Original Investigation

Effect of Bariatric Surgery vs Medical Treatment on Type 2 Diabetes in Patients With Body Mass Index Lower Than 35
Five-Year Outcomes

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IMPORTANCE It has been well recognized that metabolic surgery has short-term benefits for mildly obese patients with type 2 diabetes mellitus (T2DM), but how long these effects can be sustained is uncertain.

OBJECTIVE To compare the 5-year efficacy between gastrointestinal metabolic surgery and medical treatment on glycemic control and diabetes remission in patients with T2DM and body mass index (BMI; calculated as weight in kilograms divided by height in meters squared) lower than 35.

DESIGN, SETTING, AND PARTICIPANTS This retrospective cohort study compares long-term outcomes for mildly obese patients with T2DM receiving metabolic surgery (n = 52) vs medical treatment (n = 299). The surgical group, enrolled from August 20, 2007, to June 25, 2008, and followed up through December 31, 2013, received standard sleeve gastrectomy (n = 19) or bypass (n = 33) procedures in a regional hospital. The medical group, selected from a nationwide community cohort that was recruited from August 27, 2003, to December 31, 2005, and followed up through December 31, 2012, was matched with the surgical group by age, BMI, and diabetes duration.

MAIN OUTCOMES AND MEASURES Glycated hemoglobin (HbA_{1c}) reduction and prolonged complete and partial diabetes remission (defined as HbA_{1c} <6.0% and 6.0%-6.5% of total hemoglobin [Hb; to convert to proportion of total Hb, multiply by 0.01], respectively, for those who were exempted from any antidiabetic drugs for 5 years).

RESULTS At the end of the fifth year, the surgical group had a mean weight loss of 21.0% (from a mean [SD] BMI of 31.0 [2.4] to 24.5 [2.7]), their mean (SD) HbA_{1c} decreased from 9.1% (2.1%) to 6.3% (1.1%) of total Hb, 18 participants (36.0%) had complete remission, 14 (28.0%) had partial remission, 1 (1.9%) died, and 1 (1.9%) had end-stage renal disease. In the same follow-up period in the medical group, 3 (1.2%) had complete remission, 4 (1.6%) had partial remission, 9 (3.0%) died, and 2 (0.7%) had end-stage renal disease; their mean HbA_{1c} remained around 8% of total Hb (mean [SD], 8.1% [1.8%] of total Hb at baseline and 8.0% [1.6%] of total Hb at 5 years), and BMI also stayed similar (mean [SD], 29.1 [2.4] at baseline and 28.8 [2.6] at 5 years). The HbA_{1c} reduction and complete and partial remission rates were all significantly larger in the surgical group as compared with the medical group (all $P < .001$). However, the mortality rate and end-stage renal disease incidence were not significantly different in these 2 comparison groups ($P = .66$ and .37, respectively).

CONCLUSIONS AND RELEVANCE For mildly obese patients with T2DM, the improvement in glycemic control from metabolic surgery lasts at least 5 years. However, the survival benefit and lifelong adverse outcomes require more than 5 years to be established.

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Diabetes mellitus is increasing at an alarming rate and has become one of the major causes of mortality and cardiovascular events worldwide.[1,2] However, fewer than half of patients with diabetes are able to maintain the therapeutic goal of a glycated hemoglobin (HbA_{1c}) level lower than 7% of total hemoglobin (Hb; to convert to proportion of total Hb, multiply by 0.01) under currently available medical remedies.[3-5] Those who cannot achieve the therapeutic goal are at very high risk for developing microvascular or macrovascular diabetic complications such as neuropathy, blindness, and end-stage renal disease (ESRD).[6,7] Bariatric surgery has been proven successful in treating type 2 diabetes mellitus (T2DM) in morbidly obese patients (body mass index [BMI; calculated as weight in kilograms divided by height in meters squared] >35).[8-10] Recently, gastrointestinal metabolic surgery has been proposed as a new treatment modality for patients with T2DM who have a BMI lower than 35.[11] Several randomized trials have proven that metabolic surgery has resulted in better glycemic control than medical treatment for these patients.[12-18] Unfortunately, those randomized trials have lacked long-term outcome data. To our knowledge, all related published studies reported their results within 3 years. To be able to evaluate the true effects of metabolic surgery on glycemic control, we need more long-term information on diabetes remission after metabolic surgery in those with BMI lower than 35. The aim of this study was to examine and compare the 5-year efficacy between gastrointestinal metabolic surgery and medical treatment on glycemic control and diabetes remission in patients with T2DM who have a BMI lower than 35.

