in the univariate analysis (greater initial weight, diabetes, open approach, and larger pouch size), only diabetes (odds ratio, 3.09; 95% confidence interval, 1.35-7.09 [P = .007]) and larger pouch size (odds ratio, 2.77; 95% confidence interval, 1.81-4.22 [P < .001]) remained after the multivariate analysis.

Conclusions: Gastric bypass results in substantial weight loss in most patients. Diabetes and larger pouch size are independently associated with poor weight loss after GBP.

Arch Surg. 2008;143(9):877-884

Roux-en-Y gastric bypass (GBP) is the most common bariatric operation used in North America.1-3 When performed in high-volume centers and with a low rate of complications, GBP provides sustained and meaningful weight loss,4-6 significant improvement in quality of life,7,8 improvement or resolution of obesity-associated comorbidities,9 and extended life span.10,11 Gastric bypass achieves weight reduction mainly through restriction of intake imposed by a small gastric pouch, but also by preventing contact between the food bolus and most of the stomach, duodenum, and first portion of the jejunum while delivering it in an alimentary limb of variable length in a Roux-en-Y fashion.5,12 However, 3% to 15% of patients do not lose weight successfully, despite perceived precise surgical technique and regular follow-up.6,13

Several factors thought to be associated with poor weight loss after GBP include older age,14,15 black race,16,17 male sex,18 being married,19 greater initial weight and body mass index (BMI) (calculated as weight in kilograms divided by height in meters squared),14,16,18 the presence of diabetes mellitus,14,18,19 other obesity-associated diseases,20 physical inactivity after surgery,21 larger pouch area,22 poor follow-up after surgery,23,24 and insurance status.23 These factors include a variety of demographic and patient-related characteristics; however, 2 critical components of performing a GBP—the size of the gastric pouch and the length of the alimentary and/or the biliopancreatic limb—are seldom evaluated together as possible predictors of poor weight loss. Most centers in the United States, including ours, use a gastric pouch based on the lesser curvature of the stomach, with an estimated 30- to 50-mL volume and a 100- to 150-cm alimentary limb,25 with longer limbs reserved for patients with a BMI of more than 50.26-28 The size of the created pouch likely varies based on surgeon's technique and the patient's body habitus.22,29 In addition, most surgeons estimate the pouch size solely

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using anatomical landmarks. Only 1 study of 100 patients with 1 year of follow-up has shown an inverse correlation between gastric pouch area and weight loss, but the authors did not control for many other factors, including diabetes.22 In addition, other studies that have evaluated factors associated with poor weight loss have not taken into account all possible patient- and operative-technique–related factors that may also affect weight loss outcomes. We therefore sought to determine, using multivariate analysis, the independent effects of patient- and operative-technique–related factors on weight loss 1 year after GBP.

**METHODS**

**STUDY POPULATION**

Our study population consisted of 361 consecutive patients who underwent primary open or laparoscopic GBP from January 1, 2003, through July 30, 2006, at the University of California, San Francisco, Medical Center. Follow-up data at 12 months were available for 310 patients (85.9%). Preoperative, perioperative, and postoperative data were collected prospectively. Patients with previous bariatric operations were excluded from this analysis. All patients met the following 1991 National Institutes of Health Consensus Development Conference30 and the University of California, San Francisco, Bariatric Surgery Program eligibility criteria for bariatric operation: BMI of greater than 40, or ranging from 35 to 40 with high-risk, obesity-related comorbid conditions for at least 5 years; a documented attempt of medically supervised therapy for weight loss for at least 6 months; and participation in a 1-hour educational and screening session with a dietitian and a bariatric surgeon. All patients also underwent preoperative psychological, nutritional, and comprehensive medical evaluations. Informed consent was obtained from all patients. The study was conducted after institutional review board approval.

**OPERATIVE TECHNIQUE**

Open or laparoscopic approaches were used at the discretion of the attending surgeon, based on the clinical assessment and judgment of the likelihood and safety of performing the operation with each approach. The gastrojejunostomy suturing techniques were also used at the discretion of the attending surgeon. When conversion from a laparoscopic to an open approach was needed, the case was counted as an open case. Apart from the incision access, the GBP technique was similar for open and laparoscopic approaches. To create the lesser-curve–based gastric pouch, initial access to the lesser sac was obtained along the lesser curvature 5 cm below the estimated location of the gastroesophageal junction, usually at the level of the first gastric vein. Once the lesser sac was entered, one or two 3.5-mm linear staplers, 45 mm in length (Endo-GIA Universal stapler; United States Surgical Corporation, Norwalk, Connecticut), were used to divide the stomach in a right-to-left horizontal plane. Next, two or three 3.5-mm linear staplers, 60 mm in length, were used to create the gastric pouch divided at the level of the angle of His. Specific care was always taken not to leave redundant gastric fundus on the side of the gastric pouch.

