Association Between Bariatric Surgery and Rates of Continuation, Discontinuation, or Initiation of Antidiabetes Treatment 6 Years Later

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IMPORTANCE Few large-scale long-term prospective cohort studies have assessed changes in antidiabetes treatment after bariatric surgery.

OBJECTIVE To describe the association between bariatric surgery and rates of continuation, discontinuation, or initiation of antidiabetes treatment 6 years after bariatric surgery compared with a matched control obese group.

DESIGN, SETTING, AND PARTICIPANTS This nationwide observational population-based cohort study extracted health care reimbursement data from the French national health insurance database from January 1, 2008, to December 31, 2015. All patients undergoing primary bariatric surgery in France between January 1 and December 31, 2009, were matched on age, sex, body mass index category, and antidiabetes treatment with control patients hospitalized for obesity in 2009 with no bariatric surgery between 2005 and 2015.

EXPOSURES Bariatric surgery, including adjustable gastric banding (AGB), gastric bypass (GBP), and sleeve gastrectomy (SG).

MAIN OUTCOME AND MEASURE Reimbursement for antidiabetes drugs. Mixed-effects logistic regression models estimated factors of discontinuation or initiation of antidiabetes treatment over a period of 6 years.

RESULTS In 2009, a total of 15 650 patients (mean [SD] age, 38.9 [11.2] years; 84.6% female; 1633 receiving antidiabetes treatment) underwent primary bariatric surgery, with 48.5% undergoing AGB, 27.7% undergoing GBP, and 22.0% undergoing SG. Among patients receiving antidiabetes treatment at baseline, the antidiabetes treatment discontinuation rate was higher 6 years after bariatric surgery than in controls (−49.9% vs −9.0%, P < .001). In multivariable analysis, the main predictive factors for discontinuation were the following: GBP (odds ratio [OR], 16.7; 95% CI, 13.0-21.4), SG (OR, 7.30; 95% CI, 5.50-9.50), and AGB (OR, 4.30; 95% CI, 3.30-5.60) compared with no bariatric surgery, as well as insulin use (OR, 0.17; 95% CI, 0.13-0.22), dual therapy without insulin (OR, 0.38; 95% CI, 0.32-0.45) vs monotherapy, lipid-lowering treatment (OR, 0.76; 95% CI, 0.63-0.91), antidepressant treatment (OR, 0.67; 95% CI, 0.55-0.81), and age (OR, 0.96; 95% CI, 0.95-0.97) per year. For patients without antidiabetes treatment at baseline, the 6-year antidiabetes treatment initiation rate was much lower after bariatric surgery than in controls (1.4% vs 12.0%, P < .001). In multivariable analysis, protective factors were GBP (OR, 0.06; 95% CI, 0.04-0.09), SG (OR, 0.08; 95% CI, 0.06-0.11), and AGB (OR, 0.16; 95% CI, 0.14-0.20) vs controls, and risk factors were as follows: body mass index category (OR, 2.04; 95% CI, 1.68-2.47 for ≥50.0 vs 30.0-39.9 and OR, 1.68; 95% CI, 1.49-1.90 for 40.0-49.9 vs 30.0-39.9), antihypertensive treatment (OR, 1.49; 95% CI, 1.33-1.67), low income (OR, 1.43; 95% CI, 1.26-1.62), and age (OR, 1.04; 95% CI, 1.03-1.05) per year.

CONCLUSIONS AND RELEVANCE Bariatric surgery was associated with a significantly higher 6-year postoperative antidiabetes treatment discontinuation rate compared with baseline and with an obese control group without bariatric surgery.

Published online February 14, 2018.

