Is Type II Diabetes Mellitus (NIDDM) a Surgical Disease?

WALTER J. PORIES, M.D.,* KENNETH G. MACDONALD, JR., M.D.,* EDWARD G. FLICKINGER, M.D.,†
G. LYNIS DOHM, PH.D.,‡ MADHUR K. SINHA, PH.D.,§ HISHAM A. BARAKAT, PH.D.,‡ HAROLD J. MAY, PH.D.,||
PRABHAKER KHAZANIE, PH.D.,¶ MELVIN S. SWANSON, PH.D.,* ELIZABETH MORGAN, B.S.N.,*
NANCY LEGGETT-FRAZIER, B.S.N.,§ STUART D. LONG, B.S.,* BRENDA M. BROWN, M.R.A.,*
KEVIN O'BRIEN, PH.D.,§ and JOSE F. CARO, M.D.§

Since February 1, 1980, 515 morbidly obese patients have undergone the Greenville gastric bypass (GGB) operation. Of these, 212 (41.2%) were euglycemic, 288 (55.9%) were either diabetic or had glucose intolerance, and 15 (2.9%) were unable to complete the evaluation. After the operation, only 30 (5.8%) patients remained diabetic (and 20 of these improved), 457 (88.7%) became and have remained euglycemic, and inadequate data prevented classification of the other 28 (5.4%). The patients who failed to return to normal glucose values were older and their diabetes was of longer duration than those who did. The effect of the GGB was not only limited to the correction of abnormal glucose levels. The GGB also corrected the abnormal levels of fasting insulin and glycosylated hemoglobin in a cohort of 52 consecutive severely obese patients with non-insulin-dependent diabetes. The GGB effectively controls weight. If morbid obesity is defined as 100 pounds over ideal body weight, 89% of the patients are no longer "morbidly" obese within 2 years. In most patients, the control of the weight has been well maintained during the 11 years of follow-up; most of the upward creep in weight of 20.8% between 24 and 132 months was from the 49 (9.5%) patients who had staple line breakdowns between the large and small gastric pouches. Non-insulin-dependent diabetes, previously considered a chronic unrelenting disease, can be controlled in the severely obese by the gastric bypass. Whether the correction of glucose metabolism affects the complications of diabetes is unknown. Whether the gastric bypass should be considered for patients with advanced non-insulin-dependent diabetes but who are not severely obese deserves consideration. The GGB has an unacceptably high rate of staple line failure. Accordingly, the authors have recently changed their procedure to one that divides the stomach rather than partitions it with staples.

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Address reprint requests to Walter J. Pories, M.D., Department of Surgery, East Carolina University School of Medicine, Greenville, NC 27834.

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From the Departments of Biochemistry,‡ Family Medicine,|| Pathology,¶ Medicine,§ and Surgery of the East Carolina University School of Medicine, Greenville, North Carolina; and the Department of Surgery,† The University of Rochester, Rochester, New York*

DIABETES MELLITUS IS one of our most serious diseases. It accelerates the development of atherosclerosis, doubles the risk for stroke, and increases the risk of heart attacks twofold to threefold. Through its damage to the microvasculature, diabetes produces retinopathies, blindness, nephropathy, and neuropathy. In addition, there are broader systemic effects, such as the lessening of resistance to infection. The economic impact of the disease is enormous; in 1985 it was estimated to be $4 billion and may well be twice that high given the inflation in health care costs. Although the exact prevalence is unknown, the usual estimate is that 10 million Americans have the disease and, of these, 1.25 million take insulin, 1 to 1.5 million are on oral antidiabetic agents, and another two to three million are being managed by diet alone. Many remain undiagnosed. The disease is generally classified into two groups: type I diabetes or insulin-dependent diabetes, which afflicts about 200,000 to 300,000, and the far more common type II diabetes or non-insulin-dependent diabetes mellitus (NIDDM), which accounts for more than 95% of the cases.[1]

The basis for the current treatment of NIDDM is the maintenance of euglycemia and normal insulin levels. This "control of the diabetes" is considered the best approach to prevent the acute and chronic complications of diabetes and to ameliorate those changes that are already present.[2] Unfortunately, euglycemia cannot be achieved in most patients with NIDDM because they are usually overweight and resistant to dietary controls. In fact, their excess weight is a major factor in precipitating the overt diabetes, especially in those predisposed by heredity.[3] In Rochester, Minnesota,[4] 59% of cases of diabetes were diagnosed among men and women with a body mass index (BMI) greater than 28.3 kg/m^2, and in the Nurses' Health Study,[5] 61% of the diabetic women aged 30 to 64 had BMIs of 29 kg/m^2 or more. Among these obese women, 94% of NIDDM prevalence was attributed to obesity.

Over the last 11 years, we have treated 515 severely obese patients, most of whom demonstrated abnormalities of glucose and insulin metabolism, with surgery to control their weight. The operation, the Greenville gastric bypass (GGB), limits intake by the fashioning of a small gastric pouch, delays gastric emptying with a small outlet, and bypasses the foregut with a Roux-en-Y anastomosis. The procedure is effective: in addition to inducing long-term weight loss, it helps in the control of hypertension and returns many of those handicapped by severe obesity to functional effectiveness.

Four years ago, we[6] reported that the GGB operation restored some of the severely obese patients with NIDDM to euglycemia. This article is a report of our continued studies of the effect of the procedure on the glucose and insulin metabolism of these patients.

TABLE 1. *Diagnostic Criteria for Diabetes Mellitus and Impaired Glucose Tolerance as Defined by the National Diabetes Data Group**

Non-Insulin-dependent Diabetes Mellitus

Criteria for diabetes mellitus: Diagnosis of diabetes mellitus in nonpregnant adults should be restricted to those who have one of the following:

1. A random plasma glucose level of 200 mg/dL or greater plus classic signs and symptoms of diabetes mellitus, including polydipsia, polyuria, polyphagia, and weight loss.
2. A fasting plasma glucose level of 140 mg/dL or greater on at least two occasions.
3. A fasting plasma glucose level of less than 140 mg/dL plus sustained elevated plasma glucose levels during at least two oral glucose tolerance tests. The 2-hr sample and at least one other between 0 and 2 hr after the 75-g glucose dose should be 200 mg/dL or greater. Oral glucose tolerance testing is not necessary if the patient has a fasting plasma glucose level of 140 mg/dL or greater.