A circular anastomosis with a 21-mm stapler (EEA stapler; Ethicon Endo-Surgery Inc, Cincinnati, Ohio) was used in 22 patients (7.1%), a circular anastomosis with a 25-mm stapler (Ethicon Endo-Surgery Inc) was used in 123 (39.7%), and a 1.3-cm anastomosis with a 3.5-mm linear stapler was used in 165 (53.2%). An alimentary limb of 100 cm (n=263 [84.8%]) or 150 cm (n=47 [15.2%]) was measured, and a completely stapled side-to-side jejunojjunostomy was created. The bilio-pancreatic limb measured 40 to 50 cm from the angle of Treitz. The surgical technique and perioperative outcomes have been described in detail elsewhere.31 One patient died on postoperative day 3 (0.3% mortality) owing to a massive pulmonary embolism. No other late deaths were identified.

**POSTOPERATIVE CARE**

Routine swallow studies of the upper gastrointestinal tract were obtained on postoperative day 1 for the first 299 patients, and a selective approach was used afterward.32 Most patients were discharged on postoperative day 2 or 3. Patients were seen postoperatively at 2 weeks, every 3 months for the first year, and annually thereafter.

**STUDY VARIABLES**

**Weight Loss as Dependent on Outcome Variables**

One-year weight loss outcomes studied were the percentage of excess weight loss (EWL), absolute weight loss, and absolute change in BMI. Calculation of excess weight loss was based on Metropolitan Life Insurance height and weight tables to determine ideal body weight.31 For the multivariate analysis, weight loss was studied as a 2-level category (poor vs good). Poor weight loss was considered to be 40% or less EWL; good, more than 40% EWL.

**Independent, Potentially Predictive Variables**

The independent variables considered were age, sex, race (black vs other), marital status (married vs single), insurance status (private vs state carrier), initial weight and BMI, surgical approach (open or laparoscopic GBP), gastric pouch area (measured in square centimeters), gastrojejunostomy technique, alimentary limb length (100 vs 150 cm), and obesity-associated comorbidities. These comorbidities included type 2 diabetes mellitus (also studied in subgroups when using oral hypoglycemic agents only or with added insulin replacement), hypertension, hyperlipidemia, arthritis or degenerative joint disease, and obstructive sleep apnea. All predictive variables recorded, including medications used, were the ones defined in the immediate preoperative period.

**Calculation of the Gastric Pouch Area**

All pouch measurements were obtained from the routine swallow studies of the upper gastrointestinal tract on postoperative day 1. The imaging technique was standardized. An initial radiographic scout image was followed by oral intake of 20 to 80 mL of diluted diatrizoate meglumine and diatrizoate sodium USP solution (Gastrografin; Bracco Diagnostics Inc, Princeton, New Jersey) under fluoroscopic guidance and acquisition of multiple spot images. If no leakage of contrast was observed, the patient was given 20 to 80 mL of thin diluted barium to reach maximum distention of the pouch, and additional spot images were obtained. Finally, 1 or 2 extra overhead radiographic images were acquired. All images were available for review to calculate the pouch area. We used an anteroposterior radiograph to measure the height in centimeters of the vertebral body adjacent to the gastric pouch; next, we used fluoroscopic images to measure the same vertebral in pixels and converted that measurement to centimeters. The pouch height and width were then measured using the fluoroscopic image at the maximum distension point and converted to centimeters. The pouch area was then calculated (pouch height × width in square centimeters). All patients' pouch areas.
were measured independently by an attending radiologist (A.C.W.) and a surgeon (G.M.C.), who then together reviewed all measurements, resolving differences by consensus. The surgeon had no access to individual patient identifiers when measuring pouch area, whereas the radiologist was blinded to all clinical and outcome data. Only 36 of the 243 pouch measurements (14.8%) differed by more than 3 cm², and these were resolved by consensus. Otherwise, the value obtained by the radiologist was used.