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The worldwide prevalence of type 2 diabetes has doubled over the last 30 years. In France, according to national studies, the prevalence of treated diabetes is estimated to be 4.7% of the population. This worldwide growth of diabetes is one of the consequences of the increased prevalence of obesity. According to a national observational cohort study, a total of 15% of French adults are obese, which is not one of the highest rates in Europe. However, France has become the third leading country in the world in terms of bariatric surgery. In parallel with decreased postoperative morbidity and mortality, evidence-based studies have shown that bariatric surgery ensures sustainable weight loss and decreased long-term mortality. One of the expected benefits of bariatric surgery is type 2 diabetes remission. Since the first report in 1995 by Pories et al., many studies, including randomized controlled trials, have demonstrated the benefits of bariatric surgery on type 2 diabetes, with better outcomes for gastric bypass (GBP) compared with other procedures, such as adjustable gastric banding (AGB) and sleeve gastrectomy (SG). Although lifestyle intervention or metformin use can reduce the incidence of type 2 diabetes, bariatric surgery has been shown to more effectively reduce progression to type 2 diabetes in patients with obesity and without diabetes compared with nonsurgical treatment. Bariatric surgery could also be associated with decreased rates and improved control of obstructive sleep apnea, hypertension, and dyslipidemia.

All of these studies are based on short follow-up and small sample sizes, and high loss to follow-up or missing data rates. Using the French national health insurance database, the aim of the present study was to assess, under real-life conditions and at a national level, the discontinuation or initiation of antidiabetes treatment over a 6-year period after bariatric surgery compared with a matched control group.

### Methods

#### The French National Health Insurance Database

The SNIIRAM database covers the entire French population (64.3 million inhabitants in 2009), including low-income patients eligible for 100% coverage with Couverture Maladie Universelle. Since 2005, the database contains comprehensive data on all reimbursements for health-related expenditure, as well as demographic data and medical information on all admissions to French public and private hospitals (according to the International Statistical Classification of Diseases, 10th Revision [ICD-10]). These data are used to refund outpatient medical expenditure to the population, as well as the cost of hospital stays to public and private hospitals.

The SNIIRAM is one of the largest databases in the world and has been extensively used to guide public health policies in France. Because these data allow systematic follow-up of all medical care received in France, including for low-income people, several studies on bariatric surgery in France have been previously published.

Analyses of the SNIIRAM database for the present study were approved by the French personal data protection agency (Commission Nationale Informatique et Libertés). No other ethical approval or informed patient consent was required because this database is anonymous and all analyses were performed by French national health insurance staff.

### Population and Matching Process

All patients undergoing primary bariatric surgery in France between January 1, 2009, and December 31, 2009 (bariatric surgery group), were identified and classified based on the type of procedure performed in 2009 (AGB, GBP, SG, and others, such as biliopancreatic diversion with or without duodenal switch) based on hospital coding for bariatric surgery (eTable 1 in the Supplement). Patients with a previous coding for bariatric surgery or a revisional procedure during 2005 to 2008 were excluded.

During the same period (January 1, 2009, to December 31, 2009), all patients hospitalized with an ICD-10 code of obesity (eTable 1 in the Supplement) were identified. An obese control group included patients with no history of bariatric surgery during 2005 to 2015, as well as no cancer, pregnancy, chronic infectious disease, or serious acute or chronic disease, such as pulmonary embolism or heart failure, in 2008 to 2009.

Patients with obesity with or without bariatric surgery with no health care reimbursement (medical visit, treatment, laboratory tests, hospitalization, etc) for each of the 6 follow-up years during 2010 to 2015 were also excluded. Those patients were likely to have been out of the country during that time or to have voluntarily opted out of national health insurance and would thus be likely to have poor adherence to the recommended bariatric surgery or obesity follow-up and treatment.

Patients in the bariatric surgery group were then matched 1:1 on age (±5 years), sex, body mass index (calculated as weight in kilograms divided by height in meters squared) category, and antidiabetes treatment at baseline with control patients hospitalized for obesity in 2009 with no bariatric surgery between 2005 and 2015. Several bariatric surgery patients could be matched to the same control patient.

### Data Collection and Definitions

Data were extracted from the SNIIRAM database from January 1, 2008, to December 31, 2015. Patient follow-up was established on the basis of 12-month data, with the shortest follow-up being from January 1, 2008, to December 31, 2014.
and the longest follow-up being from December 31, 2008, to December 30, 2015.

