ORIGINAL ARTICLE

Medication Utilization and Annual Health Care Costs in Patients With Type 2 Diabetes Mellitus Before and After Bariatric Surgery

Martin A. Makary, MD, MPH; Jeanne M. Clarke, MD; Andrew D. Shore, PhD; Thomas H. Magnuson, MD; Thomas Richards, MS; Eric B. Bass, MD; Francesca Dominici, PhD; Jonathan P. Weiner, DrPH; Albert W. Wu, MD, MPH; Jodi B. Segal, MD, MPH

Objective: To examine the relationship of bariatric surgery with the use of diabetes medications and with total health care costs in patients with type 2 diabetes mellitus.

Design: We studied 2235 adults with type 2 diabetes and commercial health insurance who underwent bariatric surgery in the United States during a 4-year period from January 1, 2002, through December 31, 2005. We used administrative claims data to measure the use of diabetes medications at specified time intervals before and after surgery and total median health care costs per year.

Setting: Seven states in the Blue Cross/Blue Shield Obesity Care Collaborative.

Patients: Two thousand two hundred thirty-five patients with type 2 diabetes mellitus who underwent bariatric surgery.

Results: Surgery was associated with elimination of diabetes medication therapy in 1669 of 2235 patients (74.7%) at 6 months, 1489 of 1847 (80.6%) at 1 year, and 906 of 1072 (84.5%) at 2 years after surgery. Reduction of use was observed in all classes of diabetes medications. The median cost of the surgical procedure and hospitalization was $29 959. In the 3 years following surgery, total annual health care costs per person increased by 9.7% ($616) in year 1 but then decreased by 34.2% ($2179) in year 2 and by 70.5% ($4498) in year 3 compared with a preoperative annual cost of $6376 observed from 1 to 2 years before surgery.

Conclusions: Bariatric surgery is associated with reductions in the use of medication and in overall health care costs in patients with type 2 diabetes. Health insurance should cover bariatric surgery because of its health and cost benefits.

Arch Surg. 2010;145(8):726-731

Author Affiliations:
Departments of Health Policy and Management (Drs Makary, Shore, Weiner, and Wu and Mr Richards) and Biostatistics (Dr Dominici), Johns Hopkins Bloomberg School of Public Health, and Departments of Surgery (Drs Makary and Magnuson) and Medicine (Drs Clarke, Bass, Wu, and Segal), The Johns Hopkins University School of Medicine, Baltimore, Maryland.

THE RAPIDLY GROWING EPIdemics of obesity and diabetes threaten to overburden the world's health care systems.[1,2] From an epidemiological standpoint, once these diseases develop they are rarely reversed. Dietary, pharmaceutical, and behavior treatments for obesity are associated with high failure rates, and medical management of diabetes is also often unsuccessful.[3,4] Despite many efforts to improve the control of glucose levels in diabetes, including clinical guidelines and patient and provider education, less than half of all patients with type 2 diabetes mellitus achieve the American Diabetes Association recommendation of a hemoglobin A_{1c} level of less than 7%.[5]

Bariatric surgery results in long-term weight loss, improved lifestyle,[6] and decreased mortality.[7] The use of this intervention has increased 200% during the past 5 years, but studies of its effect on type 2 diabetes and costs are limited.[6,8,9] Our objective was to determine the impact of bariatric surgery on the use of diabetes medication and on total health care costs.

METHODS

We performed a retrospective time-series study of patients in 7 Blue Cross/Blue Shield health care plans who underwent bariatric surgery and who had evidence of preoperative diabetes based on medication use. We compared their diabetes medication use and annualized total health care costs at specified time intervals during the preoperative and postoperative periods. The data in this study were deidentified in accordance with the Health Insurance Portability and Accountability Act definition of a limited data set and were used in accordance with federal standards protecting the confidentiality of personal health information of enrollees.