Impaired Glucose Tolerance

Criteria for impaired glucose tolerance: Diagnosis of impaired glucose tolerance in nonpregnant adults should be restricted to those who have all of the following:

1. A fasting plasma glucose level of less than 140 mg/dL.
2. A 2-hr oral glucose tolerance test plasma glucose level between 140 and 200 mg/dL.
3. An intervening oral glucose tolerance test plasma glucose value of 20 mg/dL or greater.

* We have added another category, "undefined": Those patients with abnormal plasma glucose values but who do not fit into either of the above two groups.

Materials and Methods: Clinical Studies

From February 1, 1980 to August 1, 1991, 515 consecutive morbidly obese patients (each exceeding their ideal body weight by 100 pounds or more) underwent the standardized GGB.

Demographic Data

The 515 patients included 359 white and 79 black women as well as 64 white and 13 black men. Of the group, 360 were married, 44 were divorced, 83 were single, 18 were separated, and 10 were widows. The job status survey showed that 324 were employed and 191 were not.

Diabetic Status

The state of the diabetes was defined in accordance with the standards of the National Diabetes Data Group (Table 1).7 Of the 515 patients, 500 completed oral glucose tolerance tests; in 15 (2.9%), a lack of full data (because of a missing or suspicious sample in the glucose tolerance test curve) prevented accurate assessment. Of the 500 evaluable patients, 212 (41.2%) were classified as normal, and 288 (55.9%) demonstrated abnormal glucose metabolism. Of the 288 patients with abnormal glucose metabolism, 137 (26.6%) were classified as NIDDM, 63 (12.2%) as glucose impaired, and 88 (17.1%) as undefined.

Patient Selection and Eligibility

Patients of either sex were considered eligible for inclusion if they met the following criteria: (1) ages between 18 and 65 years (although an exception was made for a girl of 16); (2) severely obese, in other words, they exceeded their ideal body weight as given in the midpoint of the 1983 Metropolitan Life Insurance Tables by 100 pounds or more; (3) suitable operative risks after evaluation of their physical and emotional status; (4) capable of understanding the operation and the postoperative consequences and instructions; (5) agreement to long-term follow-up; (6) informed consent; and (7) funding for the surgery and the various required tests. Patients were excluded during the course of the evaluation if they (1) were not sufficiently obese; (2) had a history of alcohol or substance abuse within the last 5 years; (3) had a history of severe psychiatric dysfunction, especially evidence of suicidal attempts, serious depression, or paranoia; and (4) had inappropriate expectations of the surgery in spite of counseling, and met strong continued opposition by other family members.

Preoperative Evaluation

We have continued to decrease the intensity of our preoperative evaluation over the 11 years of the study with the elimination of those tests, such as levels of trace elements, that have produced too few significant abnormal levels to warrant the effort and the expense. Our current approach includes the following examinations:

1. complete history and physical examination with measurement of waist-to-hip ratios, body mass index (kg/m^2), and vital signs
2. routine admission studies, including complete blood count, SMA-12, electrolytes, vitamin B_{12} level, thyroid-stimulating hormone, prothrombin time, partial thromboplastin time, urinalysis, posteroanterior and lateral chest roentgenograms, electrocardiogram
3. glucose tolerance test
4. specialized tests for the evaluation of surgical risk, including pulmonary function testing and determination of anergy with skin tests (PPD, mumps, and fungus)
5. immersion hydrostatic weighing to determine body composition
6. the evaluation of mental health, physical function, and role function with a standardized interview with the project psychologist or psychiatrist

This description of our method is not intended to serve as a prescription for others treating severe obesity. We recognize that our evaluation, carried out to support our various studies, is more detailed and rigorous than would be needed in daily bariatric surgical practice. Even so, our patients have only rarely complained about the extent of the workup. It is our impression that most patients find the attention comforting rather than an annoyance.

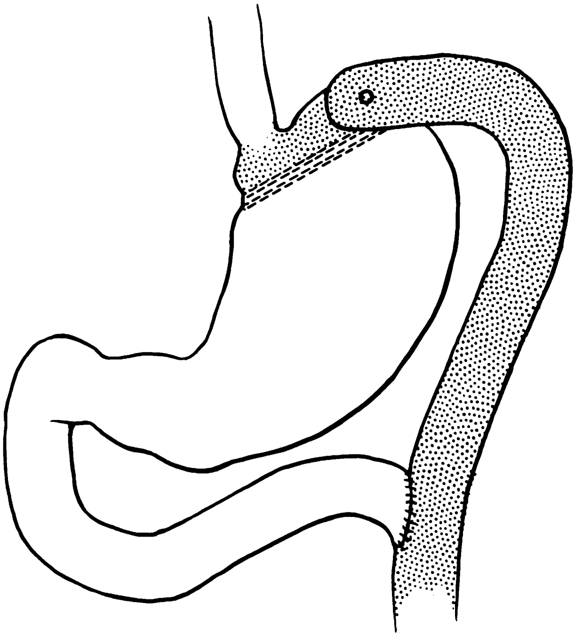

FIG. 1. The Greenville gastric bypass. The operation creates a proximal gastric pouch of 20–30 mL by the placement of a transverse double row of staples that empties into a 40-cm jejunal limb through an 8-mm gastroenterostomy. The high rate of staple line failure (9.5%) has led us recently to divide the stomach between the two staple lines.