STATISTICAL ANALYSIS

We first assessed the unadjusted association of each variable with poor weight loss by using the 2-sided t, Wilcoxon signed rank, χ², and Fisher exact tests as appropriate. Independent correlates of poor weight loss were identified using a multipredictor logistic model. Beginning with predictors associated with poor weight loss at P < .2 in unadjusted analysis, the final model was selected using a forward procedure with an entry criterion of P < .2. Overall goodness of fit was assessed using the Hosmer-Lemeshow χ² statistic. Linearity of the association between the pouch area and the logarithm of the odds of poor weight loss was assessed graphically and by adding a quadratic term in this predictor to the model. P < .05 was considered statistically significant. The analysis was conducted using Stata statistical software, version 10.1 (Stata Corp, College Station, Texas).

RESULTS

Demographic and clinical characteristics, comorbidities, operative data, and weight loss outcomes for all 310 patients who underwent GBP from January 2003 through July 2006 and completed 12 months of follow-up are presented in Table 1. The mean age of our patients was 45 years (range, 19-69) years, and 86.1% were women. The mean preoperative weight and BMI were 141.5 kg and 52 (range, 36-108), respectively. The most common obesity-associated comorbidities included obstructive sleep apnea (31.9%), diabetes mellitus (36.8%), and hypertension (64.8%). Most patients underwent a laparoscopic procedure (80.3%) and had an alimentary limb length of 100 cm (84.8%). The overall mean EWL was 60.2%. Thirty-eight patients (12.3%) had poor weight loss (<40% EWL) (Table 2). The other weight loss outcomes (absolute weight loss, change in BMI, and final BMI) are also presented in Table 2, and all were significantly worse (P < .01) for patients with poor EWL.

Only 2 differences were found when we compared demographic and clinical characteristics, comorbidities, and operative data for the 51 patients who did not complete 12 months of follow-up with those for the 310 patients who did. The 51 patients without 12 months of follow-up had a lower prevalence of type 2 diabetes mellitus (17.6% vs 36.8% [P = .007]) and hypertension (39.2% vs 64.8% [P = .01]).

The following 4 variables were associated with poor weight loss at P ≤ .05 in the univariate analysis: greater initial weight, the presence of diabetes (the highest prevalence of poor weight loss was in patients receiving added insulin replacement), the open surgical approach, and larger pouch size. There were nonsignificant trends for increasing age, higher prevalence of black race, and greater initial BMI among the group with poor weight loss. The pouch area was significantly inversely correlated with EWL (Figure).

In the multivariate analysis, only presence of diabetes (odds ratio [OR], 3.09; 95% confidence interval [CI], 1.35-7.09 [P = .007]) and larger pouch size (OR, 2.77; 95% CI, 1.81-4.22 [P < .001 per standard deviation]) were independently associated with poor weight loss. In the multivariate model, when patients with diabetes were subdivided into those receiving oral medications only and those also receiving added insulin replacement therapy, stronger associations with poor weight loss were found for the latter group (OR, 6.49; 95% CI, 1.66-25.40 [P = .007]) and the former group (OR, 2.56; 95% CI, 0.96-6.81 [P = .06]) compared with patients who did not have diabetes. Age, sex, race, preoperative weight and BMI, open vs laparoscopic approach, and hypertension were not associated with weight loss (P < .2) after adjustment and were omitted from the final adjusted model.

The primary desirable outcomes after bariatric surgery include low rates of perioperative and long-term complications, sustained and meaningful weight loss, significant improvement in quality of life, improvement or resolution of obesity-associated comorbidities, and extension of life span. All 5 outcomes have been shown to be feasible results of GBP performed at high-volume centers. Although modest weight loss has been shown to improve many of the metabolic complications of obesity, greater and long-term weight loss is likely necessary to obtain all of the long-term benefits observed with the operation. Our overall results of 60.2% EWL fit well within the range of 57% to 65% reported at 1 year in other large series of patients treated with GBP. Although some authors have suggested that the nadir of weight loss after GBP occurs at approximately 16.37 or 2 years after surgery,13,38 weight loss varies greatly among patients, 15% of whom may not lose enough weight to qualify as having a successful outcome. The very definition of successful weight loss varies among previous studies, with some using 50% EWL as a cutoff. We defined failure as 40% or less EWL because it was the cutoff used recently by Melton et al.18 Identified predictors of poor weight loss after GBP could be used to develop more specific guidelines for informing patients preoperatively about the likelihood of a suboptimal outcome and for guiding the decision to undertake bariatric surgery. They could also be used to develop better strategies to overcome modifiable risk factors. Our multivariate analysis shows that only the presence of diabetes and a larger pouch size were independently associated with poor weight loss. Like our study, others have found that patients with diabetes mellitus have poorer weight loss after GBP than do patients without diabetes. Although GBP is known to significantly improve or cure diabetes, we and others observed an independent effect of this disease on weight loss outcomes. One possible explanation is that most of these patients take exogenous insulin and/or drugs used to optimize glycemic control (sulfonylureas, meglitinides, and thiazolidinediones) that increase circulating insulin levels and/or insulin sensitivity. Because insulin is a known anabolic hormone that promotes lipogenesis, stimulation of triglyceride synthesis, adi-