STUDY POPULATION

We used the insurance claims of 15.9 million people covered by Blue Cross/Blue Shield health care plans in Pennsylvania, South Dakota, Hawaii, Iowa, Michigan, North Carolina, and Ten-

nessee as a part of the Blue Cross/Blue Shield Obesity Care Collaborative. The data set includes age, sex, enrollment dates, and longitudinal data of all claims for reimbursement for billable health care services for the duration of coverage and during the study period from January 1, 2002, through December 31, 2005. Included in these data are patient diagnoses as identified by *International Classification of Diseases, Ninth Revision* codes and medical procedures using several classification systems, including *Current Procedural Terminology* codes. We also obtained these patients' prescription drug claims, including the drug name, the prescription fill date, and the number of days' supply provided. We identified a sample of patients aged 18 to 64 years who had medical and pharmacy insurance coverage for at least 6 months before and 6 months after bariatric surgery and who had preoperative diabetes based on the presence of a claim for an active diabetes medication prescription that was filled at 3 time points within the 6 months before bariatric surgery (at 6 and 3 months before surgery and on the day of surgical admission). From the remaining cohort, we excluded 18 patients with polycystic ovarian disease who were taking metformin hydrochloride as the only diabetes medication and had no diagnosis code for diabetes because they were probably not diabetic and another 51 patients with a bowel procedure code and a diagnosis of an esophageal, gastric, small-bowel, pancreatic, or other digestive malignant neoplasm.

Our main outcomes were overall health care cost and use of diabetes medications at specified postoperative time points. Total direct health care costs were defined as the total payout by the insurer for health care claims. This cost included hospitalizations, procedures, medications, outpatient visits, consultations, and other payments made by the insurer.

Diabetes medications were classified as insulin, sulfonylureas, metformin, α-glucosidase inhibitors, thiazolidinediones, or meglitinides. Medication was considered to be present at a specified time point if a 30-, 60-, or 90-day prescription was filled 30, 60, or 90 days, respectively, before the prespecified points of interest. We studied the use of diabetes medication at 3 and 6 months before surgery, at the time of surgery, and at 3, 6, 9, 12, 24, and 36 months after surgery. Results were stratified by type of bariatric procedure. To describe the overall safety and complication rate of bariatric surgery, we used crude rates of postoperative in-hospital mortality.

STATISTICAL ANALYSIS

We report descriptive statistics for the number of patients taking any diabetes medication and the percentage of patients not taking medication, by class and overall. To explore the effect of age, sex, comorbidity, and type of bariatric operation on the discontinuation of diabetes medication therapy after surgery, we performed a bivariate analysis followed by a multivariate logistic regression of these variables.

Postoperative costs were compared with preoperative costs, and the difference and percentage of change were calculated. Costs are reported as median annualized costs per patient. To approximate baseline annual costs in this patient population before surgery and to minimize the confounding effect of preoperative workup costs, we compared the costs in the time period from 2 years to 1 year before surgery with annual costs at 1, 2, and 3 years after surgery. All statistical analyses were performed using commercially available software (SAS, version 9.1; SAS Institute Inc, Cary, North Carolina).

RESULTS

We identified the claims for 2235 patients who underwent bariatric surgery and had preoperative diabetes. The study population included individuals with varying lengths of continuous enrollment with the same Blue Cross/Blue Shield insurance plan. The mean length of enrollment was 2.1 years per person, and a total of 5566 person-years were observed in the analysis. Mean age was 48.4 years, and 74.5% of the patients were women (**Table 1**). Follow-up claims data were available for 1847 patients at 1 year, for 1072 patients at 2 years, and for 288 patients at 3 years.

Table 1. Characteristics of 2235 Patients

Characteristic	Data
Mean age, y	48.4
Female sex, %	74.5
Type of operation, %	
Roux-en-Y gastric bypass	84.2
Laparoscopic banding	0.7
Vertical-banded gastroplasty	0.9
Biliopancreatic diversion	0.4
Other[a]	13.8
Median observation period per person, y	2.1
Total time studied, person-years	5566
Mean No. of preoperative comorbid conditions	3.5

[a] Includes gastric restrictive and malabsorption procedures.

