



# Laparoscopic Magenstrasse and Mill Gastroplasty. First Results of a Prospective Study

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## Abstract

**Background** The Magenstrasse and Mill (M&M) procedure is a vertical gastroplasty creating a tubular pouch extending from the cardia to the antrum. This “incomplete sleeve” avoids gastric resection or band placement. In this paper, we report our experience of the laparoscopic approach of the technique in a selected obese population excluding prominent grazer and/or sweet eaters.

**Material and Methods** One hundred patients (39 males, 61 females) underwent the procedure in a prospective trial. Mean age was 40 years (range 18–68). Mean preoperative BMI was 43.2 kg/m<sup>2</sup> (range 35–62).

**Results** The procedure was performed by laparoscopy starting with the creation of a circular opening at the junction of antrum and corpus followed by a vertical stapling to the angle of Hiss. Mean duration of the procedure was 67 (range 40–122) min. No intraoperative complication occurred. Mean hospital stay (SD) was 2.5 (0.9) days. The single postoperative

complication consisted in a mild stenosis that responded to endoscopic dilatation. After a mean follow-up of 15 months (range 9–24), mean percentage of excess body weight loss (SD) was 48(14), 59(18) and 68(24)%, respectively at 3, 6, and 12 months. Quality of life appeared satisfactory with a low incidence of gastroesophageal reflux. The procedure was associated with improvement or resolution of diabetes, arterial hypertension, and dyslipemia at 1 year.

**Conclusions** Our experience demonstrated that the M&M procedure could be performed safely laparoscopically. The satisfactory results on weight loss, obesity-associated morbidities, and quality of life will need to be confirmed on longer follow-up.

**Keywords** Laparoscopic · Bariatric · Surgery · Sleeve · Magenstrasse and Mill · Obesity · Gastroplasty

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## Introduction

Bariatric surgery has evolved for over 50 years to an accepted and only long-term treatment of morbid obesity. Malabsorptive techniques used in the early days were associated with severe gastrointestinal and hydroelectrolytic disturbances that led bariatric surgeons to adopt Roux-en-Y gastric bypass (RYGB) as a reference procedure in term of weight loss and treatment of obesity comorbidities with low morbidity and mortality [1]. The technique is however demanding, particularly for the laparoscopic procedure. The long-term complications associated with the technique include marginal gastrojejunal ulcers (5–16 %) [2] and bowel obstruction secondary to internal hernia or adhesions [3]. It also imposes monitoring of minerals and vitamins, whose absorption is decreased by the bypass of the proximal intestine. Finally, the difficulties to assess the excluded stomach and to explore the biliary tract are also drawbacks of the technique. In series excluding sweet eaters and/or super obese patients, the gastric bypass did not prove superior to restrictive surgery (82 vs 80 % excess weight loss (EWL) at 2 years) but resulted in a higher complication rate [4, 5].

Vertical banded gastroplasty demonstrated good results on weight loss and its related metabolic complications [6, 7]. The technique suffered however from two major complications: disruption of the staple line (8–48 %) and problems associated with the band used to limit the expansion of the pouch outlet with stenosis (4–21 %) or transgastric migration [8]. The adjustable band gastroplasty took over in the 1990s because of the easier laparoscopic placement and satisfying results on weight loss. However, this technique also led to failures secondary to band slippage, pouch dilatation, band erosion, or food intolerance [9].

More recently, the sleeve gastrectomy (SG) initially proposed as a first step procedure gained rapid acceptance because it is technically less demanding than RYGB with satisfying short- and intermediate-term results on weight loss (56.1 % EWL at 1 year, range 49–81 %) [10, 11] and on resolution of obesity-associated comorbidities [12]. The SG furthermore avoided the complications related to banded gastroplasties that shadowed the 50–60 % EWL at 10 years reported in selected populations [6–8]. Those aspects explained that many surgeons chose to perform SG despite its irreversibility and a postoperative complication rate (10–13 %) similar to RYGB [10, 13].