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pocyte differentiation, and muscle synthesis, elevated levels may reduce the degree of weight loss after GBP. Other factors that may lead to weight gain in patients with diabetes include a "protective" increase in caloric intake to treat episodes of hypoglycemia, reduction of urinary glucose losses, and sodium and water retention that are a direct effect of insulin on the distal tubule in the kidney. These and the inherent metabolic derangements to glucose homeostasis that are caused by obesity likely converge to produce this effect.

Table 1. Demographic and Clinical Characteristics of All Patients Who Underwent GBP Surgery With 12-Month Follow-up Data and Those With Good vs Poor EWL

<table>
<thead>
<tr>
<th></th>
<th>All Patients (N=310)</th>
<th>Good EWL (n=272 [87.7%])</th>
<th>Poor EWL (n=38 [12.3%])</th>
<th>P Valueb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD) [range], y</td>
<td>45 (10.4) [19-69]</td>
<td>44.7 (10.4) [19-69]</td>
<td>47.6 (10) [28-65]</td>
<td>.10</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>43 (13.9)</td>
<td>38 (14.0)</td>
<td>8 (18.6)</td>
<td>.18</td>
</tr>
<tr>
<td>Female</td>
<td>267 (86.1)</td>
<td>237 (86.8)</td>
<td>30 (11.2)</td>
<td></td>
</tr>
<tr>
<td>Marital status</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>149 (48.1)</td>
<td>133 (48.9)</td>
<td>16 (10.7)</td>
<td>.43</td>
</tr>
<tr>
<td>Other</td>
<td>161 (51.9)</td>
<td>139 (48.3)</td>
<td>22 (13.7)</td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>68 (21.9)</td>
<td>55 (19.9)</td>
<td>13 (19.1)</td>
<td>.06</td>
</tr>
<tr>
<td>Other</td>
<td>242 (78.1)</td>
<td>217 (80.1)</td>
<td>25 (10.3)</td>
<td></td>
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<tr>
<td>Insurance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>State carrier</td>
<td>48 (15.5)</td>
<td>41 (15.4)</td>
<td>7 (14.6)</td>
<td>.59</td>
</tr>
<tr>
<td>Private carrier</td>
<td>262 (84.5)</td>
<td>231 (85.4)</td>
<td>31 (11.9)</td>
<td></td>
</tr>
<tr>
<td>Initial weight, mean (SD) [range], kg</td>
<td>141.6 (31.3) [86.2-283.5]</td>
<td>139.7 (29.3) [86.2-235.9]</td>
<td>151.5 (42.4) [91.6-283.5]</td>
<td>.03</td>
</tr>
<tr>
<td>Initial BMI, mean (SD) [range]</td>
<td>52 (12) [36-108]</td>
<td>51 (11) [36-96]</td>
<td>55 (14) [38-108]</td>
<td>.08</td>
</tr>
<tr>
<td>Comorbidities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>Yes</td>
<td>114 (36.8)</td>
<td>92 (30.7)</td>
<td>22 (19.3)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>196 (63.2)</td>
<td>180 (59.3)</td>
<td>16 (8.2)</td>
</tr>
<tr>
<td>DM and medication type</td>
<td>No DM</td>
<td>196 (63.2)</td>
<td>180 (91.8)</td>
<td>16 (8.2)</td>
</tr>
<tr>
<td></td>
<td>Oral medication only</td>
<td>87 (28.1)</td>
<td>71 (91.6)</td>
<td>16 (18.4)</td>
</tr>
<tr>
<td></td>
<td>Added insulin use</td>
<td>27 (8.7)</td>
<td>21 (71.4)</td>
<td>6 (22.2)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>Yes</td>
<td>108 (34.8)</td>
<td>94 (39.0)</td>
<td>14 (13.0)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>202 (65.2)</td>
<td>178 (61.0)</td>
<td>24 (11.9)</td>
</tr>
<tr>
<td>Obstructive sleep apnea</td>
<td>Yes</td>
<td>99 (31.9)</td>
<td>85 (85.9)</td>
<td>14 (14.1)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>211 (68.1)</td>
<td>187 (88.6)</td>
<td>24 (11.4)</td>
</tr>
<tr>
<td>Joint disease</td>
<td>Yes</td>
<td>177 (57.1)</td>
<td>152 (85.9)</td>
<td>25 (14.1)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>133 (42.9)</td>
<td>120 (90.2)</td>
<td>13 (9.8)</td>
</tr>
<tr>
<td>Psychiatric disorder</td>
<td>Yes</td>
<td>130 (41.9)</td>
<td>113 (86.9)</td>
<td>17 (13.1)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>180 (58.1)</td>
<td>159 (88.3)</td>
<td>21 (11.7)</td>
</tr>
<tr>
<td>Operative access</td>
<td>Laparoscopic</td>
<td>249 (80.3)</td>
<td>224 (90.0)</td>
<td>25 (10.0)</td>
</tr>
<tr>
<td></td>
<td>Open</td>
<td>61 (19.7)</td>
<td>48 (76.7)</td>
<td>13 (23.1)</td>
</tr>
<tr>
<td>Roux limb length, cm</td>
<td>100</td>
<td>263 (84.8)</td>
<td>232 (88.2)</td>
<td>31 (11.8)</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>47 (15.2)</td>
<td>40 (85.1)</td>
<td>7 (14.9)</td>
</tr>
<tr>
<td>Technique of gastrojejunostomy</td>
<td>Linear staplerc</td>
<td>165 (53.2)</td>
<td>146 (88.5)</td>
<td>19 (11.5)</td>
</tr>
<tr>
<td></td>
<td>Circular 21-mm staplerd</td>
<td>22 (7.1)</td>
<td>17 (77.3)</td>
<td>5 (22.7)</td>
</tr>
<tr>
<td></td>
<td>Circular 25-mm staplerd</td>
<td>123 (39.7)</td>
<td>109 (86.6)</td>
<td>14 (11.4)</td>
</tr>
<tr>
<td>Pouch area, mean (SD) [range], cm²</td>
<td>26 (13) [7-78]</td>
<td>25 (11) [7-67]</td>
<td>39 (17) [16-78]</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); DM, diabetes mellitus; EWL, excess weight loss; GBP, gastric bypass.