Among the 2235 patients who underwent bariatric surgery and who also had preoperative diabetes, 1918 (85.8%) were taking at least 1 diabetes medication 3 months before surgery, with a mean of 4.4 diabetes medications per patient (**Table 2**). After surgery, the use of any diabetes medication at 6 months and 1 and 2 years had decreased to 25.3%, 19.4%, and 15.5%, respectively (Table 2). Follow-up data on 288 patients at 3 years after surgery revealed that only 13.9% continued to use a diabetes medication.

Insulin was used by 550 of 2235 patients (24.6%) 3 months before surgery and by 101 of 1847 (5.5%) 1 year after surgery. Similar reductions were observed for all 6 classes of diabetes medication (**Figure**). The greatest decrease occurred with metformin, with 1182 of 2235 patients (52.9%) taking metformin 3 months before surgery and 156 of 1847 (8.4%) taking it 1 year after surgery. Overall, bariatric surgery was associated with complete elimination of diabetes medication use in 1669 of 2235 patients (74.7%) at 6 months, 1489 of 1847 (80.6%) at 1 year, and 906 of 1072 (84.5%) at 2 years after surgery (Table 2). Younger age, male sex, and Roux-en-Y gastric bypass were all independently associated with cessation of the use of diabetes medications (**Table 3**). Conversely, patients who used multiple diabetes medications preoperatively or who had diabetes complications were less likely to discontinue diabetes medication therapy after surgery.

Overall in-hospital mortality was 0.3%. Hospital readmission occurred in 7.5% of patients within 30 days and in 21.2% of patients within 1 year of bariatric surgery.

The median cost for the surgical procedure and hospitalization was $29 959. Compared with the baseline annual cost of $6376 per person, total annual health care costs in the first 3 years after surgery increased by 9.7% ($616) in year 1 but then decreased by 34.2% ($2179) in year 2 and by 70.5% ($4498) in year 3 (**Table 4**).

Table 2. Use of Diabetes Medication Before and After Bariatric Surgery

Medication Used	Preoperative Period, mo			Postoperative Period, mo					
	–6 (n=2235)	–3 (n=2235)	0 (n=2235)	3 (n=2235)	6 (n=2235)	9 (n=2032)	12 (n=1847)	24 (n=1072)	36 (n=288)
Any diabetes medication									
No. (%) of patients	1817 (81.3)	1918 (85.8)	1866 (83.5)	728 (32.6)	566 (25.3)	446 (21.9)	358 (19.4)	166 (15.5)	40 (13.9)
Mean No. of any medication class per patient	4.3	4.4	5.3	1.3	1.1	0.9	0.8	0.7	0.5
Medication by class, No. (%) of patients									
Metformin hydrochloride	1129 (50.5)	1182 (52.9)	1124 (50.3)	286 (12.8)	218 (9.8)	192 (9.4)	156 (8.4)	76 (7.1)	18 (6.2)
Thiazolidinediones	820 (36.7)	857 (38.3)	772 (34.5)	266 (11.9)	201 (9.0)	161 (7.9)	122 (6.6)	60 (5.6)	14 (4.9)
Sulfonylureas	728 (32.6)	759 (34.0)	724 (32.4)	194 (8.7)	117 (5.2)	88 (4.3)	75 (4.1)	32 (3.0)	6 (2.1)
Insulin	524 (23.4)	550 (24.6)	609 (27.2)	247 (11.1)	187 (8.4)	132 (6.5)	101 (5.5)	43 (4.0)	12 (4.2)
Meglitinides	64 (2.9)	65 (2.9)	70 (3.1)	17 (0.8)	13 (0.6)	9 (0.4)	9 (0.5)	4 (0.4)	1 (0.3)
α-Glucosidase inhibitors	14 (0.6)	15 (0.7)	13 (0.6)	2 (0.09)	1 (0.04)	1 (0.05)	1 (0.05)	1 (0.09)	0

