Gastroplasty was originally developed to simplify gastric reduction operations for the treatment of obesity and thereby avoid complications peculiar to bypasses. Lessons learned from gastric bypass about pouch and outlet size increased in importance with gastroplasty. An extensive literature exists that requires careful reading to understand the technical causes of excessively high reoperation rates. Much of the recent decline in the use of gastroplasty followed efforts to increase weight loss by obstructing the outlet, only to increase staple-line breakdown and to cause collar migration into the lumen. With adherence to tested technique, vertical gastroplasty can benefit most patients with morbid obesity and should be more frequently used. Gastroplasty may increase in popularity as the medical profession is confronted with an increasing need for long-term medical care following gastric bypass. This article is a brief review of experience that is a necessary guide to future success with gastroplasty.

BACKGROUND

Gastroplasty is to gastric bypass as Billroth I is to Billroth II gastric resection—an effort to avoid undesirable adverse effects and complications. Gastric reduction operations began with an analogue of the Billroth II gastric resection. One of the complications of Billroth II gastric resection, low body weight, was the reason for developing gastric bypass for the treatment of obesity in 1966. Conversely, one of the attractions of Billroth I was a better maintenance of body weight. This is, therefore, a story of choices between weight loss and complications, between simple restriction and bypass.

Two academic surgery training programs were recommended to me in 1944. One was with Owen H. Wangensteen, MD, at the University of Minnesota, Rochester. The other was with Lester Dragstedt, MD, at the University of Chicago, Chicago, Ill. I applied to the University of Minnesota after reading papers about animal experiments designed to identify an optimum operation for the cure of duodenal ulcer by Wangensteen and others.

While I was a surgical resident from 1947 through 1953, Wangensteen became dissatisfied with the Billroth II gastrectomy because of adverse effects and complications. Concurrently, Dragstedt was promoting vagotomy as a replacement for gastric resection. In his biography of Dragstedt, Landor provides the following interesting note about Dragstedt’s attitude toward gastrectomy: “When he was doing gastrectomy for duodenal ulcer there were few doctors, almost no gastroenterologists and absolutely no surgeons among his patients. Among his first 500 vagotomy patients, however, there were 40 doctors, 21 of whom were surgeons.”

Wangensteen was master of ceremonies for a session of the American Surgical Association in 1969 when I presented early results of gastric bypass. Wangensteen stated, “Just one final question. You said nothing about vagotomy. Do you do vagotomies with these or not?” Wangensteen was concerned about stomal ulcers resulting from an exclusion operation although we had shown in the animal laboratory that gastric bypass decreased the acid secretory response to a meal. Later, we also showed that gastric secretion in response to a meal was suppressed after
gastric bypass.\(^7\) However, there remained occasional stomal and duodenal ulcers following gastric bypass. Closed segment obstruction of the bypassed upper gastrointestinal tract, metabolic bone disease, and iron deficiency anemia are some of the other lifelong problems of gastric bypass.

**ELIMINATING THE COMPLICATIONS OF GASTRIC BYPASS BY PERFORMING GASTROPLASTY**

Early in 1971 the question was posed: if intake deficiency was the mechanism of weight loss after Billroth II gastric resection and gastric bypass, why not create a small meal-sized pouch and keep the rest of the anatomy normal? Instead of a gastroenterostomy, the pouch would empty into the distal stomach. We called this “gastroplasty.”\(^5\) The greater curvature stoma of the Billroth II gastric resection was retained.