### Prospective Study of Laparoscopic Magenstrasse and Mill Procedure

Based on those considerations, we decided to re-evaluate the Magenstrasse and Mill (M&M) procedure (Fig. 1) described by Johnston et al. in 1987 [14]. This ancestor of the SG potentially combined the advantages of the restrictive

procedures described above without resection or band placement and their associated complications. After the creation of a circular opening in the stomach at the junction between the corpus and the antrum, the stapling progressed along the small gastric curvature to create a tubular pouch similar to a sleeve but preserved a channel allowing the greater stomach to empty in the antrum.

## Material and Methods

The laparoscopic approach of the procedure was evaluated in the Department of Abdominal Surgery of the CHU of Liège in a prospective study after approval of the local ethical committee (NCT02050477). The primary end points were the evaluation of the procedure on surgical morbidity and mortality and on weight loss.

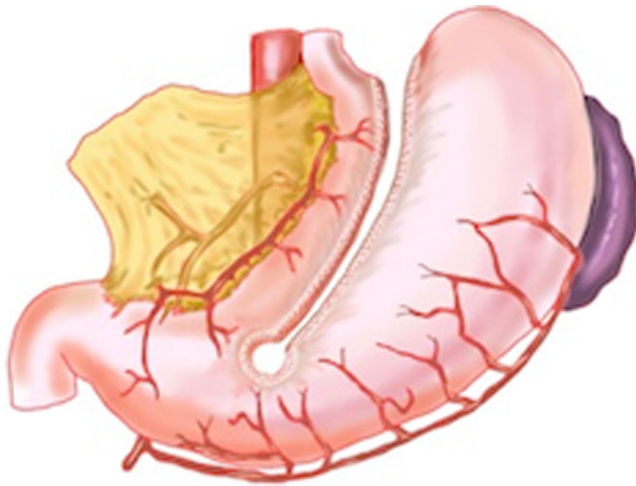
All patients were assessed by a multidisciplinary team specialized in bariatric and metabolic surgery including surgeon, endocrinologist, psychologist and/or psychiatrist, dietitian. Their alimentary behavior (especially their ability to avoid interprandial feeding) was characterized after dietetic evaluation including several interviews at the clinic and a food journal.

### Inclusion Criteria

- BMI > 40
- BMI > 35 with diabetes or sleep apnea syndrome or hypertension treated with three drugs for at least 1 year
- Male or female patients between 18 and 75 years of age; fertile female patients must use a reliable contraception method;
- No previous bariatric procedure
- Informed consent given by patient

### Exclusion Criteria

- Medical contraindication for a general anesthesia or abdominal surgery (allergies to anesthetic drugs, cardiovascular, pulmonary, or renal conditions leading to an unacceptable risk for the procedure)
- Psychological-psychiatric (bulimia, severe depression, psychotic condition)
- Non-stabilized endocrine disorder, with potential interference on weight and/or diabetic condition
- Inability to understand goal of the study, plan of treatment, and follow-up
- Large hiatal hernia and/or severe esophageal reflux disease
- Prominent grazer and/or sweet eater behavior



**Fig. 1** The Magenstrasse and Mill procedure

### Preoperative Workup

Preoperative workup included an upper GI endoscopy. Systematic preoperative research of *Helicobacter pylori* infection was carried out and treatment given if necessary with pump proton inhibitors (PPIs) 40 mg per os by day, amoxicillin 1 g per os twice a day, and clarithromycin 500 mg per os twice a day for 1 week. Eradication was controlled by endoscopy or by an urea breath test between 4 and 8 weeks after the end of treatment. All patients underwent an abdominal ultrasound. Prophylactic cholecystectomy was proposed to each patient when gallstones were detected.

