

# The Magenstrasse and Mill Operation for Morbid Obesity

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**Background:** Our aim was to evolve a simpler, more physiological type of gastroplasty that would dispense with implanted foreign material such as bands and reservoirs. The Magenstrasse, or “street of the stomach”, is a long narrow tube fashioned from the lesser curvature, which conveys food from the esophagus to the antral Mill. Normal antral grinding of solid food and antro-pyloro-duodenal regulation of gastric emptying and secretion are preserved.

**Methods:** 100 patients with morbid obesity (83M, 17F, mean age 40 years) were treated by the Magenstrasse and Mill procedure and followed-up for 1–5 years. Mean preoperative BMI was 46.3 kg/m<sup>2</sup>, and mean excess weight was 106%.

**Results:** Operative mortality was 0. Major complications occurred in 4% of patients. There were few side-effects, although mild heartburn was fairly common. Mean weight loss was 38 kg (±14 kg), equivalent to 60% of excess weight, achieved within 1 year of operation, after which no further significant gain or loss of weight occurred.

**Conclusions:** The Magenstrasse and Mill procedure is the simplest and most physiological gastroplasty yet described. Many of the drawbacks of vertical banded gastroplasty, adjustable banding and gastric bypass are avoided. It is safe, has few side-effects and leads to major and durable weight losses, similar to those produced by other types of gastroplasty.

*Key words:* Bariatric surgery, gastroplasty, banded gastroplasty, gastric bypass, antral mill, morbid obesity, lesser curvature

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## Introduction

The world-wide epidemic of obesity continues its relentless advance. In Britain, 20% of adults are now obese,<sup>1</sup> three times as many as 20 years ago. Even children and adolescents are developing co-morbid conditions such as type 2 diabetes, while an increasing proportion of adults suffer the full range of co-morbidity, such as social isolation, unemployment, depression, diabetes, cardiovascular disease, and even premature death. Clearly, medical treatment with diet, drugs and modification of lifestyle has had little effect, at least when whole populations are considered.

For these reasons, we think that obesity should be regarded as a disease, and that like any other disease, it should be diagnosed early and treated promptly and effectively: by medical means, certainly, at first, but if that approach should fail, then surgically. Surgical intervention seems particularly desirable when obesity is accompanied by co-morbid conditions such as hypertension or impaired glucose tolerance. The aim should be to prevent the onset of *clinical* cardiovascular disease or of type 2 diabetes with all its complications. Just as important, the aim of timely surgical intervention is, as one of our patients put it, “to give her back her life”: a social life, a job, a chance for happiness.

If surgery is to have a major role in the control of

obesity, it must not only be effective in producing loss of weight, but must also be safe, lead to few side-effects and metabolic sequelae, and ideally be simple, “low-maintenance” and capable of being performed laparoscopically. None of the established operative procedures, such as vertical banded gastroplasty (VBG) or gastric bypass, satisfies all these criteria. In this paper, we describe a very simple type of gastroplasty, the Magenstrasse and Mill procedure, which meets most of these requirements. Unlike VBG and gastric banding, it does not leave foreign material within the abdomen. We found that it produced few side-effects and was as effective as the more traditional types of gastroplasty in producing substantial weight loss.

## Materials and Methods

### Subjects

One hundred patients operated on for morbid obesity between 1992 and 1998 were studied before and for up to 5 years after the Magenstrasse and Mill (M&M) procedure. A further 30 patients (23%) treated by the M&M procedure in the same period were lost to follow-up, because of change of address, unwillingness to attend or because they lived a long way from Leeds.

Of the patients, 83 were female and 17 were male. Their mean age was 40 years (range 20-60), their mean weight 127 kg (89-222, SD 24) and mean BMI 46.3 kg/m<sup>2</sup> (36-82, SD 7.1). Their mean *excess* weight, compared with ideal body weight,<sup>2</sup> was 106% (61-298%). Each patient had a BMI >35, and each had failed to lose weight or to maintain weight loss over many years, despite conventional medical treatment with diets, drugs and behavior modification. Eighty-two patients were followed up for 1 year, 63 for 2 years, 47 for 3 years, 38 for 4 years and 16 for 5 years. Follow-up was in a special gastric follow-up clinic, where patients were reviewed 6 monthly for 2 years, and annually thereafter. They were weighed, questioned in detail about specific side-effects such as pain, vomiting and heartburn, and about overall quality of life; venous blood was taken for routine analysis.

