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Robot-assisted gastrojejunal anastomosis does not improve the results of the laparoscopic Roux-en-Y gastric bypass

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Abstract

Background

Traditional laparoscopic surgery presents some difficulties for morbidly obese patients due to limited motion of instruments related to a thick abdominal wall, intraabdominal fat, and a large hepatic left lobe, with consequent loss of dexterity and greater musculoskeletal discomfort. Robotic technique could potentially overcome these limitations. This study aimed to evaluate robot-assisted laparoscopic Roux-en-Y gastric bypass in morbidly obese patients and to compare the results of robotic assistance with those of traditional laparoscopic technique.

Methods

Between September 2006 and June 2009, 110 morbidly obese patients underwent laparoscopic Roux-en-Y gastric bypass with robot-assisted hand-sewn gastrojejunal anastomosis using the da Vinci Surgical System. The data for these patients was compared with the data for 423 consecutive patients treated in a standard laparoscopic manner during the same period.

Results

The patients had a mean preoperative age of 42.6 years, a mean weight of 127.5 kg, and a mean body mass index (BMI) of 46.7 kg/m^2. The total mean operative time was 247.5 min. The robotic setup time was 10.1 min, and the robotic operative time was 54.5 min. The conversion rate was nil. The intraoperative complication rate was 4.5%. The early and late major postoperative complication rates were 3.6 and 6.4% respectively. The cost per patient was 5777.76 €. For the standard laparoscopy, the operative time was significantly shorter (187 min; $p < 0.001$), and the costs per patient were significantly lower (4658.28 €; $p < 0.001$), whereas no differences were found in terms of the intra- or postoperative complication rates, revisional surgery, or hospital length of stay.

Conclusions

Although safe and intuitive, the robotic approach was burdened by a longer operative time and higher equipment costs. Moreover, it did not seem to provide a real advantage over standard laparoscopy in terms of hospital length of stay and complications rates.

Keywords

Bariatric surgery Gastrojejunal anastomosis Morbid obesity Robot-assisted gastric bypass Robotic surgery Roux-en-Y gastric bypass

To date, bariatric surgery is the only long-term effective therapy available for the morbidly obese population [*1*–*3*]. Over recent decades, laparoscopic surgical techniques have become the gold standard in bariatric surgery due to advantages such as less postoperative pain, shorter hospital stay, faster postoperative recovery, and minimal scarring [*4*–*6*]. Moreover, for the obese patient, the mini-invasive approach has demonstrated its ability to reduce postoperative mortality [*7*, *8*]. However, the inherent limitations of traditional laparoscopic surgery may cause some technical difficulties due to the limited freedom of motion for the instruments related to the thick abdominal wall and hepatomegaly, with consequent loss of dexterity and greater musculoskeletal discomfort for the surgeon [*9*].

Recently, the introduction of the da Vinci Surgical System (Intuitive Surgical Inc, Sunnyvale, CA, USA) has allowed surgeons to overcome many limitations of standard laparoscopic surgery. From a remote console, a surgeon has a three-dimensional view with magnification of the operating field and manipulates instruments with additional degrees of freedom compared with laparoscopy. Additional benefits of the robotic system include adjustable-motion scaling and filtering of tremor to allow for fine manipulation and precise suturing [*10*]. For bariatric surgery, the da Vinci system greatly improves surgeon ergonomics by allowing the surgeon to sit at the console and by alleviating fatigue caused by the torque on the instruments and trocars created by the thick abdominal wall [*10*].

The study aimed to compare the clinical results for a series of 110 consecutive laparoscopic Roux-en-Y gastric bypasses (RYGBPs) with those for robot-assisted hand-sewn gastrojejunal anastomoses performed in two Surgical Centers devoted largely to bariatric and laparoscopic surgery.

Materials and methods

Between September 2006 and June 2009, 110 morbidly obese patients underwent robot-assisted laparoscopic RYGBP in our departments. All the patients were part of a multidisciplinary preoperative approach and fulfilled the 1991 National Institute of Health (NIH) criteria for bariatric surgery [*11*].

During the study period, the robot was used each time it was available in a multispeciality program including urologists and gynecologists. There were no preoperative patient-specific inclusion or exclusion criteria. The robotic patients were compared with 423 consecutive patients who underwent gastric bypasses during the study period in a standard laparoscopic manner with a circular-stapled gastrojejunal anastomosis.

The patient variables collected included patient age, sex, body mass index (BMI), history of abdominal surgery, comorbidity, perioperative data, postoperative complications, length of hospital stay, and costs. We calculated total operative time and robotic operative time as well as the setup time needed to wrap the arms and position the robot cart. Because we used the robot only for the gastrojejunostomy, cost evaluation included only the cost for surgical tools needed to perform the anastomosis.