This initial attempt to replace gastric bypass with gastroplasty failed within the year.\(^6\) The pouch was unmeasured and too large. Both the pouch and outlet stretched. By the end of 1971 it was obvious that gastroplasty was not providing the patient with sufficient weight loss. We returned to the use of gastric bypass. However, changes in the technique were made in gastric bypass that were carried over to gastroplasty when subsequent efforts were made to use that simpler approach. Alden’s stapling-in-continuity for loop gastric bypass was one of these.\(^7\) Another was Alder and Terry’s 1977 recommendation that pouches be measured.\(^9\)

**STABILIZING THE OUTLET**

In 1977 Gomez resutured gastroplasty but with a Dacron mesh collar to stabilize the greater curvature outlet.\(^9\) Gomez believed that the obstruction that he observed with Dacron mesh in his initial patients was due to stricture from contracting scar tissue. Gomez then substituted a running, double-filamented polypropylene mesh (Prolene, Ethicon Inc, Somerville, NJ), seromuscular suture around the outside of the stoma as a replacement for the mesh. Many of us used this modification of gastroplasty for a few years. The polypropylene suture occasionally created early edema and obstruction. Later it migrated into the lumen. The outlet then dilated and weight gain followed.

I visited John Kroyer, MD, in Long Beach, Calif, who had an extensive but unpublished experience using monofilamented polypropylene mesh (Marlex; Davol Inc, Cranston, RI) on the greater curvature for stabilization of the outlet. Like Gomez, he observed obstruction after several of his early operations, but he found that it was due to distortion of the outlet from adhesions that occurred between the monofilamented polypropylene mesh and adjacent structures after the mobilized stomach returned to the attic of the abdomen. Once the adhesions were divided and the pouch brought down to the position it had been when the staple line was created, a 32F bougie would pass easily through the outlet, indicating that there was no stricture. Kroyer added a gastropexy between distal stomach and the anterior abdominal wall to hold the stomach in the lower position to prevent kinking of the greater curvature outlet of the fundic pouch. Grace\(^10\) also used a monofilamented polypropylene mesh collar in horizontal gastroplasty to stabilize the greater curvature stoma. Grace covered the monofilamented polypropylene mesh with omentum to prevent adherence to surrounding structures. Grace ultimately abandoned horizontal gastroplasty because of occasional migration of the monofilamented polypropylene mesh into the lumen.\(^11\)

I would not have used monofilamented polypropylene mesh in vertical banded gastroplasty (VBG) if it had not been for my exposure to Kroyer’s experience with horizontal gastroplasty. I became aware of Grace’s experience later after VBG was begun. In the early days of VBG, a patient of Cornelius Doherty, MD, developed an obstructing kink caused by an adhesion between the mesh and the left lobe of the liver. This led to the routine use of omentum to cover the mesh in the collaborative study of the operation.\(^12\) Doherty was in private practice in San Francisco, Calif, at that time. Later he joined the staff at the University of Iowa, Iowa City. When monofilamented polypropylene mesh is used in simple primary gastroplasty, it is rapidly covered with living tissue. This creates an additional layer over the outlet wall. The monofilamented polypropylene mesh is rapidly covered by connective tissue and serosa. As a result, the mesh is protected from infection; migration of the mesh into the lumen is rare after primary operation.

Pace et al\(^13\) reported use of gastric partitioning in 1979. This consisted of a horizontal, double row of staples with staples removed from the middle of the staple cartridge to create the stoma. Simplicity was the attraction of partitioning. With the midstaple-line location of the stoma in the operation by Pace et al, the staples pulled through on both sides. Reinforcement with Teflon pledges, sewn into the staple line on both sides of the stoma, migrated into the lumen. Such suturing causes necrosis of underlying tissue and an avenue for bacteria to reach the foreign material.

**AVOIDING PISTOL-SHOT PERFORATIONS IN SMALL POUCHES**

Nasogastric tube suction was routine during the early days of gastric reduction surgery, as it was during the use of gastrectomy for treating duodenal ulcer. However, a new problem was created when semistiff, hard-nosed, nasogastric tubes were used in patients who had small horizontal pouches. The nasogastric tube was under tension from anastomosis at the cardia and again at the outlet of the pouch. Surgeons began to exchange telephone calls and letters about pistol-shot-like perforations of the stomach in patients who underwent gastric bypass and gastroplasty. At first these were considered stress ulcers and patients were treated with medication to suppress acid secretion.