### Magenstrasse and Mill Procedure: Operative Technique

A midline epigastric incision is used. Mechanical retraction is provided by a metal frame (Omnitract®) that permits strong upward retraction of the rib cage, to provide better access to the upper stomach and esophagus. If gallstones are present, the gallbladder is removed. A 32-F bougie is passed through the mouth into the stomach, whence its tip is guided into the duodenum. Access to the lesser sac and posterior wall of the stomach is obtained by creating a large window in the gastro-colic omentum. Relaxation of the gastric smooth muscle is secured by the intravenous injection of 20 mg Buscopan® (hyoscine butylbromide). A circular stapling device (CEEA gun) is then used to create a defect in the gastric antrum, just beyond the incisura angularis, 5-6 cm from the pylorus (Figure 1). Three technical points are worthy of emphasis here:

- 1) The bougie is held firmly against the lesser curvature, so that the Magenstrasse is no larger than the diameter of the bougie. Use of a muscle relaxant to render the stomach flaccid helps in achieving the same objective.
- 2) At least one major terminal branch of the nerve of Latarjet should be preserved on the anterior and posterior walls of the antrum. The “Mill” is short, 5-6 cm only.
- 3) A wide passage must be left along the greater curvature to permit unobstructed flow of fluid from the excluded fundus and body of the stomach into the antrum: hence, a small circular stapler is used.

The “doughnuts” of gastric wall are extracted, and a long GIA linear stapler is then used to create the

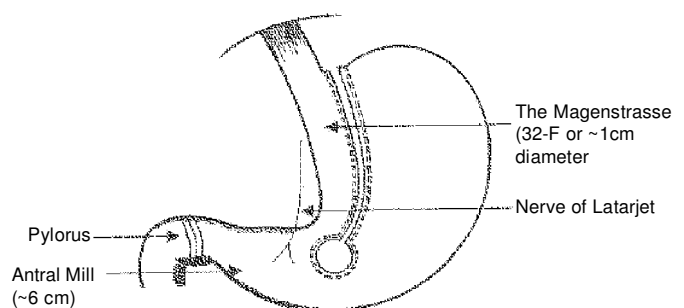


Figure 1. The Magenstrasse and Mill operation.

Magenstrasse, or “street of the stomach”, by dividing the stomach completely from the circular hole in the antrum to the angle of His (Figure 1). The surgeon's left hand holds the bougie closely pressed against the lesser curvature, while an assistant exerts traction on the mobilized greater curvature. These manoeuvres ensure that the calibre of the gastric tube or Magenstrasse accurately reflects the calibre of the bougie. At least three applications of the GIA instrument are usually needed to divide the body and fundus of the stomach completely from the Magenstrasse. The final application, near the esophagus, may prove difficult if access is restricted, and we then use a long endo-GIA laparoscopic stapling instrument to separate the fundus from the Magenstrasse. The free stapled edges of stomach are oversewn with running absorbable sutures to reinforce the staple-lines, ensure hemostasis and prevent fistulation between the gastric tube and the excluded body of the stomach.

### Calibre of the Magenstrasse

The first Magenstrasse and Mill procedure was performed by David Johnston in 1987. Between 1987 and 1992, a 40-F bougie was used to calibrate the Magenstrasse, but we found that weight regain was a significant problem (see Discussion). These patients are not included in this study. The calibre of the graduating bougie was therefore decreased progressively from 1992 onwards, from 36 to 34 and finally to 32-F. Satisfactory and durable weight losses were then achieved, even with the 36-F bougie, but since weight loss after use of the 32-F bougie was slightly greater than after use of the 34 or 36-F bougies (see Discussion), without any discernible increase in side-effects, we finally settled on the use of the 32-F bougie. In this study, the calibre of the Magenstrasse was 36-F in 41 patients, 34-F in 21 patients, 32-F in 34 patients and 30-F in 4 patients. Weight losses did not differ significantly among these groups, and the results have therefore been analyzed together.

### Postoperative Care

Use of epidural anesthesia helps the patient breathe deeply and expectorate bronchial secretions. Prophylactic antibiotics are given during the opera-

tion and for 24 hours after operation. Low-dose heparin, intermittent calf compression and physiotherapy are each used to try to prevent deep venous thrombosis. The patient is nursed on a high dependency unit for 24 h after operation. Oral fluids are commenced on day 2 and gradually increased. The patient leaves hospital 5-8 days after the operation.