Age and sex were obtained from the SNIIRAM database. Body mass index (BMI) was not reported in outpatient data but was available at the time of hospitalization based on the following 3 categories: 30.0 to 39.9, 40.0 to 49.9, and 50.0 or higher. Precarity was evaluated using 2 variables, including universal health insurance coverage for low-income families (Couverture Maladie Universelle) and a validated geographic socioeconomic deprivation index (Indice Géographique de Défavorisation).14

Medications were identified by reimbursements as those treatments not available over the counter and directly paid by health insurance when dispensed to the patient by a pharmacy. Medications were classified based on Anatomical Therapeutic Chemical code, described online by the World Health Organization (http://www.whocc.no) (eTable 2 in the Supplement). For the purposes of this study, we considered patients to be treated with antidiabetes drugs (including insulin) throughout the year when they received at least 3 drug reimbursements at different times over a 12-month period. Antidiabetes treatments were stratified into the following 3 exclusive categories based on the last 4 months of the year to reduce the risk of counting switches as multiple therapies: monotherapy without insulin, dual therapy or triple therapy without insulin, and insulin therapy (with or without other antidiabetes drugs). The baseline (preoperative) year used to describe clinical characteristics and medication reimbursements was defined as the year before bariatric surgery.

Statistical Analysis

Statistical analyses were performed using a software program (SAS, version 9.3; SAS Institute). The samples were described in terms of covariates and comparisons between bariatric surgery and control patients that were performed using χ2 test for categorical variables and t test for continuous variables.

The timing of antidiabetes treatment discontinuation and initiation was determined for each major bariatric procedure (AGB, GBP, and SG) and for the control group using Kaplan-Meier plots. Data were compared using log-rank test.

Sequence charts were also plotted to summarize the various courses of care (continuation, discontinuation, or initiation of antidiabetes treatment) of patients with at least 1 antidiabetes treatment for at least 1 year of follow-up. A software program (R, version 3.3.1; R Project for Statistical Computing) was used.

To assess changes in antidiabetes treatment during follow-up, generalized linear mixed modeling approaches were used to account for repeated measures and within-individual correlations. Mixed-effects logistic regression models with robust error variance were used to estimate (1) discontinuation of antidiabetes treatment among patients with antidiabetes treatment at baseline and (2) initiation of antidiabetes treatment among patients without antidiabetes treatment at baseline.

All factors with P < .20 were included in multivariable models, but only factors that remained significant at P = .05 were retained in the final model. Models were adjusted (when applicable) for age, sex, BMI category, and precarity. Interactions between the type of bariatric procedure and the year of follow-up were tested. Two-sided P < .05 was considered to be significant.

## Results

### Baseline Characteristics

Between January 1 and December 31, 2009, a total of 18 477 patients underwent bariatric surgery in France, and 15 650 of these patients were included in our study after excluding 2827 patients (eFigure in the Supplement). The main reason for exclusion was the absence of health care reimbursement for each of the 6 postoperative years (n = 2618). Excluded patients were younger (mean [SD] age, 33.5 [11.8] vs 38.9 [11.2] years; P < .001) and had fewer coexisting conditions (eTable 3 in the Supplement).

Overall, AGB (48.5%) was the most common procedure performed in the 15 650 bariatric surgery patients included in the study, ahead of GBP (27.7%), SG (22.0%), and other procedures (1.8%) (Table 1). Gastric bypass was the most common procedure (P < .001) performed in the subgroup of 1633 bariatric surgery patients with antidiabetes treatment at baseline (493 [30.2%] AGB, 655 [40.1%] GBP, 433 [26.5%] SG, and 52 [3.2%] others) and in the subgroup of 330 bariatric surgery insulin users (83 [25.2%] AGB, 137 [41.5%] GBP, 100 [30.3%] SG, and 10 [3.0%] others).

