Bariatric Surgery
A Systematic Review and Meta-analysis

 context

About 5% of the US population is morbidly obese. This disease remains largely refractory to diet and drug therapy, but generally responds well to bariatric surgery.

Objective
To determine the impact of bariatric surgery on weight loss, operative mortality, and 4 obesity comorbidities (diabetes, hyperlipidemia, hypertension, and obstructive sleep apnea).

Data Sources and Study Selection
Electronic literature search of MEDLINE, Current Contents, and the Cochrane Library databases plus manual reference checks of all articles on bariatric surgery published in the English language between 1990 and 2003. Two levels of screening were used on 2738 citations.

Data Extraction
A total of 136 fully extracted studies, which included 91 overlapping patient populations (kin studies), were included for a total of 22094 patients. Nineteen percent of the patients were men and 72.6% were women, with a mean age of 39 years (range, 16-64 years). Sex was not reported for 1537 patients (8%). The baseline mean body mass index for 16 944 patients was 46.9 (range, 32.3-68.8).

Data Synthesis
A random effects model was used in the meta-analysis. The mean (95% confidence interval) percentage of excess weight loss was 61.2% (58.1%-64.4%) for all patients; 47.5% (40.7%-54.2%) for patients who underwent gastric banding; 61.6% (56.7%-66.5%), gastric bypass; 68.2% (61.5%-74.8%), gastropasty; and 70.1% (66.3%-73.9%), biliopancreatic diversion or duodenal switch. Operative mortality (≤30 days) in the extracted studies was 0.1% for the purely restrictive procedures, 0.5% for gastric bypass, and 1.1% for biliopancreatic diversion or duodenal switch. Diabetes was completely resolved in 76.8% of patients and resolved or improved in 86.0%. Hyperlipidemia improved in 70% or more of patients. Hypertension was resolved in 61.7% of patients and resolved or improved in 78.5%. Obstructive sleep apnea was resolved in 85.7% of patients and was resolved or improved in 83.6% of patients.

Conclusions
Effective weight loss was achieved in morbidly obese patients after undergoing bariatric surgery. A substantial majority of patients with diabetes, hyperlipidemia, hypertension, and obstructive sleep apnea experienced complete resolution or improvement.

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Conclusions
Effective weight loss was achieved in morbidly obese patients after undergoing bariatric surgery. A substantial majority of patients with diabetes, hyperlipidemia, hypertension, and obstructive sleep apnea experienced complete resolution or improvement.
The literature on postoperative weight loss and the problems associated with various bariatric surgical procedures is extensive and has been summarized elsewhere. The literature with respect to comorbidity outcomes of bariatric surgery is also extensive, but has not been systematically reviewed and subjected to meta-analysis. We have conducted a systematic review of published observational and interventional trials that focus on bariatric surgery. The subsequent meta-analysis has concentrated on the impact of bariatric surgery on 4 selected obesity comorbidities: diabetes, hyperlipidemia, hypertension, and obstructive sleep apnea. For consistency, meta-analyses of weight loss outcomes were confined to the studies qualifying for the categories selected for assessment.

METHODS

We used a comprehensive and current database to catalog the bariatric surgery literature. The catalog was developed as an online, navigable research adjunct. The evidence database for the catalog was assembled using established systematic review methods.

The main objectives of this study were to analyze the impact of bariatric surgery on diabetes, hyperlipidemia, hypertension, and obstructive sleep apnea, as well as on health care economics and disease impact; to analyze weight reduction efficacy outcomes in the studies selected for the comorbid conditions; and to summarize operative mortality outcomes.

Data Sources

A broad search of the English-language literature was performed incorporating both electronic and manual components. The electronic search was performed using MEDLINE, Current Contents, and the Cochrane Library databases. MEDLINE (1990-2003, cut-off date June 5, 2003) was searched using the following search terms: obesity/surgery, gastric bypass, gastroplasty, bariatric, gastric banding, “anastomosis, Roux-en-Y,” biliopancreatic diversion (including duodenal switch), jejunal-
plasty, and biliopancreatic diversion or duodenal switch procedure groups, as well as for the total population, which included gastric banding, gastric bypass, gastroplasty, and biliopancreatic diversion or duodenal switch, plus mixed groups and other less common bariatric surgery procedures (biliary intestinal bypass, ileogastrostomy, jejunoleal bypass, and unspecified bariatric surgery).

Resolved and Resolved or Improved. Outcomes of the selected comorbidities were grouped into categories of resolved and resolved or improved. For the calculation of the percentage resolved, we included those studies reporting the number of patients in which co-morbid conditions disappeared or no longer required therapy. We preferentially extracted the number of patients evaluated as the denominator wherever possible. For the calculation of the percentage resolved or improved, we included studies reporting numbers of patients in both of these 2 categories (in which case, the 2 were summed), as well as studies that only used the term improved, but not the studies reporting only resolution. Consequently, the percentage resolved or improved may be lower than the percentage deemed resolved due to different study cohorts and, therefore, different denominators for the percentage calculations. Improved in lipid disorders was defined as normalization of laboratory values or the reduction or discontinuation of medical therapy.

**Statistical Analysis**

Analyses were performed only on the data from the studies in the data extraction subset. Study, patient, and treatment-level data were summarized using basic descriptive statistics (simple counts and means). The number of patients enrolled or randomized was used in the calculation of study and patient demographics.

Efficacy outcomes of interest were synthesized via meta-analytic pooling of similar surgery group results across studies with stratification by the type of surgery. In addition, meta-analysis of within-study surgery effects on weight loss and diabetes-related outcomes were stratified by studies with extractable outcomes for a general population compared with subgroups of patients with diabetes or impaired glucose tolerance.

Meta-analyses of all efficacy outcomes were conducted using a random-effects model, estimated by using the restricted maximum likelihood method. Efficacy outcomes included both proportions (eg, response rates) and raw mean before and after changes (eg, absolute weight changes). The random-effects model meta-analyses take into account both study sample size and the estimate of between-study variation (ie, study het-
heterogeneity) when weighting study effects. Meta-analytic means and mean changes are expressed with 95% confidence intervals (CIs).

Weighted means (ie, weighting results by sample size) were calculated for all studies for a given outcome to provide a non–meta-analytic comparison for each result. A drawback of the weighted means analysis is that it ignores between-study variations, providing a result similar to that found by a fixed-effects analysis. There are, however, positive aspects of the use of weighted means. In the analysis of continuous data, some outcomes had exceedingly wide fluctuations in within-study variation, allowing certain studies of the same size to be weighted quite differently.

All calculations were performed using SAS (version 8.1, SAS Institute Inc, Cary, NC) and SPSS (version 11.0, SPSS Inc, Chicago, Ill) statistical software.

**RESULTS**

**Data Retrieval**

A flow diagram outlining the systematic review process is provided ([FIGURE]). The initial literature review identified 2738 citations for screening. Of these, 1772 were rejected after reviewing the abstracts and 5 publications could not be retrieved prior to the retrieval cutoff date of July 18, 2003. Of the remaining 961 articles, 253 did not meet inclusion criteria for the catalog, and 572 studies met inclusion criteria only for the catalog but not for further analysis. Therefore, 136 fully extracted primary studies (for which there were 91 “kin” or linked publications) were available for meta-analysis.

Decisions about relationships among publications were made to maximize information on the comorbidities of interest without double counting patients. Several important studies had numerous kin publications. Outcomes of interest were typically presented in the more recently published articles in which longer periods of follow-up were reported for some or all of the patients. On the other hand, in some large studies only small subgroups of patients with outcomes relevant to the comorbidities of interest were reported and these articles were again dealt with to avoid counting patients more than once.