Good EWL was defined as greater than 40%; poor EWL, as 40% or less. Unless otherwise indicated, data are expressed as number (percentage) of patients. Comparisons of good vs poor EWL. Indicates Endo-GIA Universal stapler (United States Surgical Corporation, Norwalk, Connecticut).

Indicates EEA stapler (Ethicon Endo-Surgery Inc, Cincinnati, Ohio).
Pouch area was determined in 243 patients (214 patients who showed good EWL at the 12-month follow-up and 29 who showed poor EWL).
is observed, and although it does so at better rates than need for medications even before significant weight loss. 

Although GBP has proved to be very effective in improving insulin resistance and decreasing the weight loss. Although GBP has proved to be very effective in improving insulin resistance and decreasing the weight gain was a significant 2.9 kg greater in the intensive treatment group. Moreover, patients in the intensive treatment group who received insulin gained more weight, with a mean weight gain of 4 kg greater than that observed in the patients who received sulfonylurea. These results are consistent with our findings that diabetes was an independent risk factor for poor weight loss and that patients receiving insulin were at higher risk of poor weight loss. Although we attribute this difference to the likely individual differences in gastric wall distensibility. Many methods for achieving glycemic control that are not linked to weight gain, such as glucagon-like peptide 1 receptor agonists (eg, exenatide) and the dipeptidyl-peptidase 4 inhibitors (eg, sitagliptin and vildagliptin), may be considered in patients who continue to need exogenous glucose control and thus may improve weight loss after GBP. The role of specific antiadipic agents in weight loss after GBP should be the focus of future studies.

The restriction imposed by a small pouch size is one of the most important aspects of GBP. We know of only 1 other study that demonstrated an inverse correlation between initial gastric pouch size and EWL after GBP. In that study by Roberts et al, 100 patients underwent GBP, had gastric pouch size measured, and had follow-up data available at 12 months. The mean pouch size (64 cm²; range, 9-248 cm²) was more than double what we measured in our series (mean, 26 cm²; range, 7-78 cm²). Although we attribute this difference to the likely variability in the pouch measurements obtained between the 2 studies, it also demonstrates the variability in how different surgeons in different centers create a gastric pouch. Roberts et al also found an inverse correlation between initial gastric pouch size and EWL (r = -0.43) and that EWL was poorer in patients with larger pouches, results which support our findings. One other recent study attempted to determine the association between pouch size and EWL in 59 patients 1 year after GBP. In 4 groups according to pouch size. Madan et al failed to show a significant correlation, likely owing to a small sample size, to studying pouch sizes in groups, and to not controlling for other variables known to affect weight loss. Although pouch volume would be a preferable measurement compared with pouch area as was used in our study and the other studies mentioned, it was not feasible to obtain it routinely. Nevertheless, we believe that pouch area as measured using our methods is a useful surrogate for pouch volume, even allowing for individual differences in gastric wall distensibility. Many meth-