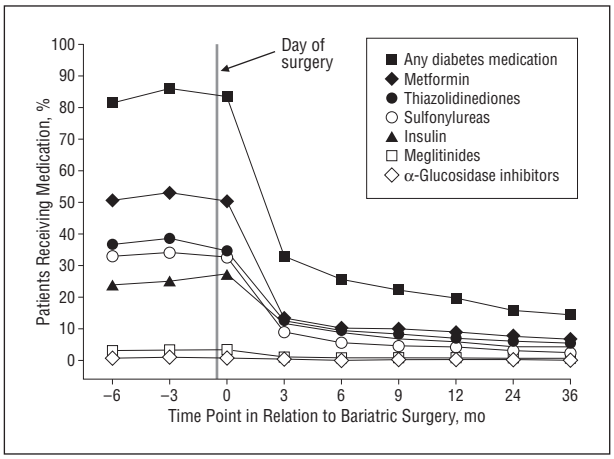

Figure. Use of diabetes medication before and after bariatric surgery.

COMMENT

In this large national study of insured patients with obesity and type 2 diabetes mellitus, bariatric surgery was associated with subsequent independence from type 2 diabetes medications in most of the patients and reduced annual health care costs within 2 years after the procedure. The data source for this study is unique in that the data represented actual use of medication (ie, medication prescriptions filled at a pharmacy) and total payment dollars for medical costs (ie, dollar expenditures). This report, to our knowledge, provides the first description of changes in annual health expenses using direct insurance payments instead of indirect cost-to-charge estimates based on hospital charges. We believe that the reductions in overall annual health care costs realized represents the improved health associated with successful therapy for obesity and type 2 diabetes.

Improvement in diabetes after bariatric surgery has been reported in limited case series.[10-12] Buchwald et al[9] reviewed published reports in 2004 and observed an overall resolution of diabetes in 76.8% of patients after bariatric surgery. In addition, in a series of patients described by Pories et al,[13] 84% of patients had resolution of their type 2 diabetes at 1 year after the operation. Our findings corroborate the observations previously reported from single institutions. However, in general, the studies were based on selected groups at single institutions (publication bias) or had incomplete postoperative follow-up.

Most recently, in a study of 60 patients randomized to conventional diabetes management vs gastric banding, Dixon et al[14] found that patients who received surgical therapy were more likely to achieve remission of type 2 diabetes and that this effect was associated with greater weight loss. These findings confirm those from a previously reported trial of bariatric surgery in which MacDonald et al[15] compared 154 patients treated with Roux-en-Y gastric bypass with a body mass index–matched control group who did not undergo surgery. The study found that use of oral diabetes medications decreased in the surgery group from 32% to 8%, whereas use in the control group increased from 56% to 87%. We found an improved long-term mortality rate in the bariatric surgery group compared with the nonsurgical group (9% vs 28%) despite longer follow-up in the bariatric surgery group (mean follow-up, 9.0 vs 6.2 years). Furthermore, the resolution of type 2 diabetes was sustained at 1 and 2 years after surgery. Because weight loss following bariatric surgery has been observed to be sustained for decades, we believe that the protective effect against complications of diabetes is also likely to be long-term. This extrapolation is supported by a report of long-term follow-up of 163 patients with type 2 diabetes mellitus from a single institution in which 95% of patients retained control of glucose levels 10 years after surgery.[16]

We observed that independence from diabetes medication was almost immediate within the initial months after surgery and did not correlate with the gradual weight loss expected. This supports the theory that the resolution of diabetes is not due to weight loss alone but is also mediated by gastric hormones,[12] with the 3 most implicated being peptide YY, glucagonlike peptide, and pancreatic polypeptide. As a known mediator of insulin regulation, glucagonlike peptide levels have been noted to increase immediately after bariatric surgery and may explain why surgeons have noted complete resolution of diabetes in some cases within days after surgery.[17]