Methods

Study Design and Participants

Surgical Group

Since 2007, we have run a clinical trial (clinicaltrials.gov identifier NCT00540462) using metabolic surgery to treat patients with T2DM and have prospectively evaluated the outcomes.[19,20] Up to 2013, we have recruited 236 obese patients with T2DM for metabolic surgery, of whom the patients were selected for further analysis in the current study if they met the criteria of T2DM diagnosis (HbA_{1c} >6.5% of total Hb, aged 18-67 years, and BMI <35). The exclusion criteria were the presence of end-organ damage, pregnancy, and previous gastrointestinal surgery. Participants were also excluded if their C-peptide level was lower than 0.9 ng/mL (to convert to nanomoles per liter, multiply by 0.331). As of 2013, 52 patients who received metabolic surgery had completed the 5-year follow-up and were selected for this study. Each participant in the surgical group provided written informed consent. The institutional review board of Min-Sheng General Hospital approved the study of metabolic surgery.

Medical Group

A matched medical group was selected from a prospective diabetes clinical trial, the Diabetes Management Through Integrated Delivery System (DMIDS) project (clinicaltrials.gov identifier NCT00288678). The detailed project protocol has been described elsewhere.[21-23] Briefly, all patients with T2DM receiving medical treatment at the collaborating community clinics were eligible to be recruited to participate in the DMIDS project. The exclusion criteria were being younger than 30 years or older than 70 years, having type 1 diabetes, being pregnant, and having major diabetes complications, including leg amputation, uremia, and major vascular diseases. The DMIDS project recruited 1209 patients from 2003 to 2005; the follow-up was carried out to the end of 2012.[21-23] For each patient in the surgical group, we identified all comparable participants from the DMIDS cohort to form a matched medical group if they had similar age (range, ±3 years), diabetes duration (range, ±3 years), and BMI (range, ±2) at baseline. Each participant in the DMIDS cohort provided written informed consent. The institutional review board of the National Health Research Institutes approved the DMIDS study.

Anthropometric measures (BMI and blood pressure) and blood chemical data (fasting plasma glucose, HbA_{1c}, serum insulin, and lipid profile) in both groups were measured at baseline and annual follow-ups.

Surgical Intervention for the Surgical Group

Among the 52 patients in the surgical group, 2 surgical procedures were performed: laparoscopic sleeve gastrectomy in 19 patients (36.5%) and gastric bypass procedures in 33 patients (63.5%). The surgical team performed standard bariatric procedures and had broad experience in these techniques.[19,24] The type of surgical procedure was decided mainly by the patient's preferences after several interviews and discussions with the multidisciplinary teams. All patients in the surgical group received care under a standard clinical pathway and were regularly followed up at the outpatient clinic by a qualified multidisciplinary team. Patients were advised to take a daily multivitamin tablet as a supplement.

Remission of Diabetes

Participants were followed up and assessed for diabetic state on a yearly basis. Complete remission of T2DM was defined as a fasting glucose level lower than 110 mg/dL (to convert to millimoles per liter, multiply by 0.0555), in addition to an HbA_{1c} level less than 6.0% of total Hb, without use of any oral antidiabetic drugs or insulin.[25] Partial remission was defined as a fasting glucose level between 110 and 126 mg/dL, in addition to an HbA_{1c} level between 6.0% and 6.5% of total Hb, without use of any oral antidiabetic drugs or insulin. We used the Modification of Diet in Renal Disease Study formula to assess the estimated glomerular filtration rate and defined an estimated glomerular filtration rate less than 15 mL/min/1.73 m^2 or undergoing dialysis as ESRD, an adverse renal outcome.[26]

Statistical Analysis

Continuous variables were expressed as mean (standard deviation), while categorical data were expressed as number (percentage). A difference-in-difference method was used to test differences in the changes of anthropometrics, metabolic profiles, use of antidiabetic drugs, and outcomes between baseline and 5-year follow-up in the surgical group and the medical group. The corresponding χ^2 tests and 2-sample *t* tests were conducted for categorical and continuous variables, respectively. All statistical analyses were performed using SPSS version 12.01 statistical software (SPSS Inc). Two-tailed $P < .05$ was considered statistically significant.

Results

Characteristics of Medical and Surgical Groups

Compared with the original DMIDS cohort, the selected medical group was younger (mean [SD] age, 57.5 [8.6] vs 51.2 [6.4] years, respectively), had a higher BMI (mean [SD], 24.8 [3.5] vs 29.1 [2.4], respectively), and had a shorter DM duration (mean [SD], 5.8 [6.0] vs 2.7 [3.2] years, respectively). Compared with their nonselected counterpart, the matched medical group also had better glycemic control at baseline (HbA_{1c}, 8.6% [2.0%] vs 8.1% [1.8%] of total Hb, respectively) and fewer deaths at the end of the fifth year (69 [7.6%] vs 9 [3.0%], respectively) (data not shown).