There were a total of 136 studies, within which there were 179 treatment groups and 22,094 patients either enrolled or analyzable in the data set, including those in comparator control.

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**Table 1. Characteristics of Total Population and Gastric Banding and Gastric Bypass Studies**

<table>
<thead>
<tr>
<th>No. of Studies</th>
<th>No. of Treatment Groups</th>
<th>No. of Patients</th>
<th>Publication year</th>
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<td>35</td>
<td>48</td>
<td>3653</td>
<td>1990-1995</td>
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<tr>
<td>99</td>
<td>131</td>
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<td>76</td>
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<td>56</td>
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<td>9,786</td>
<td>North America</td>
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<th>Study design</th>
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<td>5</td>
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<td>621</td>
<td>Randomized controlled trial</td>
</tr>
<tr>
<td>28</td>
<td>48</td>
<td>4,613</td>
<td>Nonrandomized controlled trial or series</td>
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<table>
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<th>No. of Patients</th>
<th>Institutional setting</th>
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<td>126</td>
<td>168</td>
<td>18,628</td>
<td>Single</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>3120</td>
<td>Multicenter</td>
</tr>
<tr>
<td>3</td>
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<td>346</td>
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<table>
<thead>
<tr>
<th>No. of Studies</th>
<th>No. of Treatment Groups</th>
<th>No. of Patients</th>
<th>Continuous outcomes time point, y</th>
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<td>95</td>
<td>125</td>
<td>16,651</td>
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<td>32</td>
<td>35</td>
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<tr>
<td>10</td>
<td>19</td>
<td>2,099</td>
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<th>No. of Treatment Groups</th>
<th>No. of Patients</th>
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<td>64</td>
<td>77</td>
<td>14,290</td>
<td>≤2</td>
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<tr>
<td>25</td>
<td>26</td>
<td>2,895</td>
<td>&gt;2</td>
</tr>
<tr>
<td>51</td>
<td>76</td>
<td>4,099</td>
<td>Not reported</td>
</tr>
</tbody>
</table>

*Table does not include 2 health care economics studies without efficacy or safety data.
†Includes gastric banding, gastric bypass, gastroplasty, biliopancreatic diversion or duodenal switch, as well as mixed groups and other less common procedures (biliary intestinal bypass, ileogastrostomy, jejunoileal bypass, and unspecified bariatric surgery).
‡Includes standard and long-limb gastric bypass procedures with additional components (eg, gastroplasty, band).
§Total number of studies with categorical or continuous outcomes is greater than the total number of studies because some studies contained multiple treatment groups extracted at different time points.

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groups. Health care economic outcomes were varied and not amenable to meta-analysis. We did, however, include the weight loss efficacy and operative mortality data from those studies in these respective analyses.

**Study Characteristics**

After excluding 2 health care economics studies with no weight loss or mortality data, 134 studies were extracted. Fifty-six of the extracted studies were based in North America, 58 in Europe, and 20 were conducted in other locations throughout the world (Australia, New Zealand, South America, Japan, Israel, Saudi Arabia, and Taiwan) (Table 1 and Table 2). Included were 5 randomized controlled trials, 28 nonrandomized controlled trials or series with comparison groups, and 101 uncontrolled case series. The majority of studies were conducted at single centers (n=126) and only a few were multicenter studies (n=5). At least 1 categorical outcome of interest (eg, proportion of patients with resolution or improvement in diabetes, hyperlipidemia, hypertension, or obstructive sleep apnea) or 1 continuous outcome of interest (change in a laboratory or physiological measure) was reported by each of the extracted studies.

**Patient Characteristics**

In studies reporting sex (150 treatment groups), 19.4% (n=3769) of patients were men and 72.6% (n=14082) were women (Table 3). Sex was not reported for 1537 patients (8%). The overall mean age was 38.97 years (range, 16.20-63.60 years) in studies for which this was reported. The BMI for 16944 patients at baseline was 46.85 (range, 32.30-68.80). Patient characteristics such as mean age and BMI at baseline were relatively similar across surgical procedure types.

**Weight Loss**

Given the emphasis on comorbidities, weight loss efficacy outcomes were preferentially extracted at time points for which comorbidity changes were reported. In addition, whenever possible, outcome time points representing at least 50% of the patient population undergoing surgery were used.

Substantial weight reduction was observed in this study set by both metaanalytic techniques and simple pooling across studies using weighted means (Table 4). The mean (95% CI) percentage of excess weight loss by metaanalysis at the outcome time point for which comorbidities were assessed was 47.5% (40.7%-54.2%) for gastric banding, 61.6% (56.7%-66.5%) for gastric bypass, 68.2% (61.5%-74.8%) for gastropasty, and 70.1% (66.3%-73.9%) for biliopancreatic diversion or duodenal switch. The overall percentage of excess weight loss for 10172 patients for all surgery types was 61.2% (95% CI, 58.1%-64.4%). Although less common, weight loss outcomes were also reported as a decrease in BMI (mean [95% CI], 14.2 [13.3-15.1] in 8232 patients) and a decrease in absolute weight (mean [95% CI], 81.4 [76.5-86.3] kg in 6335 patients).
Conclusions in HbA1c and fasting glucose values for unselected populations. Re-
the BMI was 14.03 (95% CI, 10.77-
46.21%-68.30%) and the reduction in
weight loss was 57.25% (95% CI,
0.60-0.88 mmol/L; n = 2092 by meta-
analysis).

There was a difference in diabetes outcomes analyzed according to the 4
categories of operative procedures. With re-
spect to diabetes resolution, there was a
gradation of effect from 98.9% (95% CI,
96.8%-100%) for biliopancreatic diver-
sion or duodenal switch to 83.7% (95%
CI, 77.3%-90.1%) for gastric bypass to
71.6% (95% CI, 55.1%-88.2%) for gas-
dropastomy, and to 47.9% (95% CI, 29.1%-66.7%)
for gastric banding. The percentage
of patients with diabetes resolved or
improved showed different results (Table 5); this variation from the trend
solely for diabetes resolved may be due
to the far greater number of patients as-
sewed assessed for this variable (n = 1846)
compared with the number assessed for the
combined variable (n = 485) in the total
population.

Hyperlipidemia. By both meta-
analysis and by weighted means, the out-
come categories of hyperlipidemia, hypercholesterolemia, and hypertriglyc-
eridemia were significantly improved across all surgical procedures (includ-
ing the mixed and other bariatric sur-
gery groups; Table 7). The percentage
of patients improved was typically
70% or higher, with some variation as a
function of the measure used and the
procedure performed. The maximum
improvements in hyperlipidemia by meta-
analysis occurred with the bilipan-
creatic diversion or duodenal switch pro-
cedure (99.1%; 95% CI, 97.6%-100%)
and with gastric banding (96.9%; 95% CI,
93.6%-100%).

In the total population, meta-
analysis of the continuous measures
demonstrated a significant decrease in
total cholesterol level (mean change,
33.20 mg/dL; 95% CI, 23.17-43.63
mg/dL [0.86 mmol/L; 95% CI, 0.60-
1.13 mmol/L; n = 2573], low-density li-
poprotein cholesterol level (mean change,
29.34 mg/dL; 95% CI, 17.76-
40.93 mg/dL [0.76 mmol/L; 95% CI,
0.46-1.06 mmol/L; n = 879], and level of
triglycerides (mean change, 79.65 mg/
dL; 95% CI, 64.60-95.58 mg/dL [0.90
mmol/L; 95% CI, 0.73-1.08 mmol/L; 
n = 2149]. While there was not a signifi-
cant increase in high-density lipopro-
tein cholesterol level in the total popu-
lation, significant improvements were
seen with gastric banding (mean change,
4.63 mg/dL; 95% CI, 1.54-7.72 mg/dL 
[0.12 mmol/L; 95% CI 0.04-0.20 mmol/
L; n = 623] and with gastropasty (mean
change, 5.02 mg/dL; 95% CI, 0.77-9.27
mg/dL [0.13 mmol/L; 95% CI, 0.02-
0.24 mmol/L; n = 253].