### Anesthesia

Patient received alprazolam 0.5 mg, ranitidine 300 mg, and domperidone 1 h prior anesthesia. After positioning in ramping position and set up of the standard baseline monitoring, patients were preoxygenated with continuous positive airway pressure (CPAP) 10 cm H<sub>2</sub>O with FIO<sub>2</sub>=1 until FeO<sub>2</sub> reaches 0.90. A rapid sequence induction was then performed with sufentanil 15 mcg, lidocaine 1 mg/kg, titrated propofol, and succinylcholine 1 mg/kg. Anesthesia was maintained with inhaled desflurane titrated on BIS monitoring, and deep muscle relaxation was achieved with repeated rocuronium boli. Lungs were ventilated using volume-controlled ventilation, a 10 cm H<sub>2</sub>O PEEP, and with a mixture of air-oxygen (FIO<sub>2</sub> 0.8). Ventilation was set to maintain an ETCO<sub>2</sub> under 45. A single dose of IV cephazoline was given prior to incision. Before the end of the surgery, patients were given IV paracetamol 2 g, tramadol 100 mg and if no contraindication, IV parecoxib 80 mg to provide efficient pain relief. To limit the incidence of postoperative nausea and/or vomiting, our anesthesia protocol avoided the use of intraoperative nitrous oxide and included the intravenous administration of dexamethasone 5 mg at the time of induction,

droperidol 0.625 mg at the end of surgery, and ondansetron 4 mg postoperatively as needed.

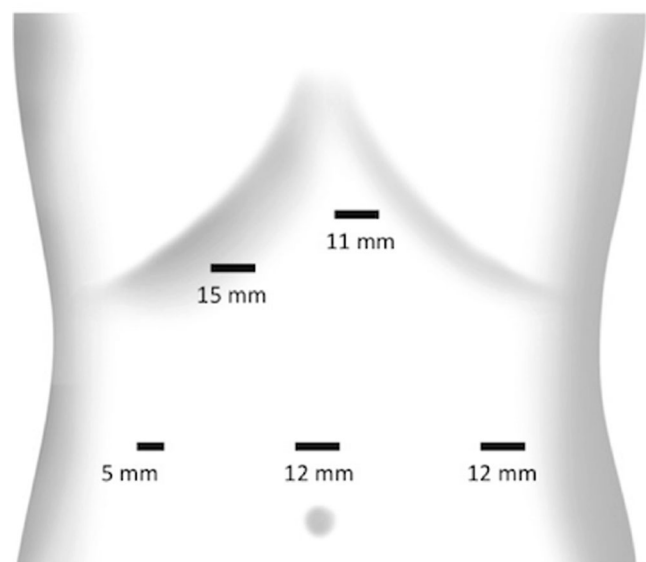
### Surgical Technique

The patient was placed in a supine position, split leg with reverse Trendelenburg position. Initial access was obtained by means of a Veress needle technique at the left anterior subcostal area. Carbon dioxide pneumoperitoneum was established to a pressure of 14 mm Hg. A 0° angle scope was used. Five ports were inserted (Fig. 2).

In the first part of the procedure, the laparoscope was placed in the lower port in the midline. After retraction of the stomach, the procedure started by the incision of the greater omentum below the antrum, preserving the gastroepiploic vessels attached to the greater curvature of the stomach to enter the lesser omental bursa. Posterior gastric adhesions were divided toward the left crux of the diaphragm.

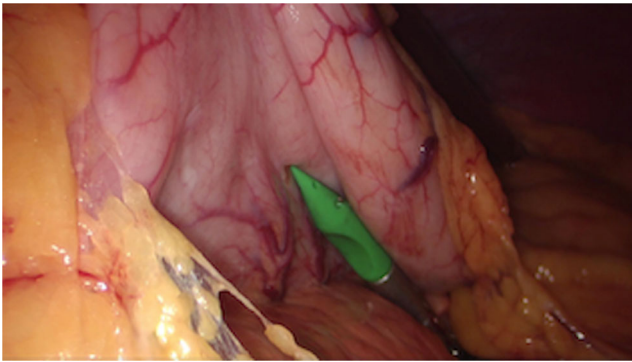
A marking with the cautery was performed on the anterior surface of the stomach at the junction of the corpus and antrum, halfway between the lesser and greater curvatures at the level of the angularis incisura. Care was taken to avoid damage to the vagal branches of the crow's foot innervating the antropyloric region. A "mirror" marking was done on the posterior wall of the stomach.