Table 1 shows differences between the surgical and medical groups. Compared with the medical group, those in the surgical group were female predominant (153 [51.2%] vs 41 [78.8%] female, respectively), were younger (mean [SD], 51.2 [6.4] vs 44.2 [9.5] years, respectively), and had longer DM duration (mean [SD], 2.7 [3.2] vs 5.0 [5.2] years, respectively) (all $P < .001$). They also had higher BMI (mean [SD], 29.1 [2.4] vs 31.0 [2.4], respectively; $P < .001$) and poorer glycemic control (mean [SD] HbA_{1c}, 8.1% [1.8%] vs 9.1% [2.1%] of total Hb, respectively; $P < .001$) at baseline.

Weight Loss, Glycemic Control, and T2DM Remission During Follow-up

The trajectories of HbA_{1c} and BMI change for both groups during the follow-up period are shown in the **Figure**. While kept relatively stable in the medical group, both HbA_{1c} and BMI sustained a significant decline since the sixth month after surgery for the surgical group. Table 1 shows that the mean (SD) BMI in the surgical group was reduced from 31.0 (2.4) at baseline to 24.5 (2.7) at 5 years, which represents an absolute reduction of 6.5 ($P < .001$) and a relative reduction of 21.0%. This indicates a significant improvement compared with the medical group ($P < .001$), whose BMI decreased by 0.3 (1.0%) during the same follow-up period (mean [SD] BMI, 29.1 [2.4] at baseline to 28.8 [2.6] at 5 years; $P = .01$).

For glycemic control, the surgical and medical groups had HbA_{1c} reductions of 2.7% and 0.03% of total Hb, respectively (for surgical vs medical groups, $P < .001$). The mean (SD) HbA_{1c} level in the surgical group decreased from 9.1% (2.1%) of total Hb at baseline to 6.3% (1.1%) of total Hb at the 5-year follow-up ($P < .001$). In the medical group, the mean (SD) HbA_{1c} level was 8.1% (1.8%) of total Hb at baseline and 8.0% (1.6%) of total Hb at the 5-year follow-up ($P = .45$).

In the surgery group, complete remission of T2DM was achieved in 18 patients (36.0%) and partial remission was achieved in another 14 (28.0%) at the end of the fifth year. In the medical group, complete remission was achieved in 3 patients (1.2%) and partial remission was achieved in 4 (1.6%) in the same follow-up. Both the complete and partial remission rates in the surgical group were significantly better than in the medical group ($P < .001$). The fact that more than 60% of the surgical group had at least partial remission of T2DM for 5 years indicates that the surgical group achieved better glycemic control. In regard to other metabolic profiles—including the control of blood pressure, triglycerides, and low-density lipoprotein cholesterol—the performance improvement at the fifth year compared with the corresponding baseline level was generally better in the surgical group than in the medical group (Table 1).

Comparison of Different Operative Procedures

There was no statistical difference in the preoperative characteristics between the sleeve gastrectomy and bypass groups (**Table 2**). There was no difference in the operative time in these 2 groups (mean [SD], 122.6 [32.7] vs 114.7 [35.2] minutes, respectively; $P = .43$), but 2 early surgical complications (6.1%) occurred in the bypass group. At the fifth year, patients in the bypass group compared with the sleeve gastrectomy group lost more weight (mean weight change, −18.7 vs −14.2 kg, respectively; $P = .008$) and achieved a lower BMI (mean BMI change, −7.4 vs −5.1, respectively $P = .001$). Patients who underwent gastric bypass also had better HbA_{1c} reduction than those who underwent sleeve gastrectomy (−3.1% vs −2.1% of total Hb, respectively; $P = .008$) and had a higher complete diabetes remission rate than patients in the sleeve gastrectomy group (complete remission: 15 [46.9%] vs 3 [16.7%], respectively; $P = .03$; partial remission: 7 [21.9%] vs 7 [38.9%], respectively; $P = .20$).

Mortality and ESRD

There was 1 death (1.9%) in the surgical group, with no statistical difference compared with the 9 deaths (3.0%) in the medical group ($P = .66$) (Table 1). The incidences of ESRD for the surgical and medical groups were 1 (1.9%) and 2 (0.7%), respectively ($P = .37$).