We also found a greater effect of medication discontinuation following the Roux-en-Y gastric bypass proce-

Table 3. Factors Associated With Discontinuation of Diabetes Medication Therapy

	Univariate Analysis		Multivariate Analysis	
	OR (CI)	*P* Value	OR (CI)	*P* Value
Age, y[a]				
18-34	4.32 (2.97-6.29)	<.001	2.93 (1.98-4.35)	<.001
35-44	2.57 (2.02-3.28)	<.001	2.20 (1.70-2.86)	<.001
45-54	1.78 (1.44-2.19)	<.001	1.76 (1.42-2.20)	<.001
Male sex	1.02 (0.84-1.23)	.88	1.27 (1.03-1.57)	.03
Gastric bypass procedure[b]	1.42 (1.13-1.78)	.003	1.63 (1.27-2.09)	<.001
No. of diabetes medications[c]				
1	6.02 (4.73-7.65)	<.001	5.59 (4.36-7.17)	<.001
2	2.23 (1.76-2.84)	<.001	2.24 (1.75-2.86)	<.001
No diabetes complications	1.77 (1.45-2.18)	<.001	1.45 (1.16-1.81)	<.001

Abbreviations: CI, confidence interval; OR, odds ratio.
[a] Relative to ages 55 to 64 years.
[b] Relative to other bariatric procedures including gastric banding and other restrictive procedures.
[c] Relative to patients using 3 or more medications.

dure compared with banding and other restrictive procedures. This finding stands contrary to current thought based on the largest published study in which Parikh et al[18] concluded from a personal series that, although a banding procedure was associated with less weight loss, the procedure type did not affect the resolution of diabetes.

Finally, we observed that bariatric surgery is safe in the large insured population studied. Complication rates are increased for any surgical procedure in an obese patient, but we report that the in-hospital mortality rate was low (0.3%), and the observed 1-year hospital readmission rate of 21% is consistent with other reports.[19]

PUBLIC HEALTH IMPLICATIONS

It is estimated that 1.1 billion people in the world are overweight and 312 million are obese.[20,21] The World Health Organization projects that the number of people with diabetes will rise from 171 million in the year 2000 to 366 million by 2030, with the greatest increase noted in people older than 65 years.[22] Even more alarming are reports that obesity is increasing more rapidly in low socioeconomic-status populations, rivaled only by the dawning of a new era of childhood obesity.[23] Most concerning are the deferred health consequences and costs associated with obesity, auguring the presentation of complications decades into the future. Current trends in rates of obesity and diabetes threaten to overwhelm the already strained health care resources in many countries. Diabetes is but one of several health consequences of the escalating global obesity epidemic, with heart disease, hypertension, hyperlipemia, degenerative joint disease, and decreased activity further compounding the complications and disability associated with diabetes. Thus the obesity epidemic has created a deferred influx of demand for diabetes-related health care services not yet realized. Until a successful nonsurgical means for preventing and reversing obesity is developed, bariatric surgery appears to be the only intervention that can result in a sustained reversal of both obesity and type 2 diabetes mellitus in most patients receiving it.

Increased health care costs in the United States have been partly attributed to the growing prevalence of diabetes and obesity.[24] This cost is seen in direct medical costs, in the indirect costs of decreased productivity and disability, and in the costs of obesity and diabetes-related complications such as renal failure, gestational diabetes, and cardiac disease. Thus, the current report has implications not only for disease management but also for public health and health care policy.

Table 4. Annual Health Care Utilization Cost Before and After Bariatric Surgery

Time Relative to Surgery	No. of Patients	Standardized Median Cost per Person, $
Before surgery		
−2 to −1 y	1163	6376
−1 to 0 y	1947	10 592
Surgical admission[a]	2235	29 959
After surgery		
First year postoperatively	1847	6992
+1 to +2 y	1072	4197
+2 to +3 y	288	1878

[a] Index date used to determine the number of full years before and after surgery.