The true cause of pistol-shot perforations became apparent when I operated on one of my patients for a leak and found the end of the tube protruding through the hole. With larger gastrectomy pouches, erosion by nasogastric tubes was seldom, if ever, seen. With smaller pouches, the end of the semistiff tube pressed at a single point on the
The plications of Tretbar et al.\textsuperscript{14} and Wilkinson et al.\textsuperscript{15} helped us break with the past and to think about the capacity of the stomach by plication, wrapping the greater curvature and with the outlet stabilized by a Silastic ring.\textsuperscript{16} The stomach unfurled, and so Tretbar et al.\textsuperscript{14} published their experience with gastric plication in 1976. The stomach unfurled, and so Tretbar et al.\textsuperscript{14} began making a lesser curvature pouch by stapling. It was Tretbar's hypothesis that a long narrow pouch (18 cm over a 36F bougie) along the lesser curvature (ma-genstrasse) would not need a collar. Tretbar wanted to call the operation "fundal exclusion." Exclusion to me meant that no food could enter that area. Exclusion had a long and alarming history involving the antrum and ulcerogenesis. It was at this time that "horizontal" and "vertical" were imbedded in the lexicon of gastroplasty. Gastroplasty had been horizontal with the greater curvature stoma because that was the way Billroth II gastrectomy pouches were created. When making up the program for our yearly colloquium on obesity surgery at the University of Iowa in 1977, I asked Tretbar to emphasize the position of the staple line in the title. When Tretbar presented his paper, he began by reviewing our remaining difference in opinion about the title by saying, "If this operation is successful, it will be called 'vertical gastroplasty' and if not, it will be called 'fundal exclusion.'"

Wilkinson et al.\textsuperscript{15} also attempted to reduce the capacity of the stomach by plication, wrapping the greater curvature around the lesser curvature like an extensive slipped Nissen. Because the stomach would not stay plicated, Wilkinson appealed to his wife for help. Mrs. Wilkinson constructed a monofilamented polypropylene mesh garment that was applied to the stomach to reduce its capacity. This technique was applied first in laboratory animals and then in patients.\textsuperscript{15} Many of these patients required removal of the wrap; this was a difficult operation. The plications of Tretbar et al.\textsuperscript{14} and Wilkinson et al.\textsuperscript{15} helped us break with the past and to think about vertical pouches. Semantics is important. There was a field change in discovery of vertical pouches.

Laws and Pantadossi\textsuperscript{16} described a vertical gastroplasty with both pouch and outlet located on the lesser curvature and with the outlet stabilized by a Silastic ring of 3-mm tubing threaded and sewn in place through the lower end of the staple line with a nonabsorbable suture. Laws recommended suturing adjacent stomach over the ring.\textsuperscript{17} Eckhout and Willbanks\textsuperscript{18} discovered that the covered ring migrated into the lumen, but migration did not occur when it was uncovered.

A 30F or 32F dilator was placed in the outlet of the pouch for calibration when the suture through the lumen of the tubing and the staple line was tied in Silastic ring gastroplasty. This can be described as internal calibration since the bougie in the lumen is the calibrating instrument. Such calibration introduced a new problem. The experience with this operation at the University of Iowa was mainly in revisions when the outlet was too narrow owing to the tension on the suture when tied. One way to avoid excessive tension during the tying would have been to use a 12-mm-diameter tonometer in the lumen. Kuzmak\textsuperscript{19} introduced this technique for internal calibration during gastric banding.

When internal calibration is used, as in Silastic ring gastroplasty, the lumen diameter may decrease depending on the degree of compression from the tying and the amount of stomach included in the outlet. It should be possible after the suture is tied and the bougie pulled back into the pouch to again pass a 32F bougie easily through the outlet to assure that the lumen is adequate. If this is impossible, then the ring is too tight and immediate replacement may save the patient's need to undergo a surgical revision. Should such a ring require later removal, it is possible to determine the intent of the surgeon by measuring the length of the Silastic ring (tubing) and to determine the actual circumference obtained by measuring the length of the removed suture that held the ring in place.\textsuperscript{20}