The Surgical Intervention: The Greenville Gastric Bypass

We have carried out the identical operation, shown in Figure 1, as described by Pories,[8] a variation of the procedure originally described by Mason and Ito,[9] since February 1, 1980. Details in bariatric surgery often mean the difference between success and failure. The operation is technically demanding and the administration of the general anesthesia in these often huge individuals is a challenge. In those patients with marginal cardiopulmonary function, the insertion of a Swan-Ganz catheter and preoperative stabilization in an intensive care unit can reduce operative risk. A Gomez self-retaining retractor or one of the other retracting mechanisms that is clamped to the operating table is essential to achieve adequate exposure. The abdomen is entered through a high midline incision that extends around the umbilicus in most cases. If the exploration does not demonstrate contraindications to the procedure, the dissection around the upper portion of the stomach is begun by inserting the index finger gently into the angle at the cardia to the left of the esophagus. At this point there is a weak, thin area of the posterior peritoneum that is easily entered by the dissecting finger. The dissection is gently continued behind the esophagus and cardia. The channel is complete when the finger is brought out, not at the right side of the esophagus, but just below the first arcade of branches from the left gastric artery about 2.3 to 3.0 cm below the cardia. A large Malecot catheter, from which the bulbous end has been cut, is used to pull one limb of the TA-90 four-staple-line device through the passage. A proximal pouch measuring 4 cm in width and 1.5 cm in height is then separated from the stomach by firing the staples. A figure-of-eight 3–0 polypropylene suture is placed at the end of the staple line to close the ends securely and to serve as guy sutures during the anastomosis. The stomach is then divided by cutting between the two paired lines of staples, and both staple lines are then oversewn with 3–0 absorbable suture. (The division of the stomach is new: the partitioning of the stomachs of the 515 patients reported in this report was accomplished with the stapler alone. The high incidence of staple line failure and the success of gastric division for revisions of failed gastric bypasses has convinced us that division is the better approach and, accordingly, on October 25, 1991, we changed our protocol, altering our procedure for the first time in over 11 years.) The jejunum is divided at the apex of the first or second arcade (depending on which provides a longer Roux-en-Y limb), about 40 cm from the ligament of Treitz, with a cutting stapling device, and the distal end is then sutured to the gastric pouch. The anastomosis is sewn to fit snugly around a 0.8-cm Salem sump tube in two layers with continuous 3–0 polypropylene suture. The entero-enterostomy is then completed by joining the proximal jejunum end-to-side to the distal jejunum with the cutting and the TA 55 staplers. It is important to fasten the Roux loop to the mesocolon with several sutures to prevent an internal hernia and to oversew the bleeders inside the entero-enterostomy before closing the intestine. The abdomen is closed with a running, double-stranded, 1-absorbable monofilament suture. The skin is closed with skin staples without a subcutaneous suture line. The operation usually can be performed in 1 to 2 hours; blood loss rarely exceeds 300 mL.

Postoperative Care

In general, the postoperative care of bariatric patients resembles that after standard abdominal surgery in high-risk patients and therefore will not be described in detail except to emphasize the need for prophylactic antibiotics, careful monitoring of vital signs, fluid balance, and glucose metabolism, and the requirement for appropriate furniture and equipment to manage these massive patients. The first 24 hours are particularly critical because of the serious consequences of a leak or intra-abdominal infection in the morbidly obese. If the pulse remains over 120 for more than 4 hours without an evident reason, if there is a rise in body temperature to over 39 C (102 F), or if the patient looks ill in spite of normal signs, prompt emergency exploration and the addition of other antibiotics may be needed. Examinations with the swallow of radiopaque materials to demonstrate leaks are not reliable and should not be used as a reason for failure to re-explore. Neglect of a perforation or intra-abdominal infection is associated with a high mortality rate. Patients generally spend the first night in the critical care unit or a monitored ward bed for close observation and then spend the rest of their hospital stay (usually a total of 5 to 6 days) on surgical wards. Nasogastric tubes are usually removed on the third day. When the patients pass flatus, they are begun on water at 1 oz/hour, followed by the addition of a high-protein fluid preparation, half-strength on the next day, and full-strength on the day of discharge. Patients are maintained on the full-strength preparation for 2 weeks and then advanced slowly to a regular diet.

Follow-up

Follow-up has been rigorous. Return visits are timed weekly for the first month, then every third month for a year, and for every 6 months for continuing follow-up. Over the 11 years we have maintained follow-up with all but 17 of the 515 patients (96.7%).

Biopsies for Studies of Insulin Action

A 10-mL sample of venous blood and biopsies of fat, liver, muscle, and pancreas were obtained in several cohorts of patients in accordance with protocols approved by the institutional review boards of the East Carolina University School of Medicine and the Pitt County Memorial Hospital. The blood and cold steel biopsies were obtained as soon as the abdomen was opened and after a thorough exploration showed no contraindications to the biopsies. The specimens of fat, measuring about 3 × 3 × 1 cm, were removed from (1) subcutaneous fat, (2) properitoneal fat, and (3) omental fat. The liver samples, measuring 2 × 2 × 3 cm, were usually obtained from the leading edge of the left lobe, but sometimes from the right, depending on the exposure. Hemostasis and closure of the defect were obtained with serosal running sutures of 3–0 absorbable braided suture. The strips of rectus muscle, measuring 1 × 0.5 × 3 cm were obtained by blunt elevation of the fibers from the muscle bed, clamping these into a specially designed clamp to maintain their stretch, and transecting the fibers proximally and distally to the clamp. Pancreatic biopsies have only been done recently. These samples, measuring 0.3 × 0.3 × 0.3 cm, were removed from the inferior side of the body of the pancreas after incising the peritoneum at the junction of the mesocolon and the posterior peritoneum. After the removal of the specimen, the pancreatic capsule was closed with one suture of 3–0 monofilament absorbable suture and covered, with the peritoneum closed with the same material. To our knowledge, and after continuing rigorous review of our records, we know of no instance in which any of the biopsies produced a complication.