### Table 2. Weight Loss Outcomes of All Patients and Those With Good vs Poor EWLa

<table>
<thead>
<tr>
<th></th>
<th>All Patients</th>
<th>Good EWL (n=272 [87.7%])</th>
<th>Poor EWL (n=38 [12.3%])</th>
</tr>
</thead>
<tbody>
<tr>
<td>EWL, %</td>
<td>60.2 (7.9-117.3)</td>
<td>64.1 (40.3-117.3)</td>
<td>32.4 (7.9-39.9)</td>
</tr>
<tr>
<td>Weight loss, kg</td>
<td>48.5 (5.0-112.5)</td>
<td>50.8 (20.9-112.5)</td>
<td>30.4 (5.0-88.9)</td>
</tr>
<tr>
<td>BMI change</td>
<td>17.8 (1.9-50.1)</td>
<td>18.8 (8.2-50.1)</td>
<td>11.9 (1.8-33.7)</td>
</tr>
<tr>
<td>Final weight, kg</td>
<td>92.5 (47.2-237.2)</td>
<td>88.5 (47.2-166.0)</td>
<td>121.1 (79.4-237.2)</td>
</tr>
<tr>
<td>Final BMI</td>
<td>33.9 (17.3-73.8)</td>
<td>32.5 (17.3-57.4)</td>
<td>43.8 (33.1-73.8)</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); EWL, excess weight loss.

a Good EWL was defined as greater than 40%; poor EWL as 40% or less. Data are expressed as mean (range).

b All weight loss outcomes are significantly worse (P<.01) for patients with poor EWL.

![Figure](https://archsurg.jamanetwork.com/) Inverse correlation between the pouch area and the percentage of excess weight loss (EWL) at 12 months after gastric bypass.
ods are used to estimate pouch size intraoperatively. Accor-
ding to a recent survey,23 70% of surgeons in the United
States estimate pouch size by measuring the distance from
the estimated location of the gastroesophageal junction
to a variable distance in the lesser curvature of the stom-
ach, and/or by the number of vessels in the lesser cur-
vature; only about 20% use a sizing balloon. As the use
of GBP continues to grow, we believe it is critical to stress
the importance of and to teach the creation of the small
gastric pouch and to better standardize the technique used
for pouch creation.

Greater initial weight and BMI14,16,18,52 have previously
been associated with poor EWL after GBP. A study of 494
morbidly obese patients, of whom 377 (76.3%) had com-
plete follow-up at 1 year, found that higher initial weight
and BMI were negatively associated with percentage of EWL
because heavier patients lost a lower percentage of weight
than did lighter patients (P < .001).14 The following 2 main
factors may support this finding in other series: a higher
rate of other obesity-associated diseases with greater weight
and BMI, and the fact that excess weight is by definition
greater when weight and BMI are greater. Both factors may
have put these patients at a disadvantage with respect to
percentage of EWL. In contrast, in our study, greater ini-
tial weight and BMI were not found to be independent pre-
dictors of poor weight loss, showing that other factors are
more important than initial weight and BMI.

Race was also not an independent factor predicting
poor weight loss in our study, but others have found
that association.10,17,33 A combination of a few known
factors may explain poorer weight loss in black
patients, such as differences in body composition, fat
distribution, resting energy expenditure, and ther-
ogenesis34; higher diabetes prevalence35; cultural and
social environment36; and the basic definition of ideal
body weight that possibly underestimates the ideal
body weight in black patients.36

Extending the alimentary and/or the biliopancreatic
limb is one of the few technical variations of GBP that
have been proposed to decrease the failure rate, but this
effect has been shown only in patients with a BMI greater
than 50.26,27,57 Several alimentary and/or the biliopancre-
atic limb lengths have been reported, and those alimen-
tary limbs greater than 200 cm have been associated with
more complications. Nevertheless, extending the limb
length is a technical aspect of the operation that needs
further study, and we suggest that the better approach
may be to tailor limb extension on the basis of indi-
vidual patient characteristics.