Hypertension. By both meta-
analysis and by weighted proportions,
hypertension significantly improved in
the total patient population and across
all surgical procedures (Table 8). The
percentage of patients in the total popu-
lation whose hypertension resolved was
61.7% (95% CI, 55.6%-67.8%). The per-
centage of patients in the total popu-
lation whose hypertension resolved or
Evidence for changes in obstructive sleep apnea was primarily available for gastric bypass patients. This was particularly so for the continuous objective variable of apneas or hypopneas per hour (4 available studies), which decreased by 33.85 per hour (95% CI, 17.47-50.23 per hour) in the total population, including 2 gastric bypass groups.

**Randomized Controlled Trials**

Data from the 5 randomized controlled trials were examined separately for weight loss and, when feasible, for the impact on mortality for 30 or fewer days and the 4 comorbidities (Table 9). These outcomes were within the range of values and the trends found for the overall meta-analysis.

**COMMENT**

Bariatric surgery in morbidly obese individuals reverses, eliminates, or significantly ameliorates diabetes, hyperlipidemia, hypertension, and obstructive sleep apnea. These benefits occur in the majority of patients who undergo surgery.

With respect to type 2 diabetes, more than three quarters of the patients experienced complete resolution of their diabetes following bariatric surgery. Of those patients not experiencing complete resolution, more than half showed demonstrable improvement. Thus, about 85% of patients with diabetes experienced improvement in their diabetes course after bariatric surgery.

A landmark article on bariatric surgery was published in 1995.28 Provocatively titled, “Who would have thought it? An operation proves to be the most effective therapy for adult-onset diabetes mellitus,” this article inspired more than 30 studies demonstrating resolution or marked improvement in type 2 diabetes.

Table 4. Efficacy Outcomes for Weight Reduction*

<table>
<thead>
<tr>
<th>Outcome Measure</th>
<th>No. of Patients Evaluated</th>
<th>No. of Treatment Groups</th>
<th>Mean Change (95% Confidence Interval)†</th>
<th>Weighted Mean Change (Range of Mean Change)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total population‡</td>
<td></td>
<td></td>
<td>7588</td>
<td>83</td>
</tr>
<tr>
<td>BMI decrease</td>
<td>8232</td>
<td>96</td>
<td>-14.20 (-15.13 to -13.27)</td>
<td>-14.01 (-27.0 to -4.10)</td>
</tr>
<tr>
<td>Initial weight loss</td>
<td>1386</td>
<td>9</td>
<td>-32.64 (-36.39 to -28.89)</td>
<td>-35.58 (-39.0% to -20.90%)</td>
</tr>
<tr>
<td>Excess weight loss</td>
<td>10 172</td>
<td>67</td>
<td>-61.23% (-64.40% to -58.06%)</td>
<td>-64.67% (-93.0% to -32.0%)</td>
</tr>
<tr>
<td>Gastric banding</td>
<td>482</td>
<td>13</td>
<td>-28.64 (-32.77 to -24.51)</td>
<td>-32.36 (-45.40 to -13.10)</td>
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<tr>
<td>BMI decrease</td>
<td>1959</td>
<td>25</td>
<td>-10.43 (-11.52 to -9.33)</td>
<td>-10.83 (-16.40 to -4.70)</td>
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<tr>
<td>Excess weight loss</td>
<td>1848</td>
<td>12</td>
<td>-47.45% (-54.23% to -40.68%)</td>
<td>-49.59% (-70.0% to -32.0%)</td>
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<tr>
<td>Gastric bypass§</td>
<td>2742</td>
<td>20</td>
<td>-43.48 (-48.14 to -38.82)</td>
<td>-47.06 (-62.70 to -21.0)</td>
</tr>
<tr>
<td>BMI decrease</td>
<td>2705</td>
<td>22</td>
<td>-16.70 (-18.43 to -14.98)</td>
<td>-17.10 (-25.0 to -8.0)</td>
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<tr>
<td>Initial weight loss</td>
<td>969</td>
<td>4</td>
<td>-34.93% (-35.61% to -34.26%)</td>
<td>-34.97% (-36.20% to -31.40%)</td>
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<tr>
<td>Excess weight loss</td>
<td>4204</td>
<td>22</td>
<td>-61.56% (-66.45% to -56.68%)</td>
<td>-68.11% (-77.0% to -33.0%)</td>
</tr>
<tr>
<td>Gastric bypass</td>
<td>2742</td>
<td>20</td>
<td>-43.48 (-48.14 to -38.82)</td>
<td>-47.06 (-62.70 to -21.0)</td>
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<tr>
<td>BMI decrease</td>
<td>2705</td>
<td>22</td>
<td>-16.70 (-18.43 to -14.98)</td>
<td>-17.10 (-25.0 to -8.0)</td>
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<tr>
<td>Initial weight loss</td>
<td>969</td>
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<td>-34.93% (-35.61% to -34.26%)</td>
<td>-34.97% (-36.20% to -31.40%)</td>
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<tr>
<td>Excess weight loss</td>
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<td>-68.11% (-77.0% to -33.0%)</td>
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<td>Gastroplasty</td>
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<td>Initial weight loss</td>
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<td>-25.90% (-28.0% to -20.90%)</td>
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<td>Excess weight loss</td>
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<td>-68.17% (-74.81% to -61.53%)</td>
<td>-69.15% (-93.0% to -48.0%)</td>
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<tr>
<td>Bilipancreatic diversion or duodenal switch</td>
<td>1282</td>
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<td>-46.39 (-51.58 to -41.20)</td>
<td>-45.96 (-54.20 to -33.0)</td>
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<td>BMI decrease</td>
<td>984</td>
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<td>-16.75 (-27.0 to -13.10)</td>
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<tr>
<td>Initial weight loss</td>
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<td>2</td>
<td>-38.98% (-40.01% to -37.94%)</td>
<td>-38.97% (-39.0% to -38.20%)</td>
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<tr>
<td>Excess weight loss</td>
<td>2480</td>
<td>7</td>
<td>-70.12% (-73.91% to -66.34%)</td>
<td>-72.09% (-75.0% to -62.0%)</td>
</tr>
</tbody>
</table>

Abbreviation: BMI, body mass index.

*Body mass index is calculated as weight in kilograms divided by the square of height in meters.

†Comparison across studies significant (P<.01) for heterogeneity except for initial weight loss for gastric bypass and bilipancreatic diversion or duodenal switch.

Includes gastric banding, gastric bypass, gastroplasty, bilipancreatic diversion or duodenal switch, as well as mixed groups and other less common procedures (biliary intestinal bypass, jejunostomy, jejunoileal bypass, and unspecified bariatric surgery).