Our methods for isolating insulin-responsive human hepatocytes,[10] human skeletal muscle,[11] and human adipocytes[12] have been previously described. Results from these *in vitro* studies have been recently reviewed by Caro and his associates.[13]

Results

Control of Weight

Weight reduction in these patients has been dramatic and well maintained over the 132 months of follow-up. Table 2 presents the weight loss of all 515 patients who have undergone the GGB in time intervals after surgery, in mean weight in pounds, in mean percentage of excess weight loss, and in mean percentage of ideal body weight as indicated by the 1983 Metropolitan Life Insurance Tables. If severe obesity is defined as 100 pounds over ideal weight, 89% of the patients are no longer "morbidly" obese within 2 years. Figure 2 demonstrates that there is some weight gain between 24 and 132 months (from a mean of 183 to 221 pounds or 20.8%), reflecting those 49 (9.5%) patients who had staple line breakdowns and others who learned to "outeat" their pouches with high-calorie liquids or continued snacking.

"Reversal" of Diabetes

Table 3 shows that of the 500 severely obese patients who completed the oral glucose tolerance test and un-

TABLE 2. *Weight Loss History With Greenville Gastric Bypass After 11 Years' Follow-up*

		Weight (lb)	% Excess Weight Lost	% of Ideal Body Weight
Time	N*	Mean (Range)	Mean (Range)	Mean (Range)
Before operation	515	296 (196–565)	0	216 (140–327)
3 mo	474	239 (124–490)	37 (6–103)	174 (97–307)
6 mo	470	211 (100–441)	55 (0–137)	154 (73–282)
12 mo	439	187 (104–466)	71 (13–124)	136 (85–268)
24 mo	348	183 (105–367)	72 (9–116)	134 (88–248)
36 mo	274	197 (112–411)	65 (−10–114)	142 (88–256)
48 mo	248	199 (114–413)	61 (−22–112)	145 (87–253)
60 mo	236	201 (107–428)	60 (−15–118)	147 (86–263)
72 mo	201	203 (121–399)	58 (8–133)	148 (79–270)
84 mo	172	203 (113–378)	59 (−10–109)	150 (94–273)
96 mo	132	204 (130–357)	56 (8–97)	153 (103–259)
108 mo	97	205 (125–392)	55 (6–95)	151 (104–276)
120 mo	44	198 (130–350)	56 (9–106)	149 (97–226)
132 mo	11	221 (174–346)	42 (29–58)	162 (139–212)

* No. of patients with recorded weight within each time interval ranging from ±15 days at 3 mo after operation to ±5 mo at 11 yr after operation.

derwent the GGB, 288 (57.6%) were either diabetic (137) or had glucose intolerance (151). Of the 137 patients with NIDDM, 107 (78.1%) went into clinical remission, 20 (14.6%) improved, and eight (5.8%) demonstrated no change. Two patients (1.5%) died in the perioperative period and could not be evaluated. Of the 151 patients who were not classified as NIDDM but who had abnormal preoperative glucose values, 13 had no follow-up glucose data. Of the 138 who did, all but two (98.6%) maintained normal fasting blood glucose levels. The two (1.2%) who did not return to euglycemia progressed to NIDDM.

Before surgery, 24 received insulin and another 25 were under treatment with oral antidiabetic agents. After surgery, three were subsequently placed on insulin and 11 on the oral medications.

The effect of the GGB is not limited to glucose levels alone. Table 4 demonstrates that the GGB corrected the abnormal levels of fasting blood glucose, fasting insulin, and glycosylated hemoglobin in a cohort of 52 consecutive severely obese patients with NIDDM.

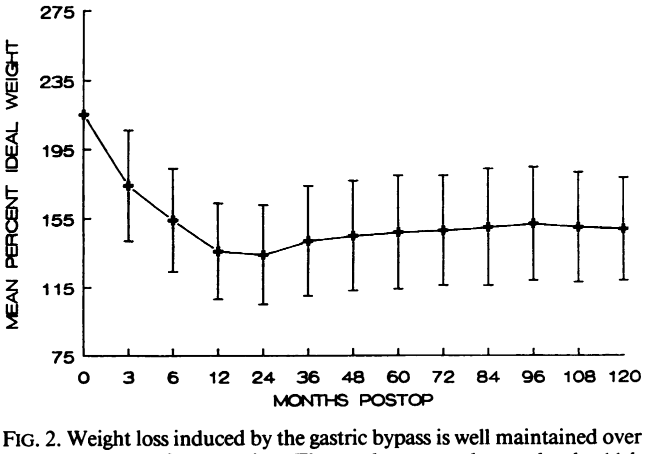

FIG. 2. Weight loss induced by the gastric bypass is well maintained over the 132 months of observation. The modest upward creep by the 11th year is primarily caused by the failure of the gastric staple lines.

The 28 NIDDM patients who did not go into complete remission and the two glucose-impaired patients who progressed to NIDDM were examined in detail. Factors that may be associated with these failures include four patients with staple line breakdowns, two patients with gastric outlet dilatation, eight patients with rising weight that may be indicative of dietary indiscretion or undiagnosed staple breakdown, one patient with Hodgkin's disease, and one patient with severe arthritis and steroid-associated weight gain, leaving 15 patients without discernible risk factors.

Patients with good glucose control were about 8 years younger (41.9 ± 1.9 *versus* 49.6 ± 2.8 years), and their diabetes was of far shorter duration (1.75 ± 0.69 *versus* 8.79 ± 2.8 years) than those patients who had poor glucose control.

The level of preoperative fasting glucose also determines the degree of postoperative control, as shown in Figure 3. The patients with the higher postoperative glucose values experienced greater drops in fasting blood sugar than their

TABLE 3. *The Control of NIDDM With the Gastric Bypass (n = 515)*

	Before Operation	After Operation
Euglycemic	212 (41.2%)	457 (88.7%)
Hyperglycemic	288 (55.9%)	30 (5.8%)
Non-insulin-dependent diabetes mellitus	137 (26.6%)	
Impaired glucose tolerance	63 (12.2%)	
Undefined, but abnormal	88 (17.1%)	
Inadequate data	15 (2.9%)	28 (5.4%)

NIDDM, non-insulin-dependent diabetes mellitus.