Although our study is 1 of the largest single-center
series currently available, with predictor variables and
outcomes obtained in 85.9% of patients, the study
population comes from a tertiary care medical center and
its demographics and clinical characteristics may differ from those of other centers. Therefore, our findings
should be validated in a multivariate analysis of a larger, independent data set. Another limitation was our
inability to determine whether postoperative use of
medications for diabetes had an effect on weight loss
because only preoperative medication use was ascer-
tained. Other factors that may have affected weight loss
for which data were not available in the present study
include physical activity level, measures of body com-
position, and fat distribution before or after surgery.
These variables should receive greater emphasis in
future studies. An additional relevant finding that may
bias our results was the lower prevalence of 2 risk fac-
tors for poor weight loss among the 51 patients omitted
from our analysis because they did not have 12 months
of follow-up data. This suggests that our estimate of the
prevalence of poor weight loss may be slightly high;
however, it is unlikely that the associations between
risk factors and poor weight loss differ in the omitted
patients. Finally, although careful adjustment using
multiple regression may remove most confounding by
measured factors, in particular when a liberal criterion
for adjustment is used, as in our study, it cannot bal-
ance unmeasured confounders.

We conclude that GBP provides good or excellent
weight loss for most patients. However, diabetes melli-
tus and larger pouch size are independently associated
with poor weight loss after GBP. Changes in the use of
diabetes medications may reduce the risk of poor weight
loss among diabetics undergoing GBP. Detailed atten-
tion to the creation of a small gastric pouch is essential
for achieving the best results.

Accepted for Publication: March 18, 2008.
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Rabl, Mulligan, Posselt, Lin, and Vittinghoff. Drafting of
the manuscript: Campos, Rabl, Westphalen, and
Vittinghoff. Critical revision of the manuscript for impor-
tant intellectual content: Campos, Rabl, Mulligan, Posselt,
Rogers, and Lin. Statistical analysis: Lin and Vittinghoff.

Obtained funding: Campos. Administrative, technical, and
material support: Campos, Rabl, Mulligan, Rogers, and
Westphalen. Study supervision: Campos and Posselt.

Financial Disclosure: None reported.

Funding/Support: This study was supported in part by
grant KL2 RR024130 from the National Center for Re-
search Resources (NCRR).

Disclaimer: The content is solely the responsibility of the
authors and does not necessarily represent the official view
of the NCRR or the National Institutes of Health.

Previous Presentation: This paper was presented at the
79th Annual Meeting of the Pacific Coast Surgical Associa-
tion; February 18, 2008; San Diego, California, and
is published after peer review and revision. The discus-
sions that follow this article are based on the originally
submitted manuscript and not the revised manuscript.

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and meta-analysis [published correction appears in JAMA. 2005;293(14):1728].


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DISCUSSION

Bruce M. Wolfe, MD, Portland, Oregon: In the last year we have seen several important developments in the field of bariatric surgery that will increase the demand for bariatric surgery. The Agency for Healthcare Research and Quality reported a 79% reduction of hospital mortality for bariatric surgery between 1998 and 2004. Researchers in Sweden and Utah reported a 30% to 40% improved survival beyond 10 years following bariatric surgery, including as much as a 60% reduction in mortality due to cancer. Dixon et al recently reported from Australia the results of a randomized trial of maximal medical treatment vs placement of an adjustable gastric band among diabetic patients [JAMA. 2008;299(3):316-323]. At 2 years, the medical patients showed no improvement of the status of their obesity or diabetes, whereas the surgical group experienced substantial weight loss and improvement of diabetes. Most recently, the funding for the NIH bariatric surgery consortium known as LABS [Longitudinal Assessment of Bariatric Surgery] was extended for an additional 5 years. In view of the vast number of potential surgical candidates already in the population, these supportive events are likely to stimulate an even greater rate of increase in the number of bariatric surgical procedures performed than we have seen in the past.

Given this progressive application of bariatric surgery to the obesity epidemic, it is appropriate to examine outcomes in greater detail. One issue that has not received extensive study or emphasis is the variability of weight loss that follows seemingly standardized interventions. Associated with this variable weight loss is a variable comorbidity response. An additional challenge is a lack of delineation in the mechanisms of action of the various operative procedures that are available to the bariatric surgeon. This issue is particularly pertinent given the general increase in short- and long-term complications associated with operations that accomplish greater weight loss. Our capacity to predict success or failure in a given patient at the present time is severely limited, thereby limiting our ability to select the appropriate operation for specific patients. I therefore applaud Dr Campos and his colleagues for tackling this critically important but difficult-to-investigate issue. Dr Campos reports 2 factors to be most predictive of successful weight loss following gastric bypass. One is a patient factor (diabetes), and the other is a process-of-care factor (pouch size).