Discussion

In this study, we report long-term outcomes for obese patients with T2DM and a BMI lower than 35 who underwent metabolic surgery. Metabolic surgery induced a substantial and sustained weight loss of 21% at the fifth year, with a prolonged complete remission of T2DM in 36% and partial remission in an additional 28%. These results are in accordance with several recent randomized trials with shorter follow-up, indicating that surgical intervention resulted in better glycemic control than medical treatment for mildly obese patients with T2DM.[12-18] This study also demonstrates that this glycemic control in patients with a BMI less than 35 is maintained for more than 5 years as shown in other single-arm studies.[27-29]

However, this study failed to demonstrate a survival benefit of metabolic surgery vs medical treatment at the 5-year follow-up. There are several reasons for lack of survival benefit in the surgical group. First, the follow-up time is still not long enough. According to a previous report of bariatric surgery for morbidly obese patients, a survival benefit could be

Table 1. Differences in Anthropometrics, Metabolic Profiles, Use of Antidiabetic Drugs, and Outcomes Between Baseline and 5-Year Follow-up in the Surgical Group and the Medical Group

Measure	Surgical Group Baseline (n = 52)	Surgical Group 5 y (n = 50)	Surgical Group Difference[a]	Surgical Group *P* Value	Medical Group Baseline (n = 299)	Medical Group 5 y (n = 250)	Medical Group Difference[a]	Medical Group *P* Value	*P* Value[b]
Male, No. (%)	11 (21.2)	...	...	...	146 (48.8)	...	...	...	<.001
Age, mean (SD), y	44.2 (9.5)	...	...	...	51.2 (6.4)	...	...	...	<.001
DM duration, mean (SD), y	5.0 (5.2)	...	...	...	2.7 (3.2)	...	...	...	<.001
Body weight, mean (SD), kg	80.9 (9.4)	63.8 (8.8)	−17.2	<.001	75.8 (9.4)	74.7 (9.9)	−1.1	.002	<.001
BMI									
Mean (SD)	31.0 (2.4)	24.5 (2.7)	−6.5	<.001	29.1 (2.4)	28.8 (2.6)	−0.3	.01	<.001
No. (%)									
<25	1 (1.9)	28 (56.0)	54.1	<.001	5 (1.7)	20 (8.0)	6.3	<.001	<.001
25-26.9	0	13 (26.0)	26.0		52 (17.4)	59 (23.6)	6.2		
27-29.9	12 (23.1)	8 (16.0)	−7.1		134 (44.8)	96 (38.4)	−6.4		
≥30	39 (75.0)	1 (2.0)	−73.0		108 (36.1)	75 (30.0)	−6.1		
Waist circumference, mean (SD), cm	100.9 (9.6)	85.4 (13.5)	−16.8	<.001	93.9 (7.8)	95.3 (8.7)	1.4	.50	.02
Central obesity, No. (%)[c]	41 (78.9)	9 (18.0)	−60.9	<.001	125 (41.8)	108 (44.3)	2.5	.54	<.001
Fasting glucose, mean (SD), mg/dL	187.9 (75.0)	106.3 (29.6)	−83.4	<.001	154.9 (56.1)	159.5 (60.9)	6.7	.17	<.001
HbA_{1c}, % of total Hb									
Mean (SD)	9.1 (2.1)	6.3 (1.1)	−2.7	<.001	8.1 (1.8)	8.0 (1.6)	−0.03	.45	<.001
No. (%)									
<7	13 (25.0)	39 (78.0)	53.0		92 (30.8)	68 (27.2)	−3.6		
7-8.9	19 (36.5)	8 (16.0)	−20.5	<.001	116 (38.8)	120 (48.0)	9.2	.82	<.001
≥9	20 (38.5)	3 (6.0)	−32.5		91 (30.4)	62 (24.8)	−5.6		
BP, mean (SD), mm Hg									
Systolic	130.4 (12.7)	121.3 (18.8)	−9.2	.02	129.9 (15.5)	134.2 (29.1)	5.1	.03	.002
Diastolic	80.5 (9.8)	73.9 (11.2)	−5.1	.006	82.7 (10.1)	80.1 (24.7)	−2.5	.12	.16
Hypertension, No. (%)[d]	11 (21.2)	5 (10.0)	−11.2	.09	74 (24.8)	97 (38.8)	14.0	<.001	.001
TG, mg/dL									
Mean (SD)	226.5 (150.7)	85.7 (35.6)	−142.7	<.001	205.5 (224.2)	166.2 (102.0)	−37.5	.001	<.001
>150, No. (%)	31 (59.6)	1 (2.0)	−57.6	.001	145 (48.5)	120 (48.0)	−0.5	.81	<.001
LDL-C, mg/dL									
Mean (SD)	130.9 (31.4)	102.5 (30.3)	−27.0	<.001	122.3 (33.3)	112.7 (32.5)	−10.0	<.001	.02
>130, No. (%)	16 (30.8)	4 (8.0)	−22.8	.001	113 (37.8)	60 (24.0)	−13.8	<.001	.30
Insulin, mean (SD), μIU/mL	18.6 (24.5)	3.3 (2.1)	−19.0	<.001	13.7 (13.6)	11.1 (13.7)	−2.9	.01	.001
Any antidiabetic drug use, No. (%)	44 (84.6)	10 (20.0)	−64.6	<.001	291 (97.3)	226 (90.4)	−6.9	.001	<.001
Insulin use, No. (%)	8 (15.4)	4 (8.0)	−7.4	.13	2 (0.7)	21 (8.4)	7.7	<.001	.002
Outcomes, No. (%)									
Remission[e]									
Complete	0	18 (36.0)	36.0	<.001	0	3 (1.2)	1.2	.08	<.001
Partial	0	14 (28.0)	28.0	<.001	2 (0.7)	4 (1.6)	0.9	.31	<.001
Mortality	...	1 (1.9)	...	...	...	9 (3.0)	...	...	.66
ESRD[f]	...	1 (1.9)	...	...	...	2 (0.7)	...	...	.37