TABLE 4. *The Correction of Abnormal Glucose Metabolism After the Gastric Bypass (n = 52)*

	Before Operation	1 Yr After Operation
Average weight (kg)	120.1 ± 4.4	83.0 ± 3.3
Fasting blood glucose (mg/dL)	212.3 ± 20.8	117.3 ± 11.5
Fasting insulin (μM/mL)	44.8 ± 4.1	13.4 ± 2.0
HbA1c	10.8 ± 0.6	6.4 ± 0.2

more normal counterparts, but leveled out at levels that were still abnormal.

The improvements in insulin levels, glycosylated hemoglobin (HbA1c), and glucose levels do not parallel each other consistently. In contrast to the insulin levels that fall predictably after gastric bypass (Fig. 4), the levels of HbA1c (Fig. 5) and fasting blood sugar (Fig. 6) on the same group of patients show a much wider scatter. The reasons for this unexpected difference in the behavior of these diabetic indices is not clear.

The glucose tolerance curves and fasting insulin levels were compared in 117 lean controls, 85 nondiabetic obese, 39 glucose-impaired obese, 29 NIDDM obese with fasting blood sugar < 140 mg/dL, and 25 NIDDM obese with fasting blood sugar > 140 mg/dL. The data, shown in Figures 7 and 8, suggest that insulin production continues to rise with increasing insulin resistance until, finally, the beta cells fail to reach effective insulin production on demand and, as a consequence, blood glucose levels rise out of control. In short, the progression of the two diseases, NIDDM and obesity, parallel each other. The diabetes, these data suggest, appears to be due to ever-increasing insulin resistance and the eventual failure of the pancreas to meet the ever higher demand for insulin production. In a way, type II diabetes mellitus, at its most severe and terminal point, resembles type 1 diabetes, with inadequate insulin production.

Control of Hypertension

The GGB favorably affected hypertension. Of the 515 patients, 301 (58.4%) were hypertensive before the operation and, of these, 169 (56.1%) were on antihypertensive medication. After the GGB, 96 of the 301 (31.9%) remained hypertensive, and 88 (29.2%) were maintained on antihypertensive therapy.

Perioperative and Late Complications

The perioperative mortality rate was 1.2%, in other words, six of 515 patients died within 30 days after their operation or during their first hospitalization, a low rate in view of the fact that 47 (9.1%) of these patients in the series were, in addition to being severely obese, also in cardiopulmonary failure before surgery. As demonstrated in Table 5, 83% of the perioperative deaths were of sepsis.

There were 17 late deaths, of which 7 (41.1%) were related to emotional problems: three were suicides, two died of cirrhosis due to alcohol abuse, and two died of self-imposed malnutrition. Another three, those from motor vehicle fatalities, are suspect because depression or other emotional factors are frequently involved in car crashes. The investigating authorities, however, have cited all three as accidents and we have been unable to obtain any further details. The death of acquired immune deficiency syndrome was caused by an infection transmitted from a transfusion during a plastic surgery procedure at another hospital; the unknown death appears to have been a result of an arrhythmia.

Perioperative complications are listed in Table 6. Wound problems and infections are the most common cause of prolonged hospitalization in the severely obese, probably related to the high incidence of NIDDM. Table 7 lists those late complications that occur at a rate of 1% or greater. The most common problems seen over the 11 years of follow-up include depression and other psychiatric problems; vitamin and iron deficiencies; incisional hernias; cholecystitis; and technical problems associated with the operation such as staple line failures, anastomotic dilatations or stenoses, and bowel obstructions due to adhesions.

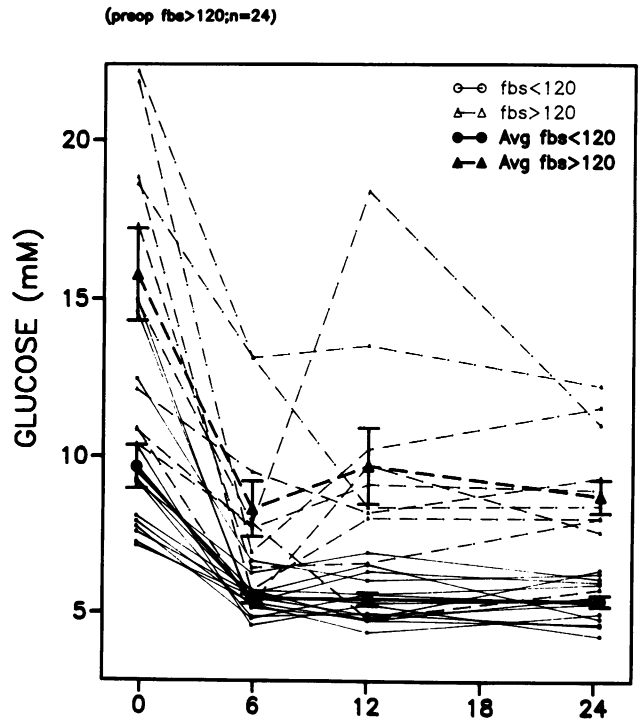

FIG. 3. Comparison between the postoperative fasting blood glucose levels in patients with NIDDM and preoperative plasma glucose readings of <120 mg/dL and >120 mg/dL. Patients with the higher preoperative glucose values experienced greater decreases in plasma glucose than their more normal counterparts, but leveled out at values that were still not fully normal.