Includes standard and long-limb procedures with additional components (eg, gastroplasty, band).
<table>
<thead>
<tr>
<th>Procedure</th>
<th>Patients evaluated</th>
<th>(%)</th>
<th>(%)</th>
<th>(%)</th>
<th>(%)</th>
<th>(%)</th>
<th>(%)</th>
<th>(%)</th>
<th>(%)</th>
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<th>(%)</th>
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<td><strong>Total Population</strong></td>
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<td>1417 (76.8)</td>
<td>414 (85.4)</td>
<td>12 (0.7)</td>
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<td>30</td>
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<tr>
<td>Mean (95% CI)</td>
<td>76.8% (70.7% to 82.9%)</td>
<td>86.0% (78.4% to 93.7%)</td>
<td>–0.40% (–0.55% to –0.24%)</td>
<td>–0.74 (–0.88 to –0.60)</td>
<td>–117.50 (–136.10 to –98.89)</td>
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<td>&lt;.01</td>
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<tr>
<td>Weighted mean change (range)</td>
<td>–0.31% (–0.60% to 0)</td>
<td>–0.86 (–4.77 to 0.49)</td>
<td>–114.57 (–269.10 to –42.0)</td>
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<td><strong>Gastric Banding</strong></td>
<td>205</td>
<td>217</td>
<td>521</td>
<td>237</td>
<td>289</td>
<td>166</td>
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<tr>
<td>No. (%) with improvement in characteristic</td>
<td>98 (47.8)</td>
<td>174 (80.2)</td>
<td>1 (0.2)</td>
<td>9</td>
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<td>2</td>
<td>2</td>
<td>14</td>
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<tr>
<td>Mean (95% CI)</td>
<td>47.9% (29.1% to 66.7%)</td>
<td>80.8% (72.2% to 89.4%)</td>
<td>–0.27% (–0.36% to –0.19%)</td>
<td>–0.78 (–1.05 to –0.51)</td>
<td>–79.72 (–99.57 to –59.87)</td>
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<td>Weighted mean change (range)</td>
<td>–0.29% (–0.40% to –0.26%)</td>
<td>–0.71 (–1.80 to –0.20)</td>
<td>–77.07 (–171.50 to –46.40)</td>
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<tr>
<td><strong>Gastric Bypass</strong>‡</td>
<td>989</td>
<td>127</td>
<td>1142</td>
<td>20</td>
<td>196</td>
<td>93</td>
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<td>No. (%) with improvement in characteristic</td>
<td>829 (83.8)</td>
<td>115 (90.6)</td>
<td>6 (0.5)</td>
<td>26</td>
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<td>9</td>
<td>6</td>
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<tr>
<td>Mean (95% CI)</td>
<td>83.7% (77.3% to 90.1%)</td>
<td>93.2% (79.3% to 100.0%)</td>
<td>–0.59% (–0.82% to –0.37%)</td>
<td>–1.25 (–1.52 to –0.97)</td>
<td>–121.26 (–137.31 to –105.20)</td>
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<td>P Value for heterogeneity</td>
<td>&lt;.01</td>
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<td>NS†</td>
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<tr>
<td>Weighted mean change (range)</td>
<td>–0.42% (–0.60% to 0)</td>
<td>–1.43 (–1.80 to –0.70)</td>
<td>–118.32 (–173.60 to –107.60)</td>
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<td>No. (%) with improvement in characteristic</td>
<td>45 (68.2)</td>
<td>34 (89.5)</td>
<td>1 (6.7)</td>
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<tr>
<td>Mean (95% CI)</td>
<td>71.6% (55.1% to 88.2%)</td>
<td>90.8% (76.2% to 100.0%)</td>
<td>–0.44 (–0.58 to –0.30)</td>
<td>–109.57 (–138.15 to –80.98)</td>
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<td>Weighted mean change (range)</td>
<td>–0.56 (–4.77 to 0)</td>
<td>–122.92 (–269.10 to –73.40)</td>
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<tr>
<td><strong>Biliopancreatic Diversion or Duodenal Switch</strong></td>
<td>288</td>
<td>101</td>
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<td>No. (%) with improvement in characteristic</td>
<td>282 (97.9)</td>
<td>89 (88.1)</td>
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<tr>
<td>Mean (95% CI)</td>
<td>98.9% (96.8% to 100.0%)</td>
<td>76.7% (42.2% to 100.0%)</td>
<td>–0.59 (–1.06 to –0.11)</td>
<td>–148.53 (–213.69 to –83.38)</td>
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<tr>
<td>P Value for heterogeneity</td>
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<td>&lt;.01</td>
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<tr>
<td>Weighted mean change (range)</td>
<td>–0.67 (–1.41 to 0.49)</td>
<td>–132.51 (–269.10 to –73.40)</td>
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</tbody>
</table>

**Abbreviations:** CI, confidence interval; HbA1c, glycosylated hemoglobin. 
SI conversion factors: To convert glucose to mg/dL, divide by 0.0555; insulin to µIU/mL, divide by 6.945. 
*Includes gastric banding, gastric bypass, gastroplasty, biliopancreatic diversion or duodenal switch, as well as mixed groups and other less common procedures (biliary intestinal bypass, jejunostomy, jejunoileal bypass, and unspecified bariatric surgery). 
†Comparison across studies not significant for heterogeneity. 
‡Includes standard and long-limb gastric bypass and gastric bypass procedures with additional components (e.g., gastroplasty, band). 
§Lower percentage (compared with resolved category) reflects several large studies reporting only number of patients with diabetes resolution, which are not included in this category. 

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diabetes after bariatric surgery. Two recently published series (after our cut-off date for inclusion) by Schauer et al and Sugerman et al report almost identical rates of resolution as our meta-analysis, 83% and 86%, respectively. In addition, at 2-year follow-up, a 60% decrease in plasma insulin and a 20% decrease in the plasma glucose were seen in the surgical weight loss group in the Swedish Obesity Subjects study. The control group at 2 years had a 3.7-fold higher risk of diabetes onset.

Resolution of diabetes often occurred days following bariatric surgery, even before marked weight loss was achieved. Resolution of diabetes was more prevalent following the predominantly malabsorptive procedures (biliopancreatic diversion or duodenal switch) and the mixed malabsorptive/restrictive gastric bypass in contrast to the purely restrictive gastroplasty and gastric banding procedures. In addition, there appeared to be a gradation of diabetes resolution as a function of the operative procedure itself: 98.9% for biliopancreatic diversion or duodenal switch, 83.7% for gastric bypass, 71.6% for gastroplasty, and 47.9% for gastric banding.

The putative extent and time relationships of the different operative procedures are presented in Table 6.

**Table 6. Efficacy for Improvement in Diabetes-Related Outcomes for Diabetic and Glucose-Intolerant Patients**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Patients evaluated</th>
<th>No. of treatment groups</th>
<th>Mean (95% CI)</th>
<th>P Value for heterogeneity</th>
<th>Weighted mean change (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Population†</strong></td>
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</tr>
<tr>
<td>Absolute Weight Loss, kg</td>
<td>266</td>
<td>8</td>
<td>–41.93 (–52.63 to –31.24)</td>
<td>&lt;.01</td>
<td>–41.25 (–65.50 to –19.70)</td>
</tr>
<tr>
<td>BMI Decrease</td>
<td>306</td>
<td>11</td>
<td>–13.63 (–17.30 to –10.77)</td>
<td>&lt;.01</td>
<td>–13.94 (–24.0 to –7.70)</td>
</tr>
<tr>
<td>Excess Loss</td>
<td>267</td>
<td>6</td>
<td>–57.25% (–69.30% to –46.21%)</td>
<td>&lt;.01</td>
<td>–58.94% (–72.20% to –38.0%)</td>
</tr>
<tr>
<td>HbA1c</td>
<td>171</td>
<td>6</td>
<td>–3.97 (–5.20 to –2.74)</td>
<td>&lt;.01</td>
<td>–2.70% (–5.0% to –0.70%)</td>
</tr>
<tr>
<td>Fasting Glucose, mmol/L</td>
<td>296</td>
<td>14</td>
<td>–63.91% (–75.58% to –52.24%)</td>
<td>&lt;.01</td>
<td>–4.10 (–8.10 to –0.50)</td>
</tr>
<tr>
<td>Fasting Insulin, pmol/L</td>
<td>160</td>
<td>8</td>
<td>–123.91 (–182.94 to –64.88)</td>
<td>&lt;.01</td>
<td>–142.02 (–250.0 to 6.70)</td>
</tr>
</tbody>
</table>

*Body mass index is calculated as weight in kilograms divided by the square of height in meters.