Michael Long, MD, in Melbourne, Australia, changed the outlet of horizontal gastroplasty from greater to lesser curvature in 1977. By 1981 he had also changed the slope of the partition from one that slanted slightly upward on the greater curvature to one that was vertical and ended (or began) at the esophagogastric angle of His. In 1987 Long and Lindsey\textsuperscript{20} added 2 braided-suture ligatures (Ethibond; Ethicon, Somerville, NJ) for stabilization of the outlet. Long presented this experience at a meeting in Genoa, Italy, in the fall of 1980. One of Long's surgical residents, Andrew Jamieson, MD, reduced the pouch size and added a third outlet suture, which lengthened the stabilized area to 22 mm.\textsuperscript{21} Jamieson has continued to use this operation and has experience with more than 3000 patients. The operation needs adaptation to the laparoscopic approach if it is to be widely adopted. Because there is no circular stapler window, the stapling (in continuity) is from the angle of His and parallel to the lesser curvature. This requires a small diameter stapler that can be maneuvered safely into position laparoscopically. Changing the staple line from horizontal to vertical made the outlet a part of the pouch instead of a defect in the partition. This eliminated the unzipping of the staple line, which started at the stoma in horizontal gastroplasty.

**INTRODUCING VBG**

In November 1980 I began using VBG with a measured pouch of 50 mL or less (ultimate recommendation =20 mL) and the outlet stabilized with a collar of monofilamented polypropylene mesh. A 30F or 32F bougie was also placed in the outlet of the pouch. As the suture was tied, the bougie was pulled back into the pouch to again pass a 32F bougie easily through the outlet to assure that the lumen is adequate. If this is impossible, then the ring is too tight and immediate replacement may save the patient's need to undergo a surgical revision. Should such a ring require later removal, it is possible to determine the intent of the surgeon by measuring the length of the Silastic ring (tubing) and to determine the actual circumference obtained by measuring the length of the removed suture that held the ring in place.\textsuperscript{22}
mented polypropylene mesh 15 mm wide (outlet length) and 5.0 cm in circumference when sewn in place. A circular stapler was used to create a window through which the collar could be placed so that it would not be sewn to the stomach wall. This window was also used for placement of the linear stapler. Outlets have area, diameter, and outer circumference as well as length.

Collars of 4.5, 5.0, and 5.5 cm in circumference were studied over a 3-year period with the conclusion that 5.0 cm should be used for all patients. The 5.5-cm-circumference collar did not provide as much weight loss as the 5.0-cm collar. The 4.5-cm-circumference collar, which was used at the University of Iowa in super obese patients, resulted not only in an increase in weight loss but also in an increase in revision rate.

**OBSTRUCTING THE VBG POUCH CAUSES COMPLICATIONS**

The position of the circular stapler window is important in the construction of a proper outlet for the pouch in VBG. There should be enough stomach wall in the outlet to provide protection of the collar when a bolus of food passes through the outlet. Makarewicz et al described applying the circular stapler tightly against the indwelling tube and using a 28F nasogastric tube. They soon switched to a 32F Ewald tube. There should be enough stomach under the collar to fill the collar. Pulling the stomach wall tightly around the tube can result in insecure stapling in addition to leaving too little stomach under the collar to fill the collar. Pulling the stomach wall tightly around the tube can result in insecure stapling in addition to leaving too little stomach wall.

The goal of Makarewicz et al seems to have been to improve weight loss by obstructing the pouch. They used a 4.5-cm-circumference collar and provided a feeding jejunostomy for use during the first 3 weeks. They abandoned the operation because too many of their patients did not reach a goal of losing at least 30% of their starting weight.

In 1987 MacLean et al reported that in contrast to other weight reducing operations, VBG resulted in rapid weight loss without the concomitant development of malnutrition even in patients who return to normal weight. In 1990 MacLean et al wrote about a series of 180 of 201 patients with an (outlet) orifice of 40 to 45 mm external circumference, which is smaller than that originally described by Mason. MacLean et al also used 2 layers of monofilament polypropylene mesh. There is a race between fibroblasts and bacteria for foreign material. Once the mesh is covered, it is protected from infection by a living surface. Two layers of mesh must have contributed to some of the difficulty that these patients had. MacLean et al were concerned that these collars might be too small because they provided each patient with a distal feeding gastrostomy for the first 6 weeks. This would also seem to increase the risk of contamination of the mesh. The modifications by MacLean et al resulted in a 48% revision rate owing to staple-line breakdown, outlet stenosis, and migration of collars into the lumen.