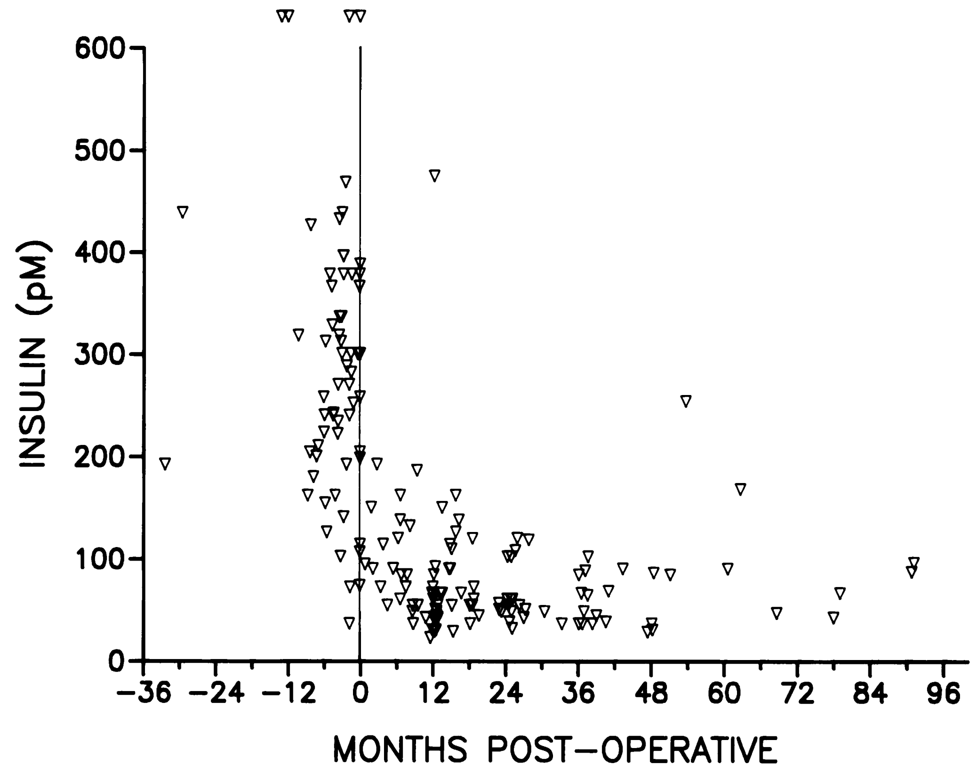

FIG. 4. Drop in insulin levels after the gastric bypass.

Discussion

One of the main goals in the management of NIDDM is euglycemia through weight control. Unfortunately, most patients with NIDDM are overweight, and further, NIDDM is especially common in patients who are severely obese, in other words, who exceed their ideal body weight by 100 pounds or more. Diets do not work in these massive individuals, and the general course of their illness is a pattern of ever-increasing weight, worsening diabetes, and progression of diabetic complications. Our data suggest that surgical intervention with the gastric bypass offers

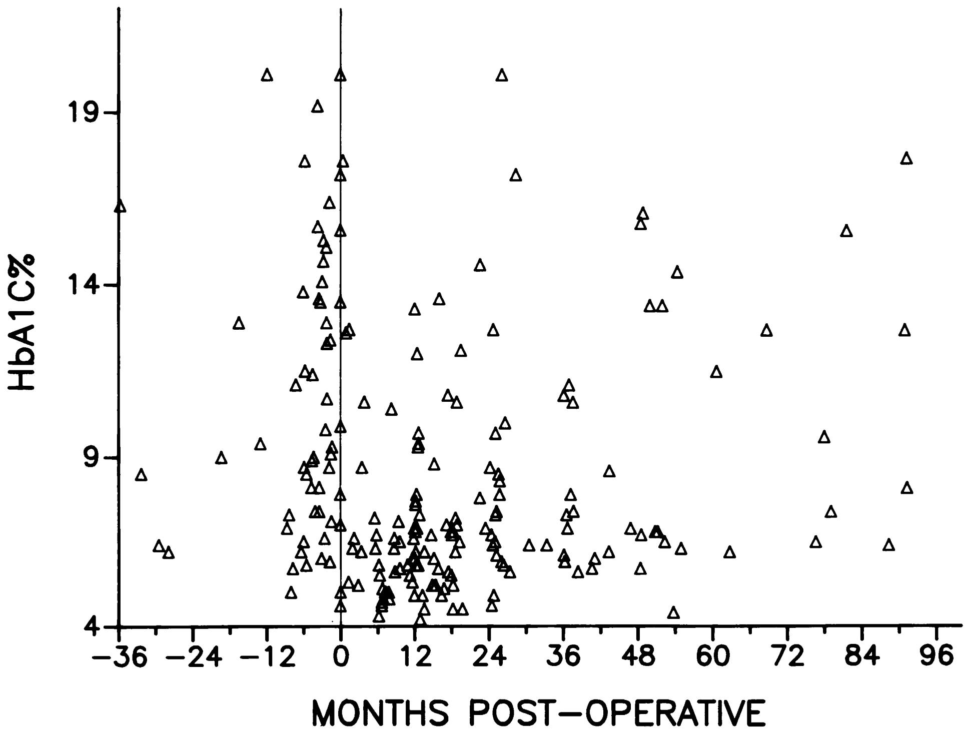

FIG. 5. Changes in Hb1Ac after gastric bypass. There is considerably greater scatter than is seen in the insulin levels.

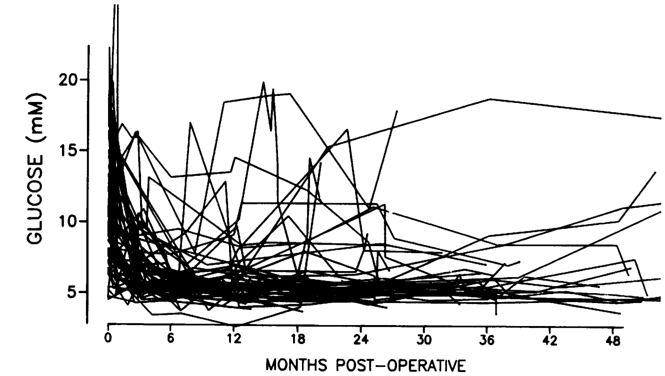

FIG. 6. Changes in fasting blood glucose levels after the gastric bypass. A great number of patients have reverted to normal values.

a new and reasonable approach to the control of NIDDM in the severely obese and perhaps in those who are moderately obese as well.