SI conversion factors: To convert glucose to mg/dL, divide by 0.0555; insulin to µIU/mL, divide by 6.945.

**Table 6 continued**...

**Gastric Banding §**

<table>
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<tr>
<th>Patients evaluated</th>
<th>56</th>
<th>56</th>
<th>83</th>
<th>83</th>
<th>56</th>
<th>56</th>
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</thead>
<tbody>
<tr>
<td>No. of treatment groups</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
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<td></td>
</tr>
<tr>
<td>Mean (95% CI)</td>
<td>–41.25 (–52.63 to –31.24)</td>
<td>–13.94 (–24.0 to –7.70)</td>
<td>–58.94% (–72.20% to –38.0%)</td>
<td>–2.70% (–5.0% to –0.70%)</td>
<td>–4.10 (–8.10 to –0.50)</td>
<td></td>
</tr>
</tbody>
</table>

**Gastric Bypass §**

<table>
<thead>
<tr>
<th>Patients evaluated</th>
<th>129</th>
<th>166</th>
<th>184</th>
<th>88</th>
<th>164</th>
<th>90</th>
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</thead>
<tbody>
<tr>
<td>No. of treatment groups</td>
<td>4</td>
<td>4</td>
<td>7</td>
<td>4</td>
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<tr>
<td>Mean (95% CI)</td>
<td>–50.54 (–60.49 to –40.59)</td>
<td>–18.02 (–24.0 to –7.70)</td>
<td>–65.64% (–72.20% to –56.00%)</td>
<td>–3.99% (–5.0% to –0.70%)</td>
<td>–3.46 (–5.99 to –0.80)</td>
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</table>

**Gastroplasty**

<table>
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<tr>
<th>Patients evaluated</th>
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<tbody>
<tr>
<td>No. of treatment groups</td>
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<tr>
<td>Mean (95% CI)</td>
<td>–4.77 (–6.87 to –2.67)</td>
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**Biliopancreatic Diversion or Duodenal Switch**

<table>
<thead>
<tr>
<th>Patients evaluated</th>
<th>14</th>
<th>17</th>
<th>67</th>
<th>14</th>
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</thead>
<tbody>
<tr>
<td>No. of treatment groups</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Mean (95% CI)</td>
<td>–60.40 (–69.37 to –51.43)</td>
<td>–7.00 (–11.36 to –2.64)</td>
<td>–5.79 (–8.20 to –3.38)</td>
<td>–115.30 (–132.93 to –97.67)</td>
</tr>
</tbody>
</table>

**Abbreviations:** BMI, body mass index; CI, confidence interval; HbA1c, glycosylated hemoglobin.

SI conversion factors: To convert glucose to mg/dL, divide by 0.0555; insulin to µIU/mL, divide by 6.945.

*Body mass index is calculated as weight in kilograms divided by the square of height in meters.

†Includes gastric banding, gastric bypass, gastroplasty, biliopancreatic diversion or duodenal switch, as well as mixed groups and other less common procedures (biliary intestinal bypass, ileogastrostomy, jejunoileal bypass, and unspecified bariatric surgery).

‡Comparison across studies not significant for heterogeneity.

§Includes standard and long-limb gastric bypass and gastric bypass procedures with additional components (e.g., gastroplasty, band).
Efficacy for Improvement in Hyperlipidemia by Surgical Procedure

<table>
<thead>
<tr>
<th>Patients Improved†</th>
<th>Cholesterol Level, mmol/L</th>
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<tbody>
<tr>
<td></td>
<td>Hyperlipidemia</td>
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<tr>
<td>Patients evaluated</td>
<td>1019</td>
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<tr>
<td>No. (%) with improvement in characteristic</td>
<td>846 (83.0)</td>
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</table>

**Total Population†**

**Gastric Banding**

<table>
<thead>
<tr>
<th>Patients evaluated</th>
<th>426</th>
<th>23</th>
<th>13</th>
<th>633</th>
<th>623</th>
<th>478</th>
<th>633</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. (%) with improvement in characteristic</td>
<td>303 (71.1)</td>
<td>18 (78.3)</td>
<td>10 (76.3)</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>10</td>
</tr>
</tbody>
</table>

**Mean (95% CI)**

- Cholesterol: 79.3% (68.2% to 90.5%) 71.3% (55.5% to 87.0%) 82.4% (71.1% to 93.7%)
- HDL: –0.96 (–1.13 to –0.60) 0.07 (0 to 0.15) –0.76 (–1.06 to –0.46)

**P Value for heterogeneity**

- Cholesterol: NS‡<0.01
- HDL: NS‡<0.01

**Weighted mean change in characteristic**

- Cholesterol: –0.49 (–3.14 to 0.30) –0.10 (–0.36 to 0.68) –0.48 (–2.46 to 0.22)
- HDL: –0.79 (–2.90 to 0.22)

**Gastric Bypass§**

<table>
<thead>
<tr>
<th>Patients evaluated</th>
<th>125</th>
<th>439</th>
<th>271</th>
<th>307</th>
<th>163</th>
<th>81</th>
<th>304</th>
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</thead>
<tbody>
<tr>
<td>No. (%) with improvement in characteristic</td>
<td>117 (93.6)</td>
<td>417 (95.0)</td>
<td>255 (94.1)</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>7</td>
</tr>
</tbody>
</table>

**Mean (95% CI)**

- Cholesterol: 96.9% (93.6% to 100.0%) 94.9% (90.7% to 99.1%) 91.2% (83.6% to 98.8%)
- HDL: –0.30 (–0.55 to –0.05) 0.12 (0.04 to 0.20) –0.11 (–0.40 to 0.17)

**P Value for heterogeneity**

- Cholesterol: NS‡<0.01
- HDL: NS‡<0.01

**Weighted mean change in characteristic**

- Cholesterol: –0.22 (–0.90 to 0.30) 0.12 (–0.19 to 0.24) –0.09 (–0.49 to 0.22)
- HDL: –0.65 (–1.80 to –0.22)

**Gastroplasty**

<table>
<thead>
<tr>
<th>Patients evaluated</th>
<th>215</th>
<th>102</th>
<th>21</th>
<th>261</th>
<th>253</th>
<th>123</th>
<th>235</th>
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</thead>
<tbody>
<tr>
<td>No. (%) with improvement in characteristic</td>
<td>174 (80.9)</td>
<td>40 (39.2)</td>
<td>15 (71.4)</td>
<td>7</td>
<td>4</td>
<td>2</td>
<td>8</td>
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</tbody>
</table>

**Mean (95% CI)**

- Cholesterol: 73.6% (80.8% to 66.3%) 36.4% (25.4% to 51.4%) 72.4% (53.4% to 91.4%)
- HDL: –0.46 (–0.88 to –0.04) 0.13 (0.02 to 0.24) –0.29 (–0.62 to 0.00)

**P Value for heterogeneity**

- Cholesterol: NS‡<0.01
- HDL: NS‡<0.01

**Weighted mean change in characteristic**

- Cholesterol: –0.38 (–1.91 to 0.18) 0.18 (–0.10 to –0.36) –0.28 (–0.65 to 0.10)
- HDL: –0.86 (–1.97 to –0.39)