The sharp tip of the anvil of an endoscopic curved intraluminal stapler (ECS21A, 21 mm, Ethicon Endosurgery, Cincinnati, USA) was pushed through the wall of the stomach from the posterior mark toward the anterior (Fig. 3). The use of an adapted "anvil holder" (Metal Instrument Head Forceps, Ethicon Endosurgery, Cincinnati, USA) was mandatory to perform the latter step precisely. After removal of the sharp



**Fig. 2** Ports placement





**Fig. 3** Positioning of the sharp tip of the anvil after opening of the gastrocolic ligament

tip of the anvil, the anvil was connected to the instrument and the ECS was fired creating a circular opening (Fig. 4).

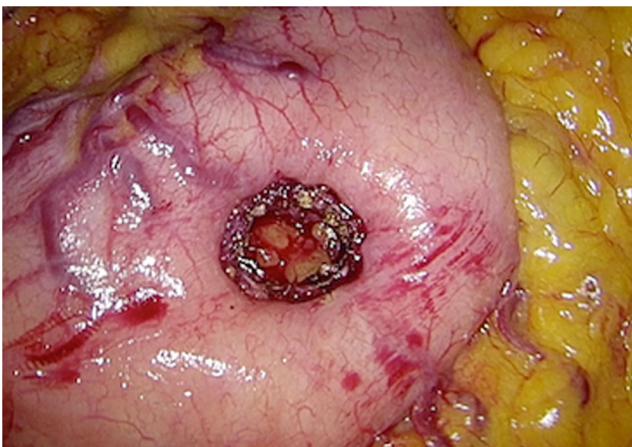
The laparoscope was then placed in the 11 mm port in the epigastric area. An orogastric calibration tube (50 Fr) was advanced through the stomach alongside the smaller curvature and on the right side of the previously made circular stapling. We fired five to six 60 mm cartridges (Echelon 60, Ethicon Endosurgery, Cincinnati, USA) from the circular opening tightly along the calibration tube toward the angle of Hiss (Fig. 5). The height of the staples were adapted to the thickness of the gastric wall, the first one or two being 3.8 mm cartridges while the others were 3.5 mm ones.

Any bleeding from the staple lines was controlled with the cautery. A running suture of Maxon 3/0 V-Loc (Covidien, Mansfield, USA) was used to reinforce the staple line from the circular stapler as it has only two rows of staples.

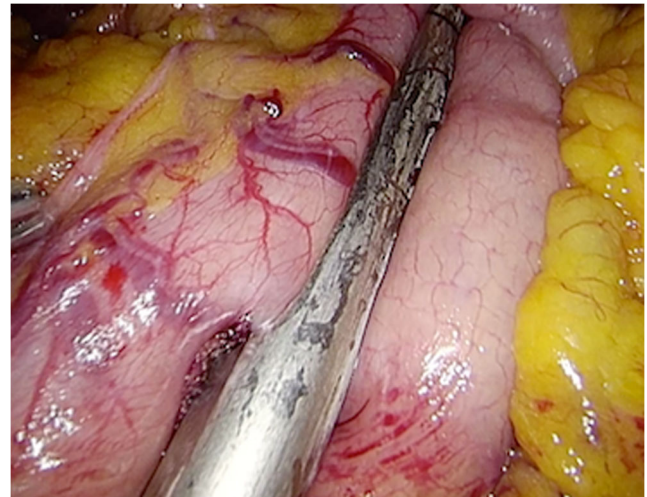
A 21 Fr silicone drain was left between the divided parts of the stomach.

#### Follow-up

To prevent deep venous thrombosis, patients received a daily subcutaneous injection with low-molecular-weight heparin



**Fig. 4** Circular stapling preserving the vagal branches of the crow's foot



**Fig. 5** Linear stapling from the circular opening toward Hiss angle

for 20 days postoperatively. PPIs were prescribed for 1 month. A multivitamin complex (Omnibionta Pronatal, Merck, Darmstadt, Germany) was prescribed for 6 months.

The patients had a clinical follow-up by the multidisciplinary team at 1, 3, 6, 12, and 24 months after surgery then yearly. A systematic evaluation reported any complaints (incl. incidence of GERD) by the patient, changes in obesity-associated morbidities and in medications. A comprehensive blood work including carbohydrate metabolism and lipid profile, minerals and vitamins was done at 3, 6, 12, and 24 months.