On March 25 through 27, 1991, the National Institutes of Health held a Consensus Conference on Gastrointestinal Surgery for Severe Obesity to examine the effectiveness of bariatric surgery. First, the panel concurred that severe obesity is an increasingly common problem: "The disorder is accompanied by reduced life expectancy and significant psychosocial and economic problems are frequently experienced by severely obese people." There is a direct relationship between the amount of excess weight and the incidence of arthritis, coronary artery disease, cerebrovascular disease, congestive heart failure, hypertension, diabetes mellitus, cholecystitis, and cancers of the stomach, uterus, and breast.[14,15] In addition, as they continue to get older and gain ever more weight, these individuals develop other health problems associated with severe obesity, including hypertension, cardiopulmonary failure, Pickwickian syndrome, sleep apnea, hyperlipidemia, coronary artery disease, gout, certain cancers, cholelithiasis, hepatic steatosis, polycystic ovary syndrome, pseudotumor cerebri, osteoarthritis, cardiomyopathy, hormonal abnormalities, and skin disease.

Patients, however, usually seek surgical intervention because of limitations in function rather than for health indications.[16] Fat people are frequently objects of public scorn and malicious ridicule. Employers are often reluctant to hire them because they are considered unattractive, have high rates of absenteeism due to illness, fall asleep on the job, and are thought to have a higher accident rate in factories because of their clumsiness and loose clothing. Obesity limits the availability of educational opportunities and a chance to find a spouse. Finally, our patients frequently mention their inabilities to meet their parental and other social roles: their children and other family members are ashamed to be seen with them at school, at athletic events, and in social situations. In short, the environment of the severely obese is neither happy nor filled with opportunities. Kral et al.[17] summarized their problems well when they concluded that the severely obese are handicapped by every measure: physically, emotionally, economically, and socially. Morbid obesity is indeed a serious disease; if diabetes is present as well, it becomes even more dangerous.

The estimated annual mortality rate in sudden death among the severely obese is 65/100,000, in other words, 40 times higher than expected in the general population.[11] An American Cancer Society study[18] disclosed deaths from all causes to be 50% higher among men and women who were merely 30% to 40% above normal weight. Mortality rate accelerates steeply when an individual becomes 50% overweight; for example, young severely obese males

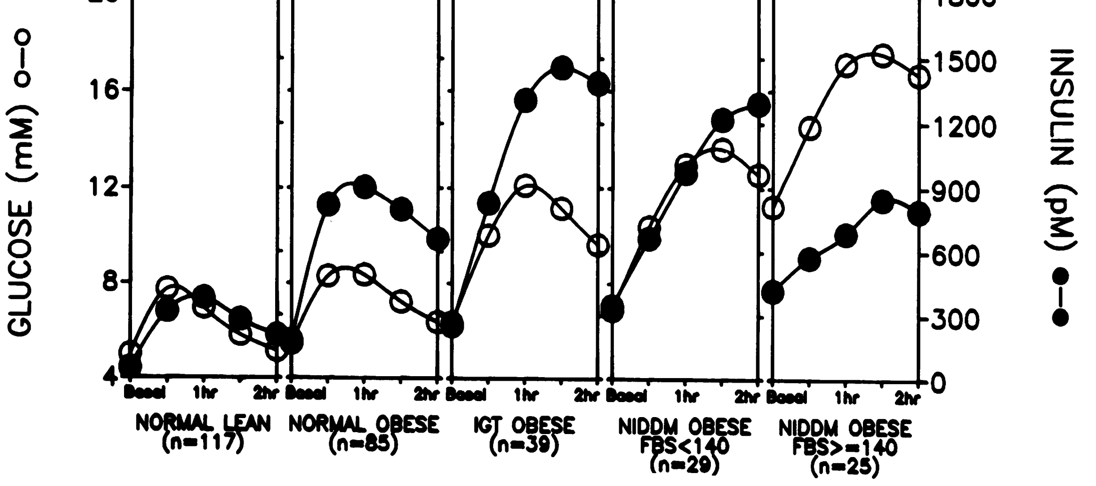

FIG. 7. Insulin resistance in normal and obese patients with and without diabetes as reflected by the oral glucose tolerance curves in 117 normal lean patients, 85 normal obese patients, 39 obese patients with IGT, 29 obese patients with NIDDM with FBS < 140 mg/dL, and 25 obese patients with NIDDM with FBS > 140 mg/dL.

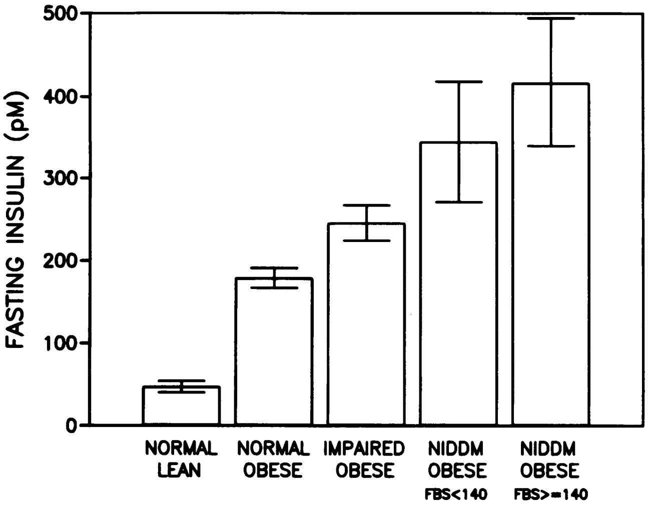

FIG. 8. Insulin resistance as reflected by the rise in fasting insulin levels in normal lean patients, normal obese patients, impaired obese patients, and diabetic patients with FBS < 140 mg/dL and > 140 mg/dL.

have a 12-fold increase in mortality rate.[19] Bray's[20] data, shown in Figure 9, graphically demonstrate the relationship of mortality to the body mass index (kg/m^2).