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); BP, blood pressure; DM, diabetes mellitus; ESRD, end-stage renal disease; Hb, hemoglobin; HbA_{1c}, glycated Hb; LDL-C, low-density lipoprotein cholesterol; TG, triglycerides; ellipses, not applicable.

SI conversion factor: To convert fasting glucose to millimoles per liter, multiply by 0.0555; to convert HbA_{1c} to proportion of total Hb, multiply by 0.01; to convert TG to millimoles per liter, multiply by 0.0113; to convert LDL-C to millimoles per liter, multiply by 0.0259; and to convert insulin to picomoles per liter, multiply by 6.945.

[a] For rows expressed as number (percentage), the difference is given as the difference between percentages.

[b] Indicates the chance to reject the null hypothesis that there is no difference in the change between the surgical group and the medical group.

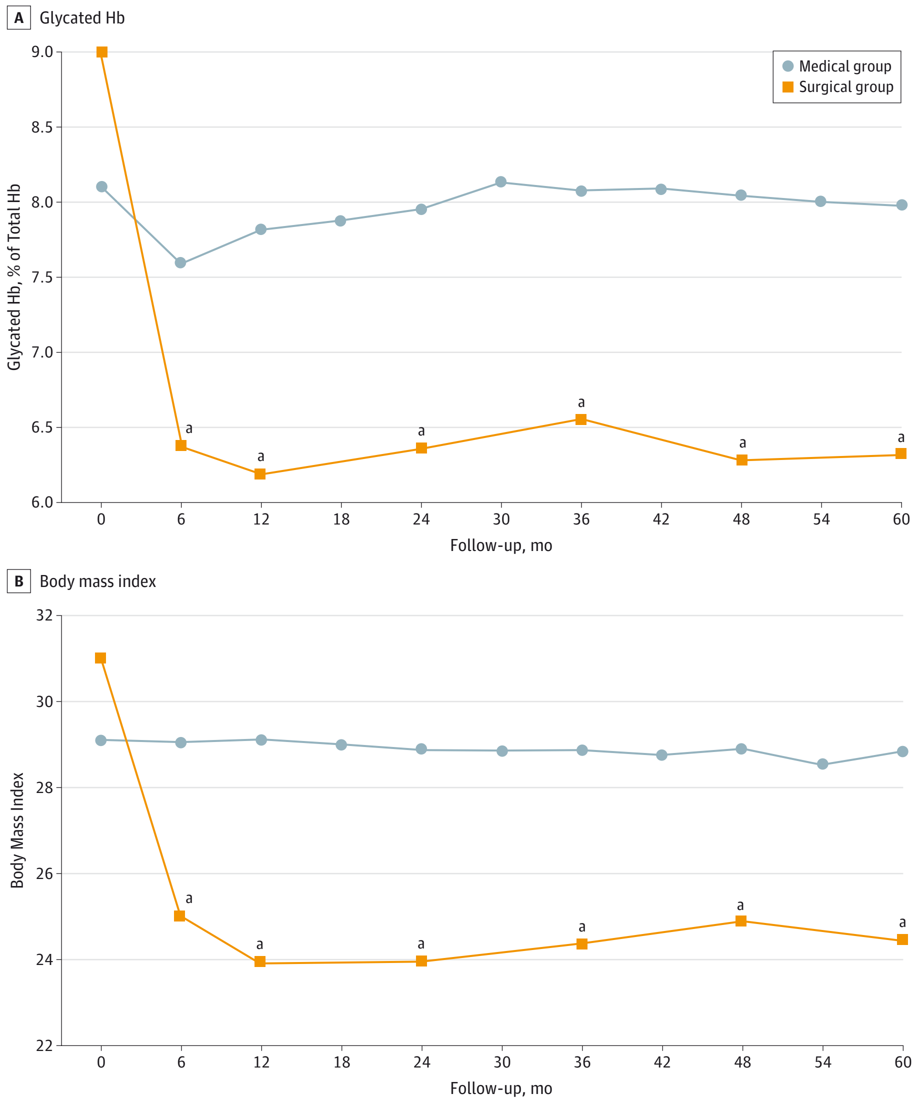
[c] Defined as a waist circumference greater than 102 cm for men and greater than 88 cm for women.