**Biliopancreatic Diversion or Duodenal Switch**

<table>
<thead>
<tr>
<th>Patients evaluated</th>
<th>200</th>
<th>1238</th>
<th>588</th>
<th>186</th>
<th>185</th>
<th>186</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. (%) with improvement in characteristic</td>
<td>199 (99.5)</td>
<td>1234 (99.7)</td>
<td>588 (100)</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

**Mean (95% CI)**

- Cholesterol: 99.1% (97.6% to 100.0%) 87.2% (92.6% to 100.0%) 100.0% (98.1% to 100.0%)
- HDL: –1.97 (–2.56 to –1.38) 0.07 (–0.22 to 0.36) –1.36 (–1.93 to –0.79)

**P Value for heterogeneity**

- Cholesterol: NS‡<0.01
- HDL: NS‡<0.01

**Weighted mean change in characteristic**

- Cholesterol: –1.81 (–3.14 to –0.86) 0.01 (–0.36 to 0.68) –1.33 (–2.46 to –0.49)

**Abbreviation:** CI, confidence interval.

SI conversion factors: To convert high-density lipoprotein, low-density lipoprotein, and total cholesterol to mg/dL, divide by 0.0259; triglycerides to mg/dL, divide by 0.0113.

*Includes patients described by study authors as having improved by virtue of elimination or reduction in therapy, patients reported to have improved lipid parameters, and all patients evaluated for improvement.

†Includes gastric banding, gastric bypass, gastroplasty, biliopancreatic diversion or duodenal switch, as well as mixed groups and other less common procedures (biliary intestinal bypass, ileo-gastrostomy, jejunoileal bypass, and unspecified bariatric surgery).

‡Comparison across studies not significant for heterogeneity.

§Includes standard and long-limb gastric bypass and gastric bypass procedures with additional components (eg, gastroplasty, band).

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Table 8. Efficacy for Improvement in Hypertension and Obstructive Sleep Apnea by Surgical Procedure

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Patients evaluated</th>
<th>Hypertension</th>
<th>Obstructive Sleep Apnea</th>
<th>Decrease in Apneas or Hypopneas per Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Resolved</td>
<td>Resolved or Improved</td>
<td>Resolved or Improved</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total Population*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>No. (%) with improvement in characteristic</td>
<td>No. (%) with improvement in characteristic</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>No. of treatment groups</td>
<td>No. of treatment groups</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean (95% CI)</td>
<td>P Value for heterogeneity</td>
<td>Mean (95% CI)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weighted mean change (range)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Population</strong></td>
<td></td>
<td><strong>4805</strong></td>
<td><strong>2141</strong></td>
<td><strong>1195</strong></td>
</tr>
<tr>
<td>Hypertension</td>
<td></td>
<td><strong>3151 (65.6)</strong></td>
<td><strong>1752 (81.8)</strong></td>
<td><strong>1051 (87.9)</strong></td>
</tr>
<tr>
<td>Obstructive Sleep Apnea</td>
<td></td>
<td><strong>67</strong></td>
<td><strong>43</strong></td>
<td><strong>38</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>61.7% (56.6% to 67.8%)</strong></td>
<td><strong>78.5% (70.8% to 86.1%)</strong></td>
<td><strong>85.7% (79.2% to 92.2%)</strong></td>
</tr>
<tr>
<td><strong>No. (%) with improvement in characteristic</strong></td>
<td></td>
<td><strong>3151 (65.6)</strong></td>
<td><strong>1752 (81.8)</strong></td>
<td><strong>1051 (87.9)</strong></td>
</tr>
<tr>
<td><strong>No. of treatment groups</strong></td>
<td></td>
<td><strong>67</strong></td>
<td><strong>43</strong></td>
<td><strong>38</strong></td>
</tr>
<tr>
<td><strong>Mean (95% CI)</strong></td>
<td></td>
<td><strong>61.7% (56.6% to 67.8%)</strong></td>
<td><strong>78.5% (70.8% to 86.1%)</strong></td>
<td><strong>85.7% (79.2% to 92.2%)</strong></td>
</tr>
<tr>
<td><strong>P Value for heterogeneity</strong></td>
<td></td>
<td><strong>&lt;.01</strong></td>
<td><strong>&lt;.01</strong></td>
<td><strong>&lt;.01</strong></td>
</tr>
<tr>
<td><strong>Weighted mean change (range)</strong></td>
<td></td>
<td><strong>−40.09 (−52.80 to −16.0)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gastric Banding</strong></td>
<td></td>
<td><strong>232 (38.4)</strong></td>
<td><strong>490 (71.5)</strong></td>
<td><strong>53 (94.6)</strong></td>
</tr>
<tr>
<td><strong>No. (%) with improvement in characteristic</strong></td>
<td></td>
<td><strong>232 (38.4)</strong></td>
<td><strong>490 (71.5)</strong></td>
<td><strong>53 (94.6)</strong></td>
</tr>
<tr>
<td><strong>No. of treatment groups</strong></td>
<td></td>
<td><strong>12</strong></td>
<td><strong>10</strong></td>
<td><strong>5</strong></td>
</tr>
<tr>
<td><strong>Mean (95% CI)</strong></td>
<td></td>
<td><strong>43.2% (30.4% to 56.9%)</strong></td>
<td><strong>70.8% (61.9% to 79.6%)</strong></td>
<td><strong>95.0% (88.8% to 100.0%)</strong></td>
</tr>
<tr>
<td><strong>P Value for heterogeneity</strong></td>
<td></td>
<td><strong>&lt;.01</strong></td>
<td><strong>&lt;.01</strong></td>
<td><strong>NS†</strong></td>
</tr>
<tr>
<td><strong>Weighted mean change (range)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gastric Bypass‡</strong></td>
<td></td>
<td><strong>1594 (75.4)</strong></td>
<td><strong>379 (87.1)</strong></td>
<td><strong>776 (86.6)</strong></td>
</tr>
<tr>
<td><strong>No. (%) with improvement in characteristic</strong></td>
<td></td>
<td><strong>1594 (75.4)</strong></td>
<td><strong>379 (87.1)</strong></td>
<td><strong>776 (86.6)</strong></td>
</tr>
<tr>
<td><strong>No. of treatment groups</strong></td>
<td></td>
<td><strong>20</strong></td>
<td><strong>11</strong></td>
<td><strong>13</strong></td>
</tr>
<tr>
<td><strong>Mean (95% CI)</strong></td>
<td></td>
<td><strong>67.5% (58.4% to 76.5%)</strong></td>
<td><strong>87.2% (78.4% to 95.9%)</strong></td>
<td><strong>80.4% (88.4% to 92.3%)</strong></td>
</tr>
<tr>
<td><strong>P Value for heterogeneity</strong></td>
<td></td>
<td><strong>&lt;.01</strong></td>
<td><strong>&lt;.01</strong></td>
<td><strong>&lt;.01</strong></td>
</tr>
<tr>
<td><strong>Weighted mean change (range)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gastroplasty</strong></td>
<td></td>
<td><strong>277 (72.5)</strong></td>
<td><strong>83 (80.6)</strong></td>
<td><strong>33 (76.7)</strong></td>
</tr>
<tr>
<td><strong>No. (%) with improvement in characteristic</strong></td>
<td></td>
<td><strong>277 (72.5)</strong></td>
<td><strong>83 (80.6)</strong></td>
<td><strong>33 (76.7)</strong></td>
</tr>
<tr>
<td><strong>No. of treatment groups</strong></td>
<td></td>
<td><strong>20</strong></td>
<td><strong>12</strong></td>
<td><strong>10</strong></td>
</tr>
<tr>
<td><strong>Mean (95% CI)</strong></td>
<td></td>
<td><strong>69.0% (59.1% to 79.0%)</strong></td>
<td><strong>85.4% (74.1% to 96.7%)</strong></td>
<td><strong>78.2% (53.6% to 100.0%)</strong></td>
</tr>
<tr>
<td><strong>P Value for heterogeneity</strong></td>
<td></td>
<td><strong>&lt;.01</strong></td>
<td><strong>&lt;.01</strong></td>
<td><strong>&lt;.01</strong></td>
</tr>
<tr>
<td><strong>Weighted mean change (range)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Biliopancreatic Diversion or Duodenal Switch</strong></td>
<td></td>
<td><strong>629 (81.3)</strong></td>
<td><strong>718 (91.8)</strong></td>
<td><strong>157 (95.2)</strong></td>
</tr>
<tr>
<td><strong>No. (%) with improvement in characteristic</strong></td>
<td></td>
<td><strong>629 (81.3)</strong></td>
<td><strong>718 (91.8)</strong></td>
<td><strong>157 (95.2)</strong></td>
</tr>
<tr>
<td><strong>No. of treatment groups</strong></td>
<td></td>
<td><strong>7</strong></td>
<td><strong>7</strong></td>
<td><strong>6</strong></td>
</tr>
<tr>
<td><strong>Mean (95% CI)</strong></td>
<td></td>
<td><strong>83.4% (73.2% to 93.6%)</strong></td>
<td><strong>75.1% (44.7% to 100.0%)</strong></td>
<td><strong>91.9% (81.9% to 100.0%)</strong></td>
</tr>
<tr>
<td><strong>P Value for heterogeneity</strong></td>
<td></td>
<td><strong>&lt;.10</strong></td>
<td><strong>&lt;.01</strong></td>
<td><strong>&lt;.01</strong></td>
</tr>
</tbody>
</table>