The complexity of patient factors that may impact weight loss and comorbidity response following a seemingly standard intervention is underscored by data we recently presented from the University of California, Davis. A population of GBP patients was noted to have EWL ranging from 25% to 116% at plateau. Visceral fat specimens taken from these patients at operation were subjected to microarray analysis of messenger RNA expression. Multiple positive correlations with weight loss were identified, including genes that control various aspects of fat metabolism and of neural and behavioral mechanisms. While very preliminary, these results indicate proof of concept that metabolic phenomena may well be of critical importance to the mechanism of action of different operative procedures and the variations of response to these procedures.

Dr Campos found pouch size to predict weight loss following bariatric surgery. Others have reported that reduction of pouch size as an operative intervention for failed weight loss is often disappointing. The finding in the present study of the correlation of weight loss and pouch size is therefore of definite interest.

Questions for the authors: (1) The statistical method used to correlate risk factors with outcome requires adequate power. To evaluate the impact of predictors of outcome that may be strong predictors but occur infrequently, the study needs to be appropriately powered. Have the data been examined with power analysis to determine whether a larger sample size might increase the number of predictors associated with postoperative weight loss? (2) Did any of the diabetic patients develop postoperative hypoglycemia, stimulating them to eat frequently, a known confounder of outcome following bariatric surgery? (3) You report a substantial variation in pouch size. Most bariatric surgeons use a standardized method for creating the gastric pouch, including the size. Do you have any explanation for the severalfold variation in pouch size in your study and any recommendations for management?

Dr Campos: The power analysis showed that, with 243 observations and 29 events, we had 80% power in 2-sided tests with α of 5% to detect ORs of 1.8 per standard deviation increase in continuous predictors, and ORs of 4 to 5 for binary predictors, depending on prevalence. However, both of these estimates of minimum detectable effects lose power when adjusted for other covariates that have smaller effects size or prevalence. In other words, the study is well powered to detect the bigger effects, but indeed we may have missed some weaker effects by chance. Nevertheless and importantly, I would like to underscore that the associations with diabetes and pouch size are very highly significant and almost surely do not represent type 1 error.

We did not specifically search or code for postoperative hypoglycemia in the diabetic patients; however, this is indeed 1 of 2 well-known possible mechanisms by which diabetic patients gain weight when receiving medications for blood glucose control; one is by replacing or stimulating insulin production that is a known anabolic hormone and the second is a “protective” increase in caloric intake to treat eventual episodes of hypoglycemia while adjustments of the diabetes medications are done in the postoperative period. We should pay closer attention to the postoperative management of the diabetic patient and consider using new classes for the diabetes medications that are not associated with weight gain, such as glucagon-like peptide 1 receptor agonists or exenatide and the dipeptidyl-peptidase 4 inhibitors such as sitagliptin or vildagliptin. These may be considered in patients who continue to need exogenous glucose control and thus may improve weight loss after GBP.

Finally, the 3 surgeons in the department who contributed to this series have, on average, similar pouch sizes. There is a small variation in the numbers, but a spread or variation in size exists for all 3 surgeons. Second, there is only 1 other paper that measured pouch size using a technique similar to ours. It is a publication from the Yale group in Surgical Endoscopy in March 2007. They report a pouch size that is, on average, double our size and also report a large spread of many-fold variation. Those 2 observations speak to the variation of how pouch size is created, not only by the individual surgeon but by different techniques in different centers. Added to this there are different individual patient characteristics. Patients have different anatomic features at around the gastroesophageal junction, such as a greater fat pad, a thicker stomach, and a larger fundus, among others, making it more difficult to create or properly size the pouch. Lastly, there is an interesting paper coming in the American Society for Metabolic and Bariatric Surgery’s journal reporting a survey on how bariatric surgeons in the United States create the gastric pouch; most will do it based on anatomical landmarks such as distance from the gastroesophageal junction. Variability exists because of many factors, and there should be an effort to disseminate better guidelines and teaching for pouch creation, as it is an important component of optimal weight loss.

Financial Disclosure: None reported.

(Reprinted) Arch Surg/Vol 143 (No. 9), Sep 2008 www.archsurg.com

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