## Results

### Surgical Procedure and Postoperative Evolution

One hundred patients (61 F/39 M) underwent the procedure with a mean follow-up of 16 months (range 10–24). Mean age was 40 (range 18–68) years. Mean preoperative weight and BMI were respectively 124 kg (range 90–196) and 43.2 kg/m<sup>2</sup> (range 35–62). Associated comorbidities are shown in Table 1.

Mean operative time (SD) was 71(27) min for the entire group. Excluding those with an associated procedure (cholecystectomy or previous abdominal surgery with peritoneal adhesions), mean duration of surgery was 67 min (range 40–122). No intraoperative complication occurred.

On postoperative day 1, an upper GI opacification was done. No leak or other complication was evidenced. Drain and intravenous infusions were removed on postoperative day 1, and a liquid diet was started and progressed on day 2 to a solid diet. One patient complained of solid dysphagia from day 2. Only a mild stenosis at the lower part of the pouch was evidenced. He had to undergo two endoscopic dilatations on

**Table 1** Associated comorbidities

Obesity-associated morbidities	%
Diabetes	18
On insulin (incl. one type 1 diabetic)	10
On oral antidiabetic drugs	5
Arterial hypertension	44
Treated	32
Dyslipemia	78
Treated	16
Sleep apnea syndrome	21
On CPAP	8
Cardiac failure	1

weeks 3 and 4 with parallel dietetic counseling. The problem resolved after 6 weeks.

Mean (SD) duration of hospital stay was 2.5(0.9) days.

At follow-up, the patients reported no undesirable symptoms except for a few episodes of postprandial dysphagia. Those were present in the early postoperative period associated with the change in eating behavior imposed by the restrictive surgery. Incidence of esophageal reflux symptoms was 11 % before surgery and 10, 7, and 14 %, respectively at 3, 6, and 12 months postoperatively. Symptomatology was mild, intermittent, and easily controlled with PPIs.

#### Evolution of Weight Loss

Mean weight (SD) decreased from 124(21) kg to 100(19), 94(19), and 89(20) kg respectively at 3, 6, and 12 months after surgery. Mean percentage of excess body weight loss (SD) was 47(14), 59(18), and 68(24)% at the same time points (Fig. 6).

#### Evolution of Obesity-Associated Morbidities

Four out of five diabetic patients on oral antidiabetic drugs could stop their medications at 1 year. The treatment of the fifth patient was decreased from bitherapy to monotherapy. Mean HBA1c level of those five patients decreased during the same period from 6.6 (range 5.7–7.9) to 5.7 % (range 5–6.1) ( $p<0.05$ ). Four out of our nine insulin-dependent type 2 diabetic patients could stop their insulin treatment after 1 year, two of them still being on oral antidiabetic drugs. The remaining six insulin dependent patients (including one patient with type 1 diabetes) could reduce their daily insulin dose to a mean 39 % of the initial dose ( $p<0.05$ ). HBA1c levels of the group preoperatively on insulin decreased from 8.2 to 7 % at 1 year ( $p=0.07$ ) while their treatment was decreased or stopped.

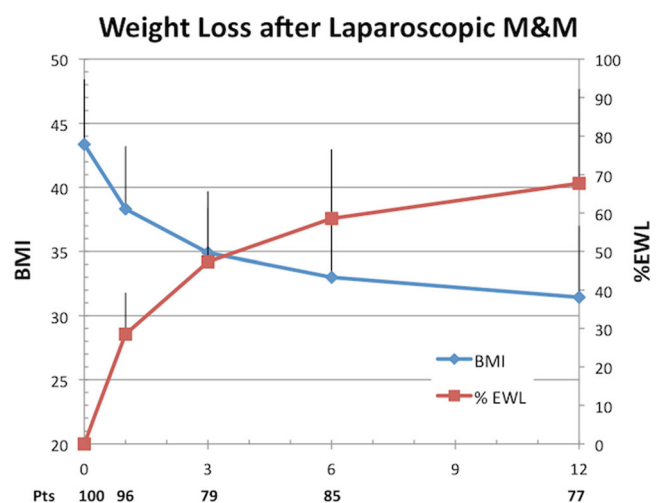
From 27 patients on hypertensive drugs before surgery for whom we had data at this point of follow-up, 7 (26 %) were able to discontinue their treatment at 1 year. Dyslipemia also