By design, the bariatric surgery and control groups were similar in terms of age (mean [SD] age, 38.9 [11.2] vs 39.4 [11.2] years; not significant), proportion of women (13241 [84.6%]), BMI between 40.0 and 49.9 (9335 [59.6%]), and antidiabetes treatment (1633 [10.4%]). However, patients in the bariatric surgery group were less likely to have lower rates of antihypertensive (24.1% vs 27.5%, P < .001), lipid-lowering (10.6% vs 12.1%, P < .001), anxiolytic (10.5% vs 14.4%, P < .001), and opioid (20.1% vs 24.1%, P < .001) treatments but had a similar rate of antidepressant treatment at baseline. Among patients with baseline antidiabetes treatment, metformin was the most common treatment in both the bariatric surgery and control groups (91.7% vs 91.0%, P > .05). Table 1 lists baseline characteristics and details about receiving antidiabetes treatment at baseline.

### Changes in Antidiabetes Treatment

#### Discontinuation of Antidiabetes Treatment

**During the 6-Year Follow-up**

During follow-up, 30.9% (n = 2348) of the 7592 patients who had undergone AGB at baseline subsequently underwent a revision procedure, including band removal in 41.4%, conversion to SG in 31.2%, GBP in 19.9%, AGB in 7.4%, and another procedure in 0.1%. Among the small subgroup with antidiabetes treatment at the time of the revision procedure (161 overall, including 66 with band removal, 42 with conver-
Table 1. Baseline Characteristics of a National Cohort of Patients Who Underwent Bariatric Surgery in 2009 and Matched Obese Controls, SNIIRAM Data