MacLean et al then made further modifications of VBG in an effort to reach a predetermined weight loss goal while reducing the reoperation rate. A 28F bougie was used in the lumen when the circular stapler window was made, which may have limited the amount of stomach in the outlet just as was the case with the patients of Makarewicz et al. The monofilament polypropylene mesh was 45 to 47 mm in external circumference, closer to the recommended 5.0 cm. However, the double layer of the monofilament polypropylene mesh was retained. The stapled stomach was divided and a temporary gastrostomy used, both of which increase the risk of contamination of the mesh. Weight loss was better than had been reported by others and was proportional to the operative weight, but did not meet the goal of MacLean et al. The reoperation rate for erosion, stenosis, and failure to lose weight remained high at 36% although there was only 1 fistula between the pouch and the main stomach.

MacLean et al then used this modified VBG in a randomized comparison with Roux-en-Y gastric bypass. A drain was used in all patients for 3 to 4 days, which may have added another avenue for contamination of the mesh. The distal gastrostomy was left in place for 6 weeks as before. The circular stapler window was made next to a 28F bougie, which leaves less stomach wall in the outlet. The staple line was divided, which adds to the risk of contamination of the mesh. A 43% reoperation rate resulted. An update of this trial was published reporting a reoperation rate of 48% chiefly due to stenosis or enlargement of the orifice (after migration of the double collar into the lumen).

Naslund et al also modified VBG by using a larger pouch than we found satisfactory (20-90 mL), an unmeasured Silastic band instead of external calibration with a 5-cm-circumference monofilament polypropylene mesh, and internal calibration using a 32F indwelling bougie. This was followed by reoperations in 14% of their patients, which they stated was much better than the 48% reported by MacLean et al. This is another article that reports changes in technique and then concludes that VBG is an unsatisfactory operation.

The use of the laparoscopic approach might not seem to have an effect on technique, but it makes measurement of pouch volume more difficult and less likely as was noted by Naslund et al in a later study. In this study expanded polytetrafluoroethylene (Gore-Tex; W. L. Gore & Associates Inc, Flagstaff, Ariz) was also substituted and the calibration was internal (tying around a 32F bougie) in earlier patients and then external (measuring the band at 5 cm and then sewing by the marks) in later patients. Reoperations were noted to be often required because of staple-line breakdown.

Technique is important not only for success in individual patients but also for the use of an operation in the treatment of obesity by all surgeons. Technical details influence (1) results; (2) satisfaction of patients and surgeon; and ultimately, (3) the choice to continue use of or to discard an operation. Unsatisfactory results indicate a need to search for changes that may have been made in the recommended technique. This applies not only to the experience of individual surgeons but also to interpretation of the surgical literature. Even randomized prospective studies must be read with care, asking the question whether the operations being compared are in wide use or have been changed. Also, a search of the literature should be made for articles in which the origi-
Sugerman et al36 have written about the improved weight loss from selecting gastric bypass for sweets eaters and like peptide 1 is a beneficial hormone for patients with type 2 diabetes mellitus. Glucagonlike peptide 1 release seems to explain these observations. This knowledge has not yet resulted in a return to use of intestinal bypass. It does explain some of the attraction of gastric bypass over gastroplasty.

Sugerman et al35 conducted a prospective randomized comparison of Roux-en-Y gastric bypass and VBG in controlling weight, based on a history of eating sweets. Sugerman et al35 have written about the improved weight loss from selecting gastric bypass for sweets eaters and limiting gastroplasty to nonsweets eaters. Lindroos et al,37 in a detailed study of 269 patients who underwent VBG and 106 who underwent gastric bypass, found that weight loss was not predicted by preoperative sugar consumption. More study was recommended. MacDonald et al38 have shown that gastric bypass decreases the mortality in obese patients who have diabetes mellitus. This may be sufficient reason for patients with morbid obesity and type 2 diabetes mellitus to accept the lifelong risks of gastric bypass. There may be a place for adding an intestinal bypass instead of converting gastroplasty to gastric bypass. There is need for further study.