improved. We had complete preoperative and 1-year postoperative blood lipid profile from 50 preoperatively dyslipemic patients. Forty-two percent of the patients with initial cholesterol and/or triglyceride levels above normal range (cholesterol  $>1.9$  g/l and triglycerides  $>1.5$  g/dl) normalized their levels at 1 year. Eight out of 16 patients on lipid-lowering treatment could stop their medication. While mean cholesterol level did not decrease significantly considering the entire dyslipemic group (2.07 preoperatively vs 1.97 at 1 year,  $p=0.07$ ), the difference reached significance considering dyslipemic patients without initial treatment (2.13 vs 1.97,  $p<0.05$ ) by the exclusion of the effect of lipid-lowering medication suppression. The decrease was significant for mean triglyceride levels in both groups, with mean values decreasing from 1.57 to 1.1 ( $p<0.05$ ) and from 1.60 to 1.08 ( $p<0.05$ ).

Clinical sleep apnea syndrome disappeared at 1 year in 9 out of 17 patients (53 %) for whom we had data at the time of analysis. From the latter group, three out of six preoperatively on CPAP could stop their treatment.

#### Evolution of Blood Vitamins and Minerals

Mean preoperative vitamin D levels were below normal range in 92 % of our population. A supplementation was given to the latter patients that led to a significant increase of its blood level at 1 year, remaining however below normal range. All other vitamins and mineral mean blood levels at 3, 6, and 12 months remained within normal range within the current follow-up. Levels of folic acid and vitamin B12 were however significantly higher than preoperative values after 3 and 6 months (and after 12 months for folic acid) postoperatively due to the prophylactic supplementation. Levels of iron, vitamin A, and



**Fig. 6** Weight loss evolution after laparoscopic M&M over a 12-month period. The number of patients (Pts) at 1, 3, 6, and 12 months follow-up is shown below the x-axis

vitamin E remained stable while a slight decrease of zinc levels was observed at 1 year.

## Discussion

Reports of the M&M procedure consisted mainly of the studies of the original series. The Johnston group [14] reported a series of 100 patients operated between 1992 and 1998 with a mean preoperative BMI of 46.3 kg/m<sup>2</sup>. Their mortality was 0 %, and major complications occurred in 4 % of patients. These included a tear at the junction between the left suprahepatic vein and the IVC, a fistula from the proximal end of the Magenstrasse and two from the excluded gastric fundus. Mean weight loss was 38(14) kg equivalent to 60 % of excess weight, obtained within 1 year of operation and maintained for 3 years [15].

Our laparoscopic series was associated with a low complication rate. Our experience with laparoscopic RYGB probably played a role in the learning curve with the technique. Our mean operative time favorably compared to the surgery duration of laparoscopic SG (average 100 min) in a systematic review [16]. The crucial part was the correct positioning of the circular stapling to avoid gastric stenosis on any side. The division of all adhesions between the posterior aspect of the stomach, and the pancreas were also mandatory to perform a regular tubular pouch. The procedure itself avoids any high-pressure zone distally to the gastric tube with the preservation of the antrum motricity (dependent of the avoidance of vagus nerve lesion) that could decrease the risk of staple line dehiscence compared to a sleeve.

At this point of follow-up, the clinical results of the laparoscopic M&M compares favorably to other bariatric techniques with 68 % EWL at 1 year. The reduced sensation of hunger after the procedure seemed to play a major role, property shared with gastric bypass or sleeve gastrectomy. The side effects of the procedure appeared mild with a low incidence of dysphagia or gastroesophageal reflux. This good quality of life thus mirrors the 88 % satisfaction rate of the study of Carmichael et al. [17]. The role of the multidisciplinary team in the preoperative and postoperative care could also play a role to explain the low incidence of upper GI symptoms with a special emphasis on meal fractioning and volume limitation. We believe that it also participated to the results obtained so far on weight loss, not only in the selection of patients (exclusion of predominant grazer and sweet eater behavior) but also on the preoperative modification of diet behavior. This might explain the lower results obtained in the only other laparoscopic report of the procedure in a super obese population of seven patients [18].