### Statistical Analysis

Data are expressed as mean and standard deviation. Kruskal-Wallis ANOVA with repeated measures was used to analyze weight loss after the operation, with Mann-Whitney U testing used as post-hoc analysis.

## Results

### Mortality and Morbidity

There was no operative mortality. There have been no late deaths related to the procedure during follow-up, and all re-operations (see below) were accomplished without mortality.

Major operative or postoperative complications occurred in five (4%) of the 123 patients. One patient developed hemorrhage at operation from a tear of the inferior vena cava at the site of entry of the left hepatic vein. Pressure and direct suture controlled the bleeding, but minor ooze persisted, so a pack was inserted and removed under anesthesia 2 days later. A pericardial effusion developed and was drained at thoracotomy.

In the second patient, a fistula developed from the excluded gastric fundus, resulting in a left subphrenic abscess. At re-operation, pus was drained and the gastric fundus, spleen and tail of pancreas were resected. CT-guided drainage of the left subphrenic space was subsequently required. The patient also developed a pulmonary embolus and required anti-coagulation, but eventually made a good recovery

The third patient developed a left subphrenic abscess, which was drained at re-operation, but a fistula developed from the proximal end of the Magenstrasse, which healed after several weeks of parenteral nutrition.

The fourth patient also developed a subphrenic abscess secondary to a leak from the gastric fundus, which was drained at re-operation, with resection of the upper half of the excluded stomach.

Finally, one patient required splenectomy at the time of the initial operation, because of persistent hemorrhage from a tear of the splenic capsule.

### Elective Re-operations

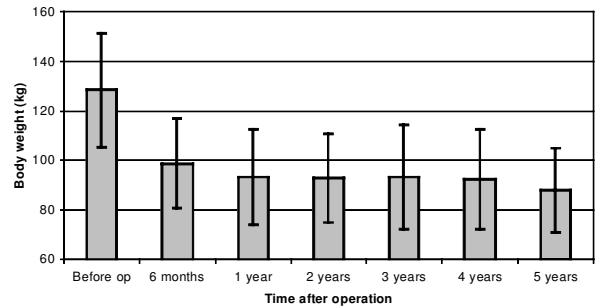
No other emergency re-operations were required, but 8% of patients underwent elective re-operation for repair of incisional hernia and 28% have undergone “apronectomy”. Only one patient (1%) has undergone re-operation on account of inadequate weight loss: Roux-en-Y gastric bypass was performed 2 years after the M&M procedure.

### Weight Loss

Details of weight loss are given in Table 1 and shown in Figures 2 and 3. All patients lost weight. Mean weight loss 1 year after operation was 38 kg, which represented 29% of preoperative weight and 58% of excess weight. Two years after the operation, mean weight loss was 41 kg, equivalent to 31% of preoperative body weight and 61% of excess weight. Thereafter, no further significant gain or loss of weight took place, and mean weights 3, 4 and 5 years after operation were little different from weights 1 and 2 years after operation (Table 1, Figures 2 and 3). Loss of >50% of excess weight was recorded in 72% of patients after 1-3 years of follow-up. However, only 30% of patients achieved a BMI of less than 30, and 11% of patients remained morbidly obese (Table 1).

**Table 1.** Analysis of weight loss after the Magenstrasse and Mill gastroplasty

Total weight loss %	% of patients	% Excess weight loss	% of patients	BMI 1-3 yrs after operation	% of patients
>20%	79	>30%	97	<25	4
>25%	63	>40%	86	25-30	26
>30%	43	>50%	72	30-35	41
>40%	8	>60%	39	35-40	18
>50%	1	>70%	16	>40	11



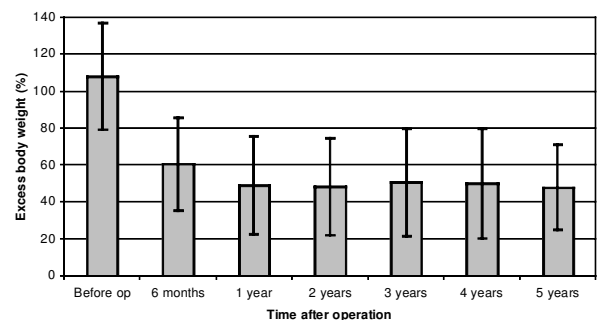
**Figure 2.** Total body weight before and after the Magenstrasse and Mill procedure.