<table>
<thead>
<tr>
<th>Variable</th>
<th>Bariatric Surgery (n = 15 650)</th>
<th>Controls (n = 15 650)</th>
<th>P Valuea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>38.9 (11.2)</td>
<td>39.4 (11.2)</td>
<td>.19</td>
</tr>
<tr>
<td>Female, No. (%)</td>
<td>13 241 (84.6)</td>
<td>13 241 (84.6)</td>
<td>.99</td>
</tr>
<tr>
<td>BMI category, No. (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30.0-39.9</td>
<td>4358 (27.8)</td>
<td>4358 (27.8)</td>
<td>.99</td>
</tr>
<tr>
<td>40.0-49.9</td>
<td>9335 (59.6)</td>
<td>9335 (59.6)</td>
<td></td>
</tr>
<tr>
<td>≥50.0</td>
<td>1144 (7.3)</td>
<td>1144 (7.3)</td>
<td></td>
</tr>
<tr>
<td>Obesity (BMI unspecified)</td>
<td>813 (5.2)</td>
<td>813 (5.2)</td>
<td></td>
</tr>
<tr>
<td>Universal health insurance coverage for low-income families, No. (%)</td>
<td>2418 (15.5)</td>
<td>2691 (17.2)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Geographic socioeconomic deprivation index quintile 5 (most deprived), No./Total No. (%)</td>
<td>2851/14 970 (19.5)</td>
<td>2850/14 970 (19.5)</td>
<td>.82</td>
</tr>
<tr>
<td>Type of bariatric procedure, No. (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AGB</td>
<td>7592 (48.5)</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>GBP</td>
<td>4331 (27.7)</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>SG</td>
<td>3445 (22.0)</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>BPD ± DS</td>
<td>282 (1.8)</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Antihypertensive treatment, No. (%)a</td>
<td>3775 (24.1)</td>
<td>4300 (27.5)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Antidiabetes treatment, No. (%)b</td>
<td>1633 (10.4)</td>
<td>1633 (10.4)</td>
<td>.99</td>
</tr>
<tr>
<td>Specific antidiabetes treatment, No./Total No. (%)c</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metformin</td>
<td>1497/1633 (91.7)</td>
<td>1486/1633 (91.0)</td>
<td></td>
</tr>
<tr>
<td>Sulfonylurea</td>
<td>540/1633 (33.1)</td>
<td>662/1633 (40.5)</td>
<td></td>
</tr>
<tr>
<td>Glucagon-like peptide-1 analogue</td>
<td>86/1633 (5.3)</td>
<td>204/1633 (12.5)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>DPP4 inhibitor</td>
<td>201/1633 (12.3)</td>
<td>252/1633 (15.4)</td>
<td></td>
</tr>
<tr>
<td>Glitazone</td>
<td>401/1633 (24.6)</td>
<td>389/1633 (23.8)</td>
<td></td>
</tr>
<tr>
<td>Glucagon-like hormone</td>
<td>117/1633 (7.2)</td>
<td>155/1633 (9.5)</td>
<td></td>
</tr>
<tr>
<td>α-Glucosidase inhibitor</td>
<td>87/1633 (5.3)</td>
<td>108/1633 (6.6)</td>
<td></td>
</tr>
<tr>
<td>Insulin</td>
<td>330/1633 (20.2)</td>
<td>626/1633 (38.3)</td>
<td></td>
</tr>
<tr>
<td>Obstructive sleep apnea syndrome treatment, No. (%)</td>
<td>4322 (27.6)</td>
<td>736 (4.7)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Lipid-lowering treatment, No. (%)b</td>
<td>1660 (10.6)</td>
<td>1891 (12.1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Antidepressant treatment, No. (%)b</td>
<td>2706 (17.3)</td>
<td>2761 (17.6)</td>
<td>.41</td>
</tr>
<tr>
<td>Anxiolytic treatment, No. (%)b</td>
<td>1646 (10.5)</td>
<td>2260 (14.4)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Opioid treatment, No. (%)b</td>
<td>3139 (20.1)</td>
<td>3771 (24.1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>History of heart failure, No. (%)</td>
<td>139 (0.9)</td>
<td>149 (1.0)</td>
<td>.55</td>
</tr>
<tr>
<td>History of ischemic heart disease, No. (%)</td>
<td>238 (1.5)</td>
<td>490 (3.1)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Abbreviations: AGB, adjustable gastric banding; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); BPD ± DS, biliopancreatic diversion with or without duodenal switch; DPP4, dipeptidyl peptidase-4; GBP, gastric bypass; NA, not applicable; SG, sleeve gastrectomy; SNIIRAM, Système National d’Information Inter-régimes de l’Assurance Maladie.

a P values were calculated using χ² test for categorical variables and paired t test for continuous variables.

b Defined as at least 3 reimbursements at different times during the same year except for anxiolytic treatment, which was defined as at least 6 reimbursements.

c Defined as at least 1 reimbursement with or without another associated antidiabetes treatment during the last 4 months.

In multivariable analysis, all types of bariatric surgery were independent protective factors for initiation of antidiabetes treatment compared with controls, with odds ratios of 0.06 (95% CI, 0.04-0.09) for GBP, 0.08 (95% CI, 0.06-0.11) for SG, and 0.16 (95% CI, 0.14-0.20) for AGB. Major predictive factors for initiation of antidiabetes treatment for bariatric surgery and control patients were as follows: higher BMI (OR, 2.04; 95% CI, 1.68-2.47 for ≥50.0 vs 30.0-39.9 and OR, 1.68; 95% CI, 1.49-1.90 for 40.0-49.9 vs 30.0-39.9), male sex (OR, 1.92; 95% CI, 1.69-2.17), antihypertensive treatment (OR, 1.49; 95% CI, 1.33-1.67), low income (OR, 1.43; 95% CI, 1.26-1.62), and older age (OR, 1.04; 95% CI, 1.03-1.05 per year) at baseline (Table 3).