[d] Defined as BP of 140/90 mm Hg or higher.

[e] Complete remission indicates no antidiabetic drug taken and an HbA_{1c} level lower than 6.0% of total Hb; partial remission, no antidiabetic drug taken and an HbA_{1c} level between 6.0% and 6.5% of total Hb.

[f] Indicates that the patient was undergoing dialysis or had an estimated glomerular filtration rate less than 15 mL/min/1.73 m^2.

Figure. Changes in Glycated Hemoglobin (Hb) and Body Mass Index in the Surgical and Medical Groups



Changes in glycated Hb (to convert to proportion of total Hb, multiply by 0.01) (A) and body mass index (calculated as weight in kilograms divided by height in meters squared) (B) over time in the surgical and medical groups of patients with type 2 diabetes mellitus who have a body mass index lower than 35.

[a] $P < .001$ for the comparison between the surgical group and medical group, calculated from a repeated-measures model that considers data over time.

demonstrated only 8 years after surgical intervention and this effect would continually increase with a longer follow-up period.[30] It is possible that a longer follow-up is required for showing a survival advantage in the surgical group. Second, the risks of mortality and major complications may be lower in this selected group of obese patients with T2DM. The obesity paradox has been observed in previous studies, where mild obesity had a protective effect and a lower mortality could be seen in some specific groups such as those with old age, heart disease, and chronic kidney disease.[31,32] In this study, we also observed a lower mortality in our matched medical group compared with other nonselected patients in the DMIDS cohort. The patients with T2DM who were candidates for metabolic surgical treatment are relatively healthy and have a better prognosis than other patients with T2DM. Therefore, a much longer follow-up period may be necessary to demonstrate a survival benefit in the surgically treated patients with T2DM. Third, surgical procedures that induce weight loss lead to better glycemic control than experienced by the medical group but may not translate to better survival. In the Look AHEAD trial, although an intensive lifestyle intervention was associated with better weight reduction and glycemic control, this metabolic improvement did not translate into a reduction of the cardiovascular events in mildly obese patients with T2DM.[33,34]

In this study, gastric bypass surgery established greater weight loss and glycemic control than sleeve gastrectomy. This result agrees with several recent randomized trials with shorter follow-up that found gastric bypass had better glycemic control than sleeve gastrectomy for mildly obese patients with T2DM.[12-18] The superiority of gastric bypass in the treatment of T2DM is possibly related to the mechanism of duodenum exclusion.[11,18] Duodenum exclusion in T2DM may rapidly decrease the insulin resistance of patients with T2DM and was recently found to be associated with the decrease of some specific protein factors.[35] However, sleeve gastrectomy, a less in-

Table 2. Differences in Anthropometrics, Metabolic Profiles, Use of Antidiabetic Drugs, and Outcomes Between Baseline and 5-Year Follow-up in the Surgical Group for Those Who Received Laparoscopic Sleeve Gastrectomy vs Gastric Bypass