Abbreviation: CI, confidence interval.

*Includes gastric banding, gastric bypass, gastroplasty, biliopancreatic diversion or duodenal switch, as well as mixed groups and other less common procedures (biliary intestinal bypass, ileogastrostomy, jejunal bypass, and unspecified bariatric surgery).

†Comparison across studies not significant for heterogeneity.

‡Includes standard and long-limb gastric bypass and gastric bypass procedures with additional components (eg, gastroplasty, band).
creases of inflammatory indicators (C-reactive protein and interleukin 6)\textsuperscript{38}; improvement in insulin sensitivity correlated with increases in plasma adiponectin\textsuperscript{32,39}; significant changes in the enteroglucagon response to glucose\textsuperscript{40}; significant reduction in ghrelin levels following gastric bypass\textsuperscript{41} but not gastric banding\textsuperscript{42}; and significant improvement in beta cell function following gastric banding.\textsuperscript{43}

Considerable attention recently has focused on the Swedish Obesity Subjects study, in which 2010 patients after gastric bypass, gastroplasty, or gastric banding were compared with 2037 matched-pair controls who underwent conventional nonoperative obesity management. After 2 years, the incidence of hyperlipidemia was lower by 10-fold in the surgical weight loss group compared with the control group.\textsuperscript{31} Similar findings have been reported by others.\textsuperscript{34,44} In 1990, the Program on the Surgical Control of the Hyperlipidemias reported marked reductions in the levels of total (23%) and low-density lipoprotein cholesterol (38%), in association with increases in high-density lipoprotein cholesterol (4%) after a surgical distal ileal malabsorptive procedure.\textsuperscript{18} In the current meta-analysis, the improvement in hyperlipidemia also was more prevalent with the malabsorptive procedures.

Resolution or improvement of hypertension by weight reduction is well-known. Even a modest weight loss (eg, 10%) can lower blood pressure significantly. As a generalization, a decrease of 1% in body weight will decrease systolic blood pressure by 1 mm Hg and diastolic blood pressure by 2 mm Hg.\textsuperscript{40,45} The bariatric surgery literature extracted for this analysis is replete with reports of the resolution or improvement in hypertension postoperatively. This reduction in blood pressure, in distinction to the effect of weight loss on type 2 diabetes and hyperlipidemia, seems to be independent of the operative procedure performed.

In the current analysis, improvement in obstructive sleep apnea was dramatic—in the 80% or higher range. The extracted bariatric surgery literature is quite prolific on this subject. In association with the clinical findings, improvements in oxygen saturation, de-

### Table 9. Surgical Outcomes for the 5 Randomized Controlled Trials

<table>
<thead>
<tr>
<th>Source</th>
<th>Type of Surgery</th>
<th>Duration of Follow-up, mo</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashy and Merdad,\textsuperscript{23} 1998</td>
<td>Vertical banded gastroplasty (n = 30)</td>
<td>6</td>
<td>Patients experienced 87% excess weight loss</td>
</tr>
<tr>
<td></td>
<td>Laparoscopic adjustable gastric banding (n = 30)</td>
<td>6</td>
<td>Patients experienced 50% excess weight loss</td>
</tr>
<tr>
<td>Hall et al,\textsuperscript{24} 1990</td>
<td>Gastrogastrostomy, vertical gastroplasty, Roux-en-Y gastric bypass (n = 310)</td>
<td>36</td>
<td>Patients experienced 53% excess weight loss; 6 of 8 diabetes cases improved (medication reduced and/or laboratory values improved); 22 of 29 cases of hypertension were resolved (medication discontinued and/or blood pressure was normalized)</td>
</tr>
<tr>
<td>Mingrone et al,\textsuperscript{25} 2002</td>
<td>Biliopancreatic diversion in women (n = 31)</td>
<td>12</td>
<td>Mean (SD) decreases; BMI, 48.3 (6.3) to 35.2 (7.6); fasting blood glucose, 5.26 (0.26) mmol/L to 4.57 (0.30) mmol/L; insulin, 163.8 (17.4) pmol/L to 84.0 (25.2) pmol/L; total cholesterol level, 4.55 (1.09) mmol/L to 3.67 (0.57) mmol/L; HDL cholesterol level, 0.77 (0.16) mmol/L to 1.03 (0.34) mmol/L; and LDL cholesterol level, 4.00 (1.19) mmol/L to 1.96 (0.49) mmol/L</td>
</tr>
<tr>
<td></td>
<td>Biliopancreatic diversion in men (n = 15)</td>
<td>12</td>
<td>Mean (SD) decreases; BMI, 48.0 (5.4) to 30.4 (3.5); fasting blood glucose, 5.27 (0.43) mmol/L to 3.86 (0.35) mmol/L; insulin, 164.2 (40.8) pmol/L to 51.0 (27.0) pmol/L; total cholesterol level, 5.39 (1.05) mmol/L to 3.61 (0.45) mmol/L; HDL cholesterol level, 0.66 (0.16) mmol/L to 1.34 (0.29) mmol/L; and LDL cholesterol level, 2.79 (1.17) mmol/L to 2.03 (0.69) mmol/L</td>
</tr>
<tr>
<td>Nguyen et al,\textsuperscript{26} 2001</td>
<td>Laparoscopic gastric bypass (n = 79)</td>
<td>6</td>
<td>Mean (SD) excess weight loss: 54% (14%)</td>
</tr>
<tr>
<td></td>
<td>Open gastric bypass (n = 76)</td>
<td>6</td>
<td>Mean (SD) excess weight loss: 45% (12%)</td>
</tr>
<tr>
<td>Thorne et al,\textsuperscript{27} 2002</td>
<td>Swedish adjustable gastric band (n = 25)</td>
<td>24</td>
<td>Mean (SD) decreases; BMI, 9.0 (6.0); fasting blood glucose, 0.70 (0.70) mmol/L; insulin, 68.4 (47.2) pmol/L; and total cholesterol level, 0.9 (0.8) mmol/L</td>
</tr>
<tr>
<td></td>
<td>Swedish adjustable gastric band with omentectomy (n = 25)</td>
<td>24</td>
<td>Mean (SD) decreases; BMI, 13.0 (5.0); fasting blood glucose, 1.80 (0.88) mmol/L; and insulin, 120.1 (64.6) pmol/L</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; HDL, high-density lipoprotein; LDL, low-density lipoprotein.