### Side-Effects of Operation

Apart from the expected inability of the patients to eat large meals, or to eat quickly, there were remarkably few side-effects. Patients were usually able to eat normal, solid food, albeit in smaller quantities than before operation. Dumping, diarrhea and vomiting, in particular, were notable by their absence. A few patients (6%) developed constipation. Mild intermittent dysphagia was experienced by 5% of patients, but none required endoscopic dilatation. The most frequent side-effect was heartburn or indigestion, which occurred in 28% of patients, and which usually responded well to use of H<sub>2</sub>-receptor antagonists or proton pump inhibitors. In most patients, heartburn and reflux improved with time, as weight diminished, and were thus regarded as mild. No patient developed peptic ulceration of the stomach or duodenum.

### Metabolic Sequelae

No evidence of vitamin B<sub>12</sub> or folate deficiency was found at annual hematological check-ups. One patient developed mild iron-deficiency anemia, pos-



**Figure 3.** Percentage of excess body weight before and after the Magenstrasse and Mill procedure.

sibly unrelated to the operation. Megaloblastic anemia was not recorded. There has been no sign of bone disease so far.

## Discussion

The Magenstrasse and Mill (M&M) procedure differs fundamentally from other types of gastroplasty, such as the *original* "horizontal" gastroplasty introduced by Printen and Mason in 1973.<sup>3</sup> Unlike VBG,<sup>4</sup> no foreign material such as mesh or silastic band<sup>5,6</sup> is used to control outflow of food from a small gastric pouch. It differs also from adjustable gastric banding in that no band, subcutaneous reservoir or connecting tubing is used. The idea for such a simple procedure arose in part from our disillusionment with VBG, which in our hands, as in others',<sup>7,8</sup> yielded poor results because of band erosion, fistulation and a high rate of re-operation. We were reluctant, however, to resort to the routine use of Roux-en-Y gastric bypass (RYGBP), because of its greater operative risk, side-effects and potential long-term sequelae such as anemia,<sup>9</sup> bone disease<sup>10</sup> and peptic ulceration.<sup>11</sup> We therefore developed the M&M procedure as a relatively physiological and "low-maintenance" alternative to VBG and RYGBP. We hoped that the Magenstrasse would still convey normal, solid food (rather than the purées that often have to be ingested after VBG) to the antral mill, which would continue to subserve its normal functions of mixing, grinding, retropulsion and, finally, well-regulated expulsion of chyme into the duodenum.<sup>12,13</sup> There, normal mixing with bile and pancreatic juices should ensure normal absorption of iron, calcium and vitamins. We also thought that preservation of the "acid stream" from the excluded fundus and body of the stomach over the antral mucosa would inhibit gastrin release, evoke normal inhibitory mechanisms in the duodenum and thus avoid problems with peptic ulceration in the long term.<sup>14</sup> The advantages of dividing the stapled gastric pouch from the remainder of the stomach are well documented,<sup>11,15,16</sup> whereas there is a relatively high incidence of gastro-gastric fistula formation and ulceration if the stomach is stapled in continuity.

We were, at the time, unaware of the work of

Tretbar, who used a TA90 linear stapler to staple the stomach vertically downwards from the angle of His and who reported encouraging early results in abstract form.<sup>17</sup> Tretbar's gastroplasty differed from the M&M procedure, however, in certain important respects. The gastric tube that he created was shorter than the Magenstrasse which we describe, the graduating bougie that he used was wider, and the stomach was not divided but rather stapled. Thus, several apparently minor differences in operative technique may explain the long-term failure of the Tretbar procedure, compared with the results that we describe. It is interesting that Tretbar states that as time went on he reduced the size of the graduating bougie, just as we did.<sup>17</sup> Our early efforts, before the series reported here, in which a 40-F bougie was used, were also encouraging initially, but were ultimately disappointing because of early weight regain, whereas when we progressively decreased the diameter of the bougie, greater and more durable weight losses were obtained. For example, the mean weight loss after use of a 40-F bougie was 25% at 2 years after operation, compared with 31% in this study; and after 3 years, only 19%, compared with 30% in this study. Thus, significant increases in weight were observed within 2-3 years of operation when a 40-F bougie was used in construction of the Magenstrasse, whereas when narrower (32-36 F) graduating bougies were used, significant regain of weight did not take place among 47 patients who were followed for 3 years, 38 patients followed for 4 years and 16 patients followed for 5 years after operation.