Measure	Laparoscopic Sleeve Gastrectomy		Gastric Bypass		*P* Value[a]	
	Baseline (n = 19)	5 y (n = 18)	Baseline (n = 33)	5 y (n = 32)	Baseline	5 y
Male, No. (%)	6 (31.6)	...	5 (15.2)	...	.16	...
Age, mean (SD), y	46.6 (7.9)	...	42.8 (10.1)	...	.17	...
DM duration, mean (SD), y	6.9 (4.9)	...	4.1 (5.2)	...	.09	...
Body weight, kg	82.3 (11.2)	68.1 (7.6)	80.1 (8.4)	61.4 (8.6)	.42	.008
BMI						
Mean (SD)	31.2 (2.6)	26.1 (2.5)	30.9 (2.2)	23.5 (2.3)	.63	.001
No. (%)						
<25	1 (5.3)	5 (27.8)	0	23 (71.9)	.29	.009
25-26.9	0	6 (33.3)	0	7 (21.9)		
27-29.9	3 (15.8)	6 (33.3)	9 (27.3)	2 (6.3)		
≥30	15 (79.0)	1 (5.6)	24 (72.7)	0		
Waist circumference, mean (SD), cm	101.8 (9.4)	88.4 (7.3)	100.4 (9.9)	80.8 (8.8)	.64	.01
Central obesity, No. (%)[b]	14 (73.7)	7 (38.9)	27 (81.8)	2 (6.3)	.49	.004
Fasting glucose, mean (SD), mg/dL	197.2 (73.0)	118.2 (27.2)	182.5 (76.6)	100.9 (29.5)	.50	.08
HbA_{1c}, % of total Hb						
Mean (SD)	9.0 (2.2)	6.9 (1.2)	9.1 (2.1)	6.0 (0.9)	.90	.008
No. (%)						
<7	6 (31.6)	11 (61.1)	7 (21.2)	28 (87.5)	.69	.10
7-8.9	6 (31.6)	5 (27.8)	13 (39.4)	3 (9.4)		
≥9	7 (36.8)	2 (11.1)	13 (39.4)	1 (3.1)		
BP, mean (SD), mm Hg						
Systolic	131.4 (13.0)	122.1 (17.5)	129.9 (12.8)	121.0 (19.7)	.69	.88
Diastolic	82.6 (9.6)	78.3 (11.7)	79.3 (9.8)	72.0 (10.6)	.25	.16
Hypertension, No. (%)[c]	7 (36.8)	2 (11.1)	4 (12.1)	3 (9.4)	.04	.84
TG, mg/dL						
Mean (SD)	233.5 (166.3)	111.0 (43.7)	222.5 (143.5)	73.6 (23.6)	.80	.003
>150, No. (%)	12 (63.2)	1 (5.6)	19 (57.6)	0	.69	.18
LDL-C, mg/dL						
Mean (SD)	138.4 (24.8)	114.1 (40.8)	126.6 (34.5)	96.7 (22.5)	.31	.14
>130, No. (%)	9 (47.4)	3 (16.7)	7 (21.2)	1 (3.1)	.05	.09
Insulin, mean (SD), μIU/mL	17.8 (15.9)	4.1 (2.5)	18.9 (27.9)	3.0 (1.8)	.89	.23
Any antidiabetic drug use, No. (%)	15 (79.0)	6 (33.3)	29 (87.9)	4 (12.5)	.40	.08
Insulin use, No. (%)	4 (21.1)	4 (22.2)	4 (12.1)	0	.39	.005
Operative characteristics						
Time, mean (SD), min	122.6 (32.7)	...	114.7 (35.2)	...	.43	...
Complications, No. (%)	0	...	2 (6.1)	...	.27	...
Outcomes, No. (%)						
Remission[d]						
Complete	0	3 (16.7)	0	15 (46.9)	...	.03
Partial	0	7 (38.9)	0	7 (21.9)	...	.20
Mortality	...	0	...	1 (3.0)	...	.44
ESRD[e]	...	1 (5.3)	...	0	...	.18

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); BP, blood pressure; DM, diabetes mellitus; ESRD, end-stage renal disease; Hb, hemoglobin; HbA_{1c}, glycated Hb; LDL-C, low-density lipoprotein cholesterol; TG, triglycerides; ellipses, not applicable.

SI conversion factor: To convert fasting glucose to millimoles per liter, multiply by 0.0555; to convert HbA_{1c} to proportion of total Hb, multiply by 0.01; to convert TG to millimoles per liter, multiply by 0.0113; to convert LDL-C to millimoles per liter, multiply by 0.0259; and to convert insulin to picomoles per liter, multiply by 6.945.

[a] The baseline *P* values compare baseline characteristics between the laparoscopic sleeve gastrectomy group and the gastric bypass group; the 5-year *P* values compare the characteristics at the fifth year between the laparoscopic sleeve gastrectomy group and the gastric bypass group.

[b] Defined as a waist circumference greater than 102 cm for men and greater than 88 cm for women.

[c] Defined as BP of 140/90 mm Hg or higher.