SI conversion factors: To convert glucose to mg/dL, divide by 0.0555; insulin to µIU/mL, divide by 6.945; HDL, LDL, and total cholesterol to mg/dL, divide by 0.0259.

*Body mass index is calculated as weight in kilograms divided by the square of height in meters.
creases in arterial carbon dioxide, and increases in arterial oxygen content have been demonstrated. These favorable physiological changes in the blood contents, which in turn affect the neurological pathways and cerebral centers responsible for respiration, are primarily the result of an increase in diaphragmatic excursion. This increase is brought about by a reduction in intra-abdominal pressure after successful bariatric surgery.

Reversal of or marked improvement in diabetes, hyperlipidemia, hypertension, obstructive sleep apnea, and obesity itself, should markedly increase life expectancy. A large, prospective, observational study, which controlled for unintentional weight loss and for smoking, of 43,457 women had a 12-year follow-up and showed that a weight loss of at least 9 kg was associated with a 53% reduction in all obesity-related deaths. A growing amount of evidence relates increased longevity with successful bariatric surgery. The Swedish Obesity Subjects study in diabetic patients has shown an 80% decrease in the annual mortality in the surgical weight loss group. Specifically, the obese diabetic patients in the surgical group had a 9% mortality at 9 years, whereas, the control group had a 28% mortality, with most deaths related to cardiovascular disease. In a comparable study, MacDonald et al reported that diabetic patients treated with an oral hypoglycemic had a 4.5% mortality rate for every 9 years of follow-up compared with a 1% mortality rate for every 9 years of follow-up. Therefore, the obese diabetic patients in the surgical group had a 9% mortality at 9 years, whereas the control group had a 28% mortality, with most deaths related to cardiovascular disease. In a comparable study, MacDonald et al reported that diabetic patients treated with an oral hypoglycemic had a 4.5% mortality rate for every 9 years of follow-up compared with a 1% mortality rate for every 9 years of follow-up.

In summary, in addition to the effective weight loss achieved by patients undergoing bariatric surgical procedures, a substantial majority of patients with diabetes, hyperlipidemia, hypertension, and obstructive sleep apnea experienced complete resolution or improvement of their comorbid condition.

Author Contributions: Dr Buchwald had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Buchwald, Avidor, Porjes, Pfahrbach, Schoelles.

Acquisition of data: Buchwald, Avidor, Porjes, Pfahrbach, Schoelles.

Analysis and interpretation of data: Buchwald, Avidor, Porjes, Pfahrbach, Schoelles.

Drafting of the manuscript: Buchwald, Avidor, Porjes, Pfahrbach.

Critical revision of the manuscript for important intellectual content: Buchwald, Avidor, Porjes, Pfahrbach, Schoelles.

Statistical expertise: Buchwald, Pfahrbach.

Obtained funding: Avidor.

Administrative, technical, or material support: Buchwald, Avidor, Porjes, Pfahrbach, Schoelles.

Study supervision: Buchwald, Avidor, Schoelles.

Funding/Support: Sponsored by Ethicon Endo-Surgery Inc, a Johnson & Johnson Company, Cincinnati, Ohio.

Role of the Sponsor: Ethicon Endo-Surgery Inc paid for the services of MetaWorks (Medford, Mass). The sponsor had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; or the preparation, review, or approval of the manuscript.

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of serving bowl size on consumption was statistically significant for men ($P = .02$) but not women ($P = .17$).

In the sensitivity analysis to estimate the potential impact of the 5 nonparticipants, the effect of bowl size remained significant ($P = .02$).

**Comment.** Small environmental factors can have a large influence on food consumption. At this party, large serving bowls led to a 56% greater intake (a mean of 142 more calories/person). The size of a serving bowl (or of a portion) may provide a consumption cue that implicitly suggests an appropriate amount to eat. Larger bowls, like larger packages or portions, may suggest that a proportionately larger amount is appropriate to consume. Although this study was not conducted in a medical setting, it is possible that if a physician giving diet-related advice recommends using smaller serving bowls, patients may serve themselves smaller portions.

Portion distortion has generally focused on how consumption cues lead people to overeat less healthy, energy-dense foods. An appropriate area for further research is whether these same cues, ie, larger serving bowls, can be used to encourage people to eat greater amounts of healthier foods such as fruits and vegetables.

Brian Wansink, PhD
Wansink@Cornell.edu
Applied Economics and Management
Cornell University
Ithaca, NY

Matthew M. Cheney, MS
Graduate School of Library and Information Science
University of Illinois
Champaign


**CORRECTIONS**

**Incorrect Data:** In the Clinical Review entitled “A Simplified Approach to the Management of Non–ST-Segment Elevation Acute Coronary Syndromes” published in the January 19, 2005, issue of *JAMA* (2005;293:349-357), incorrect data were reported. In the “Anticoagulation” rows of the Table on Page 352, “creatinine clearance $\leq 60 \text{ mL/min}$” should have been reported as “$<30 \text{ mL/min}$.” Also, in the center column on page 353, “creatinine clearance $<60 \text{ mL/min} \rightarrow 1.0 \text{ mL/s}$” should have been reported as “$<30 \text{ mL/min} \rightarrow 0.5 \text{ mL/s}$.”

**Incorrect Information:** In the Medical News & Perspectives article “Michael E. DeBakey, MD: Father of Modern Cardiovascular Surgery” published in the February 23, 2005, issue of *JAMA* (2005;293:913-918), President John F. Kennedy was erroneously described as one of the world leaders who were treated by DeBakey. DeBakey worked with Kennedy on medical legislation for Medicare.

**Reference Error:** In the Review entitled “Bariatric Surgery: A Systematic Review and Meta-analysis” published in the October 13, 2004, issue of *JAMA* (2004;292:1724-1737), there was a reference error. The Swedish Obese Subjects Intervention Study has not published any of its mortality data. On page 1736, column 1, first full paragraph, sentences 4 and 5 should be deleted. Sentence 6 should be “MacDonald et al57 reported that diabetic patients treated with an oral hypoglycemic had a 4.5% annual mortality rate for 9 years of follow-up compared with a 1% mortality rate in diabetic patients who underwent gastric bypass.”

**Error in Table:** In the Preliminary Contribution entitled “Detection of Paternally Inherited Fetal Point Mutations for $\beta$-Thalassemia Using Size-Fractionated Cell-Free DNA in Maternal Plasma” published in the February 16, 2005, issue of *JAMA* (2005;293:843-849), there was an error in Table 2. On pages 847 and 848, Table 2 should have read as follows. For each case (2 rows), the genotype and results (circulating fetal DNA and chorionic villus sampling) information (3 columns) was switched for mother and father. For example, in case 1 for paternal IVSI-1 mutation, “Codon 39/N” and “IVSI-1” and “IVSI-1/N” should be in the row with “Mother,” and “IVSI-1/N” should be in the row with “Father” in that order. The subsequent rows of genotype and results information should be switched for each case for the rest of the Table. Also, on page 848, the column heading “Parent Sex” should read “Parent.”