LIMITATIONS

This study has several important limitations. The patients studied are covered by Blue Cross/Blue Shield health care plans, and the conclusions may not be directly generalizable to uninsured patients, patients with limited coverage, or patients in other health care plans. However, we believe that the patients studied are a reasonable sample of patients undergoing bariatric surgery in the United States at present. Although we had good longitudinal data that are comprehensive during enrollment, limited variables were available. For example, we do not know the impact of bariatric surgery stratified by body mass index. In addition, owing to the high turnover that is characteristic of health insurance coverage in the United States, 3-year follow-up data were available for a limited number of patients. Nonetheless, the results for these pa-

tients were consistent with the trend observed 1 and 2 years after surgery for the larger cohort. Furthermore, we have no reason to believe that switching private insurance (ie, being unavailable for follow-up in this analysis) would be associated with an enrollee being more likely to have a better or worse outcome than someone who maintained continuous insurance coverage. We also recognize the limitations of using claims data to include and exclude patients, such as excluding patients with polycystic ovarian disease who were taking metformin. However, given the small fraction of patients taking only metformin, this group, if underappreciated, would not influence our results significantly. Finally, we used the assumption that most patients undergoing bariatric surgery lose weight because this effect has been clinically validated. However, it is possible that patients who did not have resolution of obesity did have an improvement in their diabetes owing to caloric restriction.

FUTURE DIRECTIONS

Further research is needed to evaluate the impact of weight loss on preventing acute and chronic diseases. Bariatric surgery may serve a protective effect in preventing obstetric and gynecological complications, such as gestational diabetes and poor fetal outcomes. In addition, the weight loss experienced may prevent, stabilize, or improve obesity-related conditions, such as urinary incontinence and osteoarthritis. Considerations such as these, which are measurable, can help quantify the associated preventable harm and cost to patients and society.

Bariatric surgery may also decrease complications after other surgical procedures (ie, orthopedic procedures); further research is needed to examine the impact of bariatric surgery on the success of these procedures after weight loss. It is possible that complications following many common surgical operations could be reduced if the patients were less obese. This hypothesis may also have implications for cancer surgery and cancer care. In addition, future studies may show that bariatric surgery can reduce cancer risk associated with obesity.

CONCLUSIONS

Bariatric surgery is associated with a significant reduction in medication-dependent type 2 diabetes with little risk. Obese patients with type 2 diabetes mellitus should be counseled regarding the potential benefits of bariatric surgery for the treatment of both obesity and diabetes compared with other options. Based on these data, we have identified several important implications for health care delivery and public policy. Foremost, eligible obese patients should be properly informed of the risks and benefits of bariatric surgery compared with nonsurgical health management. Health care providers should consider discussing bariatric surgery in the treatment of obese patients with type 2 diabetes.

Health insurers, private and public, should pay for bariatric surgery for appropriate candidates, recognizing a potential annualized cost savings in addition to the benefit to health. Bariatric surgery centers should be supported in providing excellence in outcomes through regular means of standardization and quality improvement. Coverage of bariatric surgery should be available to all obese patients who meet criteria regardless of their degree of coverage provided the patient possesses the appropriate degree of personal health responsibility and access to a physician in the event of a surgical complication.

In the current system, patients with Medicaid do not have equal and uniform access to bariatric surgery. In most states, enrollees are not given the certainty of coverage they need to proceed with such a potentially expensive endeavor. This disparity results in some obese patients with diabetes having limited access to the procedure and, as a result, suboptimal management of diabetes in some cases. Medicaid should provide assured and appropriate medical coverage to obese patients with diabetes who meet standard criteria and in whom medical management fails.