The overall clinical results obtained 1-5 years after the M&M procedure were also very encouraging. Operative mortality in the 100 patients reported here was 0, and indeed there has been no operative mortality among the 230 patients who have been treated in this hospital by the M&M operation. Serious postoperative complications occurred in only 4% of patients, and there have been no later emergency re-operations. Side-effects such as dumping, diarrhea and vomiting have been absent, and aside from the inevitable restriction in the size of meals, the only significant side-effects have been mild dysphagia (5%), and heartburn (28%) which was mild and responsive to antacids in most patients. Because mild heartburn is also common among obese patients before operation, it is possible

that in many cases the symptom was not actually caused by the operation.

Weight loss itself was satisfactory in most patients (Table 1, Figures 2 and 3), averaging 60% of excess weight. Mean BMI decreased from 46 to 32. These weight losses are similar to those reported after other types of gastroplasty<sup>7,18-20</sup> and gastric banding,<sup>21</sup> but are somewhat less than those achieved after RYGBP.<sup>22</sup> Maximal weight loss was usually achieved 1 year after operation, after which no significant increase in weight occurred.

Mean loss of excess weight at 1-3 years was 63% after use of the 32-F bougie, 60% with the 34-F bougie and 58% with the 36-F bougie. These differences were not statistically significant, but since side-effects were no greater when the 32-F bougie was used, we have continued to favor use of the 32-F bougie.

The success of anti-obesity operations cannot be judged simply by the degree of weight loss. Rather, it is a function of many "domains".<sup>23,24</sup> If crude yardsticks such as a BMI <35, loss of >50% of excess weight or loss of >25% of total body weight are used, approximately 70% of our patients were successful in losing adequate amounts of weight (Table 1).

Previous publications by our group described the effects of the Magenstrasse and Mill procedure on gastric emptying,<sup>25</sup> quality of life<sup>24</sup> and risk of coronary heart disease.<sup>26</sup> These studies were carried out in various sub-groups of patients who were operated upon between 1987 and 1994, and thus represent different or overlapping groups of patients from those described in this paper. The M&M procedure was successful in improving risk factors for cardiovascular disease, such as hypertension and dyslipidemia, and lowered the Framingham risk score in high-risk individuals.<sup>26,27</sup> Similarly, in unpublished studies, we have found that the M&M procedure has a beneficial effect on diabetes, abolishing impaired glucose tolerance in all patients who have this before operation and improving or abolishing diabetes in most patients with established type 2 diabetes. These findings are in agreement with previous reports that successful bariatric surgery "cures" type 2 diabetes in most diabetic patients.<sup>28,29</sup> Not a single patient has developed peptic ulceration after the M&M procedure, which suggests that gastrin release from the antral mucosa is not excessive and

that gastric stasis is absent. Our previous studies of gastric emptying after the M&M gastroplasty confirmed that emptying of radio-labeled solids and liquids was normal, while stasis of food did not occur.<sup>25</sup> Quality of life improves significantly after the M&M procedure.<sup>24</sup> The incidence of re-operation is very low, apart from elective re-operation for removal of pendulous fatty apron or repair of incisional hernia.

In conclusion, this is the definitive clinical paper on the M&M procedure for morbid obesity, with medium-term follow-up, and with exclusion of the earlier series in which a 40-F bougie had been used to calibrate the Magenstrasse, when early regain of weight within 1-3 years of operation was common. In this series where a 32-36 F bougie was used to calibrate the Magenstrasse, patients experienced greater, lasting weight loss. The M&M gastroplasty has thus far fulfilled our hopes that it would prove to be a "low-maintenance" procedure, after which patients would need little medical supervision and not require regular mineral and vitamin supplements. While the results are certainly encouraging, deficiencies of the study are that 23% of patients were lost to follow-up, and that relatively few patients were followed for >4 years after operation. These defects are common to most studies of morbidly obese patients, who are notoriously difficult to follow, but they nevertheless underline the need for more protracted studies and for unbiased, prospective comparison with the current alternative operations.

We also speculate that the M&M procedure may be particularly suitable for use in the "lighter" obese patient with BMI 35-45, while for super-obese patients, more aggressive forms of surgery may still be necessary.

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