Courses of Care

Sequence charts summarize the various courses of care (continuation, discontinuation, or initiation of antidiabetes treatment) in patients with at least 1 antidiabetes treatment before or after inclusion (8-year period) for bariatric surgery (1895 in Figure 2A) and control (3633 in Figure 2B) groups, according to the various types of antidiabetes treatment. For patients

sion to SG, 38 with GBP, and 15 with AGB), the 6-year antidiabetes treatment discontinuation rate was higher among patients who underwent conversion to GBP (18 of 38 [47.4%]) and SG (17 of 42 [40.5%]) compared with the small number of patients who underwent band replacement (2 of 15 [13.3%]) (P < .001).

In multivariable analysis, all types of bariatric surgery were independent predictive factors for the 6-year antidiabetes treatment discontinuation rate compared with controls, with a much higher association of GBP. The odds ratios were 16.7 (95% CI, 13.0-21.4) for GBP, 7.3 (95% CI, 5.5-9.5) for SG, and 4.3 (95% CI, 3.3-5.6) for AGB (Table 2).

Initiation of Antidiabetes Treatment During the 6-Year Follow-up

For patients without antidiabetes treatment at baseline, the 6-year antidiabetes treatment initiation rates were 1.4% and 12.0%, respectively, for the bariatric surgery and control groups (P < .001). Figure 1B shows Kaplan-Meier plots of the 6-year cumulative antidiabetes treatment initiation in bariatric surgery patients and controls without antidiabetes treatment at baseline (28 034 overall).

In multivariable analysis, all types of bariatric surgery were independent protective factors for initiation of antidiabetes treatment compared with controls, with odds ratios of 0.06 (95% CI, 0.04-0.09) for GBP, 0.08 (95% CI, 0.06-0.11) for SG, and 0.16 (95% CI, 0.14-0.20) for AGB. Major predictive factors for initiation of antidiabetes treatment for bariatric surgery and control patients were as follows: higher BMI (OR, 2.04; 95% CI, 1.68-2.47 for ≥50.0 vs 30.0-39.9 and OR, 1.68; 95% CI, 1.49-1.90 for 40.0-49.9 vs 30.0-39.9), male sex (OR, 1.92; 95% CI, 1.69-2.17), antihypertensive treatment (OR, 1.49; 95% CI, 1.33-1.67), low income (OR, 1.43; 95% CI, 1.26-1.62), and older age (OR, 1.04; 95% CI, 1.03-1.05 per year) at baseline (Table 3).
undergoing AGB (20.0%), SG (36.0%), and GBP (57.0%), the rates of total discontinuation from year 2 to year 6 were higher than for controls (2.0%) \((P < .001)\).

Discussion

This nationwide observational population-based cohort study demonstrates that bariatric surgery is associated with high 6-year antidiabetes treatment discontinuation rates and low treatment initiation rates compared with matched control patients. A marked association after GBP was seen.

The efficacy of bariatric surgery as treatment for metabolic conditions associated with morbid obesity, especially type 2 diabetes, has been widely studied in the literature.\(^9,10,15,16,18,23\) However, few long-term studies with a matched control group based on large sample sizes have been published. Long-term type 2 diabetes remission rates after bariatric surgery have been reported to range between 24% and 69%, and these rates mostly vary with the type of surgery.\(^10,15,19,20\) Gastric bypass has been found to be most effective for type 2 diabetes remission compared with SG and AGB.\(^18,20\) Our study shows a 50.1% 6-year antidiabetes treatment discontinuation rate, which is consistent with these findings, as well as a much greater association of GBP compared with SG and AGB (odds ratios of 16.7, 7.3, and 4.3, respectively) vs a control group. One possible explanation is that GBP was associated with a greater weight loss (a variable not available in the database during outpatient follow-up),\(^23\) but Purnell et al\(^20\) showed higher rates of type 2 diabetes remission after GBP compared with AGB irrespective of weight loss. The long-term data of the Longitudinal Assessment of Bariatric Surgery\(^20\) study will provide a major contribution, despite that this prospective cohort is not matched to control patients and that no data will be provided for SG.\(^18\)

Even when antidiabetes treatment was not discontinued in our study, it was often simplified. Six years after bariatric surgery, 40.0% of patients using insulin at baseline had switched to another treatment, and 57.0% of patients receiving dual therapy had switched to monotherapy or no antidiabetes treatment (Figure 2A).