Future research may help elucidate the role of bariatric surgery in general medical care by studying its effect on common operations, maternal and neonatal outcomes, and long-term health outcomes. Ultimately, bariatric surgery—or a future less-invasive variant—could play a key role in the management of common medical conditions, such as heart disease and diabetes-related organ failure.

Accepted for Publication: January 13, 2010.
Correspondence: Martin A. Makary, MD, MPH, Department of Surgery, The Johns Hopkins University School of Medicine, Cancer Research Bldg II, Ste 507, 1550 Orleans St, Baltimore, MD 21231 (kos@jhmi.edu).
Author Contributions: All investigators had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design:* Makary, Clarke, Shore, Magnuson, Bass, Dominici, Weiner, Wu, and Segal. *Acquisition of data:* Clarke, Shore, Magnuson, Richards, Weiner, and Wu. *Analysis and interpretation of data:* Makary, Clarke, Shore, Magnuson, Richards, Bass, Dominici, Weiner, Wu, and Segal. *Drafting of the manuscript:* Makary, Shore, Magnuson, Richards, and Wu. *Critical revision of the manuscript for important intellectual content*: Makary, Clarke, Magnuson, Richards, Bass, Dominici, Weiner, Wu, and Segal. *Statistical analysis:* Shore, Magnuson, Richards, Dominici, Wu, and Segal. *Obtained funding:* Makary, Clarke, Bass, Wu, and Segal. *Administrative, technical, and material support:* Clarke, Shore, Richards, Weiner, and Wu. *Study supervision:* Makary, Magnuson, and Wu.
Financial Disclosure: None reported.
Funding/Support: This study was supported under contract HHSA290-05-0034-1-TO2-WA2 (project 20-EHC-2) from the Agency for Healthcare Research and Quality (Johns Hopkins University Developing Evidence to Inform Decisions About Effectiveness Center). The data set used in the present study was originally created for a different research project on patterns of obesity care within selected Blue Cross/Blue Shield (BCBS) plans, which was supported by unrestricted research grants from Ethicon Endo-Surgery, Inc (a Johnson & Johnson company); Pfizer, Inc; and GlaxoSmithKline. The data and in-kind database development support and guidance were provided by the BCBS Obesity Care Collaborative, which consists of the following organizations af-

filiated with the BCBS Health Services Research Alliance: BCBS Association, BCBS of Tennessee, BCBS of Hawaii, BCBS of Michigan, BCBS of North Carolina, Highmark, Inc, of Pennsylvania, Independence Blue Cross of Pennsylvania, Wellmark BCBS of Iowa, and Wellmark BCBS of South Dakota. Additional funding was provided by The Mr. and Mrs. Chad and Nissa Richison Foundation.

Role of the Sponsors: No statement may be construed as the official position of the Agency for Healthcare Research and Quality of the US Department of Health and Human Services.

Additional Contributions: Renee Wilson, MSc, helped with the preparation of the manuscript.