The M&M technique offers potential advantages compared to a SG. The preservation of the greater curvature may be

useful in the repair of a fistula or a stricture at the level of the gastric tube, which in the case of a sleeve can lead to repeated stent placement or gastrectomy with esophageal anastomosis [19, 20]. The absence of gastrectomy avoids dissection of the gastrosplenic ligament associated to a risk of vascular or splenic lesions. The more limited surgical trauma could decrease the risk of portomesenteric thrombosis reported after bariatric surgery including sleeve gastrectomy [21, 22]. The absence of organ to extract limits the parietal trauma. Postoperative biological controls in our study confirmed at this point the absence of vitamins or mineral deficiencies reported by the Johnston group [23]. Our mean 15-month follow-up and the use of prophylactic multivitamin complex during the first 6 months limit however the interpretation of our data. The restrictive nature of the surgery and the absence of gastric resection that should ensure normal gastric pH and intrinsic factor production should nevertheless limit the latter risk observed after SG [24, 25].

The preservation of the gastric fundus and corpus raised several questions. The concerns about difficulty of greater stomach part emptying were not encountered in the current follow-up. Postoperative upper GI opacification demonstrated in our study preferential emptying in the duodenum with only partial filling of the fundus. This potential complication was neither reported in the series from Johnston et al. who reported no alteration in gastric emptying studies [23]. The removal of the greater curvature of the stomach in SG is also believed to explain the results obtained by the latter procedure in terms of weight loss and improvement of comorbidities by hormonal modifications. The present study demonstrated an improvement of obesity-associated morbidities. In particular, four out of five non-insulin-dependent diabetic patients could stop their medication with a normal HbA<sub>1c</sub> at 1 year. Only four insulin-dependent type 2 diabetics out of nine could stop their insulin treatment. Those nine patients had however a long history of diabetes with a minimum period on insulin of 10 years except for one of the two patients currently in remission (5 years duration of insulin treatment). The limited number of patients and the absence of control group do not allow us to draw conclusions but justify future prospective randomized studies.

The reason for which the procedure did not gain widespread recognition and popularity may be related to the limited report of the technique and the expansion of the laparoscopy at the same period that led surgeons to choose other bariatric procedures more easily to translate with the laparoscopic instruments available in those early days.

Its durability can only be extrapolated at this time from the results of the original series [15]. Concerns about its efficacy that led to investigate variations of the original technique [15, 26] are not supported by literature evidence as large-size long-term studies are lacking. Many questions remain. We used in this study a 50 Fr bougie to limit solid food dysphagia and avoid patient orientation toward a more liquid hypercaloric



diet. The use of a smaller size bougie might improve long-term control of weight, as was suggested in the original report of the M&M [14]. The issue remains controversial in reports after SG while the price to pay may be a higher postoperative leak rate [27–29]. It however might be of particular importance in subsets of patients, such as the super obese population with the greatest alimentary behavior imbalance reflected by the negative correlation of BMI and postoperative weight loss in most studies [30]. The M&M remains in any case a pure restrictive procedure that requires preoperative patient education and selection and postoperative follow-up.

This paper reports, to our knowledge, the largest experience on laparoscopic M&M. These results suggest that the laparoscopic M&M procedure could be a first choice technique for patients that are not prominent grazer or sweet eaters. The absence of food intolerance or malabsorption might not position this surgery as a first choice procedure for part of the super obese population with a severe alimentary misbehavior. Its role as a first step surgery could however be considered as the preservation of stomach integrity would keep open all surgical possibilities in case of failure. Further studies remain to be done to validate these results on longer follow-up, define the effects on obesity-related illnesses, and identify the patient population best helped by this procedure to position the M&M as a valid alternative to existing laparoscopic bariatric techniques.

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**Conflict of Interest** Amaud De Roover: no conflict of interest.

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**Ethical Approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Informed Consent** Informed consent was obtained from all individual participants included in the study.

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