Second, the National Institutes of Health panel agreed that surgery has become the therapy of choice. According to the summary of the conference, more than 12 million Americans are severely overweight, and 4 million of these are "so overweight that their obesity harms their health and well-being, making them candidates for surgical treatment."[21] The panel endorsed two surgical treatments for severe obesity: vertical banded gastroplasty and the Roux-en-Y gastric bypass operation. These two procedures, gradually improved over the last three decades, can now safely and effectively control weight over long periods and either reverse or avoid many of the health and social problems associated with severe obesity. These operations are, however, not the only bariatric operations that ameliorate or reverse diabetes. Most operations reported to induce weight loss, including the intestinal bypasses, gastric bypasses, and gastroplasties, have shown this effect. It is our impression that the gastric bypass, with its bypass of the hormonal axis of the foregut and greater weight loss, does this more effectively than the gastroplasties, but our evidence for this remains fragmentary.

TABLE 5. *Deaths With Greenville Gastric Bypass After 11 Years' Follow-up*

Cause	N
Perioperative	
Sepsis	5
Pulmonary embolus	1
	6/515 (1.2%)
Late	
Suicide	3
Auto accident	3
Cirrhosis	2
Cancer	
Liver	1
Larynx	1
Myocardial infarction	1
Anemia, pernicious	1
Non-GGB sepsis	1
Malnutrition	1
AIDS	1
Unknown	1
Positional asphyxia	1
	17/515 (3.3%)
Total deaths	23/515 (4.5%)

GGB, Greenville gastric bypass.

TABLE 6. *Perioperative Complications With Greenville Gastric Bypass After 11 Years' Follow-up (N = 515)*

Complication Label	N
Wound complications	
Minor wound infection	50 (9.7%)
Wound seroma	35 (6.8%)
Severe wound infection	18 (3.5%)
Wound dehiscence	5 (1.0%)
Operative complications	
Spleen tear or laceration	13 (2.5%)
Subphrenic abscess	12 (2.3%)
Liver tear	8 (1.6%)
General complications after operation	
Temperature	45 (8.7%)
Anastomosis/stenosis	10 (1.9%)
Arrythmia	8 (1.6%)
Readmit	41 (8.0%)
Reoperate	12 (2.3%)
Patients with ≥1 perioperative complications	315 (61.2%)

Conclusion

The gastric bypass operation is an effective therapy for the treatment of NIDDM in the severely obese. The operation can be done with acceptable morbidity and mortality rates, and the effects of the procedure are well maintained over 11 years of observation. The procedure, with the modification that divides rather than staples the stomach, should now be considered for obese patients who are

TABLE 7. *Late Complications With Greenville Gastric Bypass After 11 Years' Follow-up (N = 507)*

Complication Label	N
Vitamin deficiency	233 (46.0%)
Anemia	232 (45.8%)
Readmit	187 (39.6%)
Depression	121 (23.9%)
Incisional hernia	107 (21.1%)
Gastritis	65 (12.8%)
Cholelithiasis	60 (11.8%)
Staple line failure	49 (9.7%)
Small bowel obstruction	28 (5.5%)
Dehydration/malnutrition	28 (5.5%)
Anastomosis failure	26 (5.1%)
Revision	25 (4.9%)
Ulcer	23 (4.5%)
Dilated pouch	17 (3.4%)
Anastomosis stenosis	15 (3.0%)

* Eight patients < 30 days after surgery.

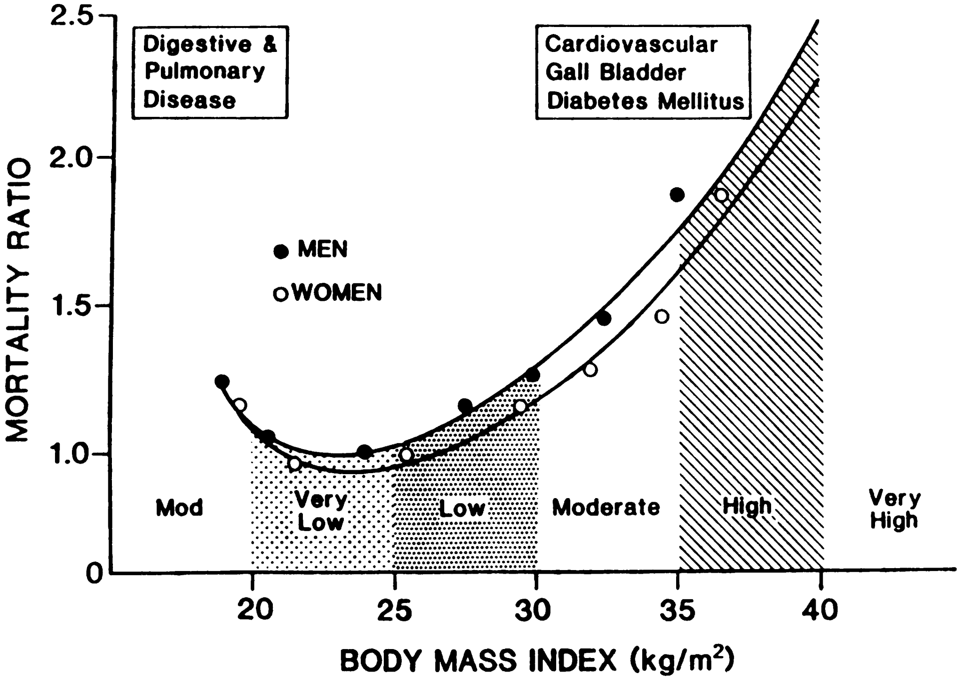

FIG. 9. Mortality rate rises sharply from all causes with increases in the BMI (kg/m^2). For reference, a woman 5'5" tall, with an ideal body weight of 134 lb. according to the 1983 Height and Weight Standards of the Metropolitan Life Insurance Company Tables has a BMI of 22.3. With a BMI of 30, 35, or 40, she would weigh 179 lb, 210 lb, or 240 lb, respectively. Patients are considered "clinically severely obese" or "morbidly obese" if they exceed a BMI of 35 with comorbid conditions or a BMI of 40 without obesity-associated illnesses. Reproduced with permission from Bray.[20]

not heavy enough to be classified as severely obese, but whose diabetes is difficult to control. Whether the euglycemia and restoration of normal insulin levels prevents the long-term development of diabetic complications remains unknown.

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