Few studies have assessed the incidence of diabetes after bariatric surgery compared with control patients. Two studies, one in which surgery mostly consisted of vertical banded gastroplasty\(^22\) and another based on short follow-up (median, 2.8 years),\(^23\) reported an incidence of diabetes after bariatric surgery of less than 1% and 4.3%, respectively. In our study, the incidence of diabetes after bariatric surgery based on treatment initiation was 1.4% at 6 years, which is much lower than the rate observed in our matched control patients (12.0%), with a greater association of GBP and SG than AGB. Our findings support the hypothesis that the benefits of bariatric surgery persist many years after the procedure.

Other predictive factors for antidiabetes treatment discontinuation or initiation were also identified. As expected, the intensity of treatment at baseline (insulin use or dual therapy without insulin) and older age were the 2 major factors limiting the probability of discontinuation, while patients with antidepressant or lipid-lowering treatment at baseline were also less likely to discontinue antidiabetes treatment. Recent studies\(^33,34\) have focused on the relationship between depression and diabetes distress.
Table 2. Multivariable Analysis of Predictive Factors for Discontinuation of Antidiabetes Treatment Over 6 Years (2009-2015) in a Cohort of Patients With Antidiabetes Treatment at Baseline, SNIIRAM Data for 3266 Patients Overall

<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of procedure and years of follow-up</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AGB vs control at 3 y</td>
<td>11.8 (8.0-17.3)</td>
<td></td>
</tr>
<tr>
<td>SG vs control at 3 y</td>
<td>10.0 (7.3-13.7)</td>
<td></td>
</tr>
<tr>
<td>GBP vs control at 3 y</td>
<td>36.1 (27.3-47.7)</td>
<td></td>
</tr>
<tr>
<td>AGB vs control at 6 y</td>
<td>4.3 (3.3-5.6)</td>
<td></td>
</tr>
<tr>
<td>SG vs control at 6 y</td>
<td>7.3 (5.5-9.5)</td>
<td></td>
</tr>
<tr>
<td>GBP vs control at 6 y</td>
<td>16.7 (13.0-21.4)</td>
<td></td>
</tr>
<tr>
<td>Antidiabetes treatment</td>
<td>Dual or triple therapy (without insulin) vs monotherapy (without insulin)</td>
<td>0.38 (0.32-0.45)</td>
</tr>
<tr>
<td></td>
<td>Insulin use vs monotherapy (without insulin)</td>
<td>0.17 (0.13-0.22)</td>
</tr>
<tr>
<td>Age</td>
<td>1-y Unit increase</td>
<td>0.96 (0.95-0.97)</td>
</tr>
<tr>
<td>Antidepressant treatment</td>
<td>Yes vs no</td>
<td>0.67 (0.55-0.81)</td>
</tr>
<tr>
<td>Lipid-lowering treatment</td>
<td>Yes vs no</td>
<td>0.76 (0.63-0.91)</td>
</tr>
</tbody>
</table>

Abbreviations: AGB, adjustable gastric banding; GBP, gastric bypass; OR, odds ratio; SG, sleeve gastrectomy; SNIIRAM, Système National d’Information Inter-régimes de l’Assurance Maladie.

a An interaction (P < .001) was found between the type of procedure and the year of follow-up. Therefore, outcomes of mixed models are provided for 3 years and 6 years of follow-up.

b Adjusted for sex, body mass index (calculated as weight in kilograms divided by height in meters squared) category, and precarious.