REFERENCES

1. Zimmet P, Alberti KG, Shaw J. Global and societal implications of the diabetes epidemic. *Nature*. 2001;414(6865):782-787.
2. Leibson CL, Williamson DF, Melton LJ III, et al. Temporal trends in BMI among adults with diabetes. *Diabetes Care*. 2001;24(9):1584-1589.
3. Norris SL, Zhang X, Avenell A, et al. Long-term effectiveness of lifestyle and behavioral weight loss interventions in adults with type 2 diabetes: a meta-analysis. *Am J Med*. 2004;117(10):762-774.
4. Ferchak CV, Meneghini LF. Obesity, bariatric surgery and type 2 diabetes—a systematic review. *Diabetes Metab Res Rev*. 2004;20(6):438-445.
5. Saaddine JB, Engelgau MM, Beckles GL, Gregg EW, Thompson TJ, Narayan KM. A diabetes report card for the United States: quality of care in the 1990s. *Ann Intern Med*. 2002;136(8):565-574.
6. Sjöström L, Lindroos AK, Peltonen M, et al; Swedish Obese Subjects Study Scientific Group. Lifestyle, diabetes, and cardiovascular risk factors 10 years after bariatric surgery. *N Engl J Med*. 2004;351(26):2683-2693.
7. Adams TD, Gress RE, Smith SC, et al. Long-term mortality after gastric bypass surgery. *N Engl J Med*. 2007;357(8):753-761.
8. Kopp HP, Kopp CW, Festa A, et al. Impact of weight loss on inflammatory proteins and their association with the insulin resistance syndrome in morbidly obese patients. *Arterioscler Thromb Vasc Biol*. 2003;23(6):1042-1047.
9. Buchwald H, Avidor Y, Braunwald E, et al. Bariatric surgery: a systematic review and meta-analysis. *JAMA*. 2004;292(14):1724-1737.
10. Torquati A, Lutfi R, Abumrad N, Richards WO. Is Roux-en-Y gastric bypass surgery the most effective treatment for type 2 diabetes mellitus in morbidly obese patients? *J Gastrointest Surg*. 2005;9(8):1112-1118.
11. Cossu ML, Noya G, Tonolo GC, et al. Duodenal switch without gastric resection: results and observations after 6 years. *Obes Surg*. 2004;14(10):1354-1359.
12. Rubino F, Gagner M, Gentileschi P, et al. The early effect of the Roux-en-Y gastric bypass on hormones involved in body weight regulation and glucose metabolism. *Ann Surg*. 2004;240(2):236-242.
13. Pories WJ, Swanson MS, MacDonald KG, et al. Who would have thought it? An operation proves to be the most effective therapy for adult-onset diabetes mellitus. *Ann Surg*. 1995;222(3):339-352.
14. Dixon JB, O'Brien PE, Playfair J, et al. Adjustable gastric banding and conventional therapy for type 2 diabetes: a randomized controlled trial. *JAMA*. 2008;299(3):316-323.
15. MacDonald KG Jr, Long SD, Swanson MS, et al. The gastric bypass operation reduces the progression and mortality of non-insulin-dependent diabetes mellitus. *J Gastrointest Surg*. 1997;1(3):213-220.
16. Pories WJ, MacDonald KG Jr, Morgan EJ, et al. Surgical treatment of obesity and its effect on diabetes: 10-y follow-up. *Am J Clin Nutr*. 1992;55(2)(suppl):582S-585S.
17. le Roux CW, Aylwin SJ, Batterham RL, et al. Gut hormone profiles following bariatric surgery favor an anorectic state, facilitate weight loss, and improve metabolic parameters. *Ann Surg*. 2006;243(1):108-114.
18. Parikh M, Ayoung-Chee P, Romanos E, et al. Comparison of rates of resolution of diabetes mellitus after gastric banding, gastric bypass, and biliopancreatic diversion. *J Am Coll Surg*. 2007;205(5):631-635.
19. Zingmond DS, McGory ML, Ko CY. Hospitalization before and after gastric bypass surgery. *JAMA*. 2005;294(15):1918-1924.
20. Haslam DW, James WP. Obesity. *Lancet*. 2005;366(9492):1197-1209.
21. Hossain P, Kawar B, El Nahas M. Obesity and diabetes in the developing world—a growing challenge. *N Engl J Med*. 2007;356(3):213-215.
22. Wild S, Roglic G, Green A, Sicree R, King H. Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. *Diabetes Care*. 2004;27(5):1047-1053.
23. Fagot-Campagna A, Pettitt DJ, Engelgau MM, et al. Type 2 diabetes among North American children and adolescents: an epidemiologic review and a public health perspective. *J Pediatr*. 2000;136(5):664-672.
24. Brandle M, Zhou H, Smith BR, et al. The direct medical cost of type 2 diabetes. *Diabetes Care*. 2003;26(8):2300-2304.