RECOMMENDING GASTROPLASTY FOR PATIENTS WITH A BODY MASS INDEX BETWEEN 35 AND 45

Sjöstrom39 has recommended at least 1 obesity center for each 500000 population in developed countries. He has also indicated a need for 500 to 1000 operations per year for the treatment of obesity for each center. Sjöstrom, an internist, is comparing 2000 patients operated on for obesity with 2000 matched-control subjects. This Swedish Obese Subjects (SOS) study has been continuous for more than 10 years. Sjöstrom recommends that gastroplasty be used in patients whose body mass index is between 35 and 45, with gastric bypass restricted to use in heavier patients. He also recommends that gastric bypasses be restricted to centers where lifelong follow-up can be assured. In the Swedish Obese Subjects study, technical details could be a gold mine of information about the long-term effects of operations for obesity.

Surgeons, when in the operating room, must be consistent in measuring, recording, and following exact specifications if they are to continue to improve results. The Wangensteens' subtitle of their historical treatise, The Rise of Surgery, From Empiric Craft to Scientific Discipline,60 the history of development of gastroplasty has given me a greater appreciation of the thought behind the Wangensteens' subtitle.

PREDICTING THE FUTURE OF GASTROPLASTY

I believe we could provide optimum lifelong care, for more patients, by making greater use of VBG. Vertical banded gastroplasty, performed according to the recommended technique, remains a valuable operation. Lee et al41 have developed a laparoscopic VBG that is technically close to the open operation developed at the University of Iowa. Jamieson's technique for Long gastroplasty is also attractive, but needs adaptation to the laparoscopic approach. Gastroplasty does not disturb anatomical and functional relationships of the upper gastrointestinal tract. It avoids the complications peculiar to gastric bypass.

There is more to the care of the persons with morbid obesity than an operation. There are many severely obese persons who need counseling regarding a history of adverse childhood events.62 Schwartz et al43 found that revision surgery for Roux-en-Y gastric bypass was not worthwhile when the goal was to improve weight control. This also applies to VBG if the pouch remains small, intact, and without any anatomical abnormality. Counseling and efforts to help patients with the effects of adverse childhood events is often needed before converting a failed gastroplasty to a more malabsorptive operation. Roux-en-Y gastric bypass also fails to control weight long-term for some patients, which has led surgeons to increase the malabsorption component. This increases the risk of malnutrition especially if the patient is provided a small gastric pouch and a short common limb.

The recent appearance of new knowledge about the harmony of hormones and hypothalamic neurons that control hunger, satiety, and body weight reminds us of the complexity of both stomach physiology and weight control.44 Ghrelin, a hormone that increases food intake in rodents and humans, has just been discovered.44 It is produced in the stomach, stimulates hydrochloric acid secretion, and is a powerful stimulus of hunger. PYY3-36, a Y2R agonist produced in the intestine after a meal, has been discovered to induce a strong feeling of satiety.46
Ghrelin and PYY3-36 open new avenues for development of effective medicinal treatment of obesity. This adds to the need for surgical conservatism lest we create a greater need for medical care than is necessary, or that can be provided for the increasing number of candidates for surgical treatment of obesity.

There remains a need for gastropasty in the treatment of obesity by surgeons and for their patients, who have discussed the short- and long-term implications of simple and complex operations and have agreed to (1) set a realistic weight loss goal, (2) preserve a near-normal anatomy, (3) avoid gastric bypass complications, and (4) use other forms of treatment as needed and as they become available.

Accepted for publication December 17, 2002.

Corresponding author: Edward E. Mason, MD, PhD, Department of Surgery, University of Iowa Hospitals and Clinics, Iowa City, IA 52240 (e-mail: edward-mason@uiowa.edu).

REFERENCES