Strengths and Limitations

The main strength of our study is that it was based on the nationwide, comprehensive inpatient and outpatient SNIIRAM database, with more than 15,000 bariatric surgery patients, compared with control patients. This is the largest population-based study to report the long-term course of antidiabetes treatment after bariatric surgery compared with control patients. In France, information on treatment is comprehensively collected for all reimbursed drugs. Patients are identified by their personal smart card and only have to pay a co-payment for each drug dispensed, and remote data transmission to the French national health insurance network is performed by pharmacists on a daily basis. The costs of antidiabetes treatment, as well as laboratory tests and consultations with a physician, are reimbursed, including for low-income patients, for whom co-payment is waived. Therefore, access to health care for patients undergoing bariatric surgery should not constitute a limitation to receiving appropriate care during follow-up, except when patients consider that they do not require and thus do not seek medical care. While the number of patients lost to follow-up after bariatric surgery is a critical point for other studies, as well as during medical care, our use of an extensive national database largely eliminates this bias. The only individuals excluded from the study population were those who were out of the country or those who did not seek medical care, in whom diabetes status could not be assessed.

The major limitation of our study is that some important data were not available, such as weight loss, results of laboratory tests, or duration of type 2 diabetes at baseline, which can all influence the treatment discontinuation rate. Therefore, we used treatment as a marker of type 2 diabetes, while other large studies with shorter follow-up and smaller sample sizes may have also included laboratory test results, such as glycated hemoglobin level. Long-term antidiabetes treatment discontinuation rates could be overestimated in our study and influenced by poor treatment adherence because patients who have undergone bariatric surgery may not seek further medical follow-up. This type of bias related to patients lost to follow-up is also present in other investigations, explaining why few studies report long-term results after bariatric surgery. Finally, 226 patients who died during follow-up were excluded from our study.

Another limitation is that our control group was composed of hospitalized patients with obesity because BMI is only reported in the database when patients are hospitalized. The control group was matched with cases based on age, sex, BMI category, and antidiabetes treatment. It differed from the bariatric surgery group, with more frequent coexisting conditions, such as antihypertensive, lipid-lowering, anxiolytic, and opioid treatments, as well as insulin use (despite being matched on existing antidiabetes treatment) and less frequent treatment (which is likely due to systematic screening before bariatric surgery) for obstructive sleep apnea syndrome, leading to a potential bias that controls could have had a higher risk of obesity-related complications than cases. However, other case-matched studies published in the literature were also based on unbalanced groups at baseline. Despite these limitations, our study reflects the real-life and health care courses of patients undergoing bariatric surgery compared with control patients matched on age, sex, BMI category, and antidiabetes treatment.

Conclusions

This large-scale nationwide study based on health care reimbursement data found significant improvement in the
frequency and complexity of antidiabetes treatment 6 years after bariatric surgery, with a marked association for patients undergoing GBP. In parallel, we demonstrated a low rate of antidiabetes treatment initiation 6 years after bariatric surgery. However, patients and physicians should be aware that morbid obesity remains a chronic disease even after bariatric surgery because 50.1% of patients with preexisting antidiabetes treatment remained on treatment 6 years after surgery. Our study highlights the message that these patients require careful lifelong follow-up to monitor obesity complications.

ARTICLE INFORMATION

Accepted for Publication: November 5, 2017.
Published Online: February 14, 2018.

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Conflict of Interest Disclosures: None reported.

REFERENCES


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Invited Commentary

Toward a National Surgical Strategy for Type 2 Diabetes Resolution Can We Do Better?

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In a study of more than 30 000 adults in France published in this issue of JAMA Surgery, Thereaux et al1 observed that bariatric surgery was associated with a significantly higher antidiabetic treatment discontinuation rate 6 years after surgery (50%) compared with the discontinuation rate in a control group of patients with obesity (9%), with gastric bypass being the most effective procedure. Beyond the usual and obvious dangers of interpreting data from an administrative database, this analysis lacks a defined criteria for type 2 diabetes and weight loss; however, it confirms other analyses, such as those resulting from the Swedish Obesity Study.2 A small percentage of patients with type 2 diabetes receive bariatric surgery in France (1%); in the United States, this percentage is less than 30%.3 Moreover, it remains to be seen if French surgeons will do Roux-en-Y gastric bypass for every French citizen that requires bariatric surgery (and has

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