[d] Complete remission indicates no antidiabetic drug taken and an HbA_{1c} level lower than 6.0% of total Hb; partial remission, no antidiabetic drug taken and an HbA_{1c} level between 6.0% and 6.5% of total Hb.

[e] Indicates that the patient was undergoing dialysis or had an estimated glomerular filtration rate less than 15 mL/min/1.73 m^2.

vasive procedure, was also reported to be an effective alternative in treating nonmorbidly obese patients with diabetes.[19] In clinical settings, we recommend that clinicians fully disclose advantages and disadvantages of these 2 procedures and respect patients' preferences for final decision. Further studies are needed to elucidate the mechanism of duodenum exclusion and develop possible new treatments for T2DM.

Despite the promise of T2DM metabolic surgery indicated in this study, our results should be interpreted with caution because this study was not a randomized trial. However, our control group, the matched medical group, was selected from a managed study cohort[21] whose members were recruited from ordinary communities in Taiwan and whose status of glycemic control was at about the national level.[36] From the sustained improvement of glycemic control, metabolic profiles, and weight reduction shown in the surgical group, we believe the 5-year efficacy of metabolic surgery for the mildly obese patients with T2DM in this study is an unbiased estimate. Another limitation of this study is that the patient number in the surgical group may be too small to secure sufficient statistical power for outcome analysis. However, to our knowledge, the surgical group investigated in this study is the largest so far in the literature for mildly obese patients with T2DM undergoing metabolic surgery.

Conclusions

We show that metabolic surgery can provide long-term control of T2DM for mildly obese patients, with a prolonged complete remission rate up to 36% at 5 years, which is significantly better than that experienced with medical treatment. However, this better glycemic control did not reduce the mortality rate in mildly obese patients with T2DM at 5-year follow-up.

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Invited Commentary

Is Metabolic and Bariatric Surgery a Population Solution for Obesity and Type 2 Diabetes?

Robin P. Blackstone, MD

Metabolic and bariatric surgery (MBS) is shown to be more effective in the treatment of type 2 diabetes mellitus and obesity than medical weight loss in the retrospective study comparing surgical and medical cohorts with body mass index (BMI; calculated as weight in kilograms divided by height in meters squared) lower than 35 in this issue of *JAMA Surgery*.[1] Rates of follow-up are 96.2% in the surgical group and 83.6% in the medical group at 5 years. The effect of treatment for diabetes and obesity followed up for 5 years demonstrates durability. A comparison of 2 MBS procedures, gastric bypass (n = 33 at baseline) and sleeve gastrectomy (n = 19 at baseline), shows higher complete remission of type 2 diabetes for gastric bypass than for sleeve gastrectomy (46.9% vs 16.7%, respectively) and comparable results between the 2 procedures in the treatment of obesity. The procedure groups are small. The indication for procedure choice was patient preference. The BMI range is appropriate as East Asian patients and citizens of Asian ancestry in the United States are affected by diabetes at a much lower BMI than other groups.[2]

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This study offers comparable rates of diabetes remission and obesity with MBS as shown in prospective studies with 3-year follow-up and higher BMI.[3,4] Results of MBS were equally durable in patients with BMI higher than 35 at 6 years[5] and 20 years.[6] Also, MBS results in effective treatment for other components of the metabolic syndrome,[7] and the quality-adjusted life-years of bariatric surgery meet criteria for an effective intervention.[8] The question remains: should MBS be more widely adopted?

The barriers are significant. Cost of the procedure, complications, lack of surgical manpower, poor access to financially supported care, the problems of weight regain, and clinician and payer bias against surgery limit application as a population solution. These barriers are unlikely to change and may be magnified in very large populations. In China alone, more than 90 million people have type 2 diabetes.[9] However, the need to find an effective solution is urgent based on predictions of the future.[10]

How are we going to meet this challenge if not with surgery? Many advocate adopting behavioral treatment, which has far less efficacy and durability but is more widely applicable.[11] Weight regain appears to be driven by the genetic reset that occurs when epigenetic changes hardwire the phenotype of obesity.[12] How else can it be explained that when a person loses weight in comparison with a similar patient who was always lean, the formerly obese patient has to take in significantly fewer calories to maintain the same weight?[13] The study of MBS in animal models and humans is helping to unlock critical relationships in signaling in the gut-brain axis. Scientists working in molecular genetics are exposing epigenetic inherited interactions that may be able to be manipulated to affect obesity.[14,15] This new knowledge will need to engender disruptive innovation that can be widely applied to the population at risk, is inexpensive to administer, and can be repeated as necessary. The pace of this work needs to be accelerated with increased funding and collaboration.