The patients were followed up at routine intervals of 1 month, 3 months, 6 months, and 1 year, then annually thereafter. All the patients in this series had at least a 6-month follow-up period.

Statistical analysis was carried out using the Student's t-test. A p value less than 0.05 was considered significant.

Surgical technique

The robot-assisted procedure is performed as a hybrid procedure incorporating two stages. The first stage is standard laparoscopy, and the second stage is robot assisted using the da Vinci robot system.

The operating surgeon controlled the robot at the console, and the assistants, once the standard laparoscopic portion of the procedure was completed, handled the laparoscopic instruments inserted in the accessory trocars. The operating room for the robotic procedures was staffed by a team of nurses and technicians experienced in robotic procedures.

Because it is difficult to replace the robotic system during the operation, optimal installation is crucial to a smooth procedure. This includes positioning of the patient and placement of the trocars. Patients are positioned in a 20° to 25° reversed Trendelenburg position with their right arm extended, and their left arm at their side. The instruments are semidisposable. The robot tracks the number of times the instruments are used and will not operate an instrument after the 10th use. In all cases, a 30° angled scope was used.

After creation of a 14-mmHg pneumoperitoneum, the necessary ports are introduced. Optimal port placement is essential to avoid collisions between the robotic arms and camera arm and to obtain sufficient access at the gastroesophageal junction.

We start with placement of six ports, all 10- or 12-mm Ethicon trocars (Ethicon Endosurgery, Cincinnati, OH, USA). We use the double-cannulation technique [*12*], with the da Vinci ports placed inside conventional laparoscopic Ethicon ports.

During the laparoscopic portion of the procedure, a 100-cm Roux-en-Y limb is created. The jejunum is divided with a 45-mm Ethicon Endostapler approximately 50 cm from the angle of Treitz. The mesentery then is divided using ultrasonic scissors. A Roux-en-Y limb of 100 cm is measured. At this site, the jejunostomy is stapled, with hand-sewn closure of the resulting defect. All mesenteric defects are closed with nonabsorbable sutures.

We move next to the upper abdomen. The liver is retracted by a liver retractor. The angle of His is dissected with an electrocautery hook. Then we start dissection on the lesser curvature approximately 6 cm from the gastroesophageal junction. With the lesser curvature held in an elevated position, the retrogastric space is entered for placement of the stapling device. We fire one stapler cartridge horizontally and three stapler cartridges upward toward the angle of His to create the pouch, calibrated on a 12-mm endogastric bougie. Then we bring up the alimentary loop and fix it to the gastric pouch with two stay stitches at the corners. At this moment, the da Vinci is turned on, after which the robotic arms are wrapped and introduced into the Ethicon ports.

A 2-cm gastrojejunostomy is created on the anterior stomach and the jejunum with the hook cautery. A running two-layer anastomosis is created with absorbable sutures (PDS is used for the inner mucomucosal layer and Vicryl for the outer seromuscolar layer). Finally, the anastomosis is tested with a methylene blue test to check for leaks and patency, and a peri-anastomotic drain is placed. The robot then is withdrawn, and the skin incisions are closed.

Results

Between September 2006 and June 2009, 110 morbidly obese patients (27 men and 83 women) underwent laparoscopic Roux-en-Y gastric bypass with robot-assisted, hand-sewn gastrojejunal anastomosis. The mean age of the patients was 42.6 years (range, 24–62 years). Their mean preoperative weight was 127.5 kg (range, 83–232 kg), and their mean BMI was 46.7 kg/m^2 (range, 33.7–78.2 kg/m^2). The demographic data for the patient population are presented in Table 1.

Table 1

Demographic patient data

	Robotic RYGBP	**Laparoscopic RYGBP**	**p Value**
n	110	423	NS
M/F	27/83	105/318	
Age: years (range)	42.6 (24.0–62.0)	41.1 (19.0–64.0)	NS
Preoperative weight: kg (range)	127.5 (83.0–232.0)	129.3 (60.0–205.0)	NS
Preoperative BMI: kg/m^2 (range)	46.7 (33.7–78.2)	47.3 (23.4–70.3)	NS

NS not statistically significant, BMI body mass index

Of the 110 patients, 68 (61.8%) had undergone previous abdominal surgery including 44 appendectomies, 13 cholecystectomies, and 25 varied gynecologic procedures. Furthermore, 12 patients had previously undergone bariatric surgical procedures including 10 adjustable gastric bandings, 1 vertical banded gastroplasty, and 1 gastric pacemaker. All these patients underwent conversion to Roux-en-Y gastric bypass due to weight regain. Major obesity-related comorbidities included hypertension at a rate of 51.8%, type 2 diabetes mellitus at a rate of 19.1%, and obstructive sleep apnea at a rate of 20.9%.

All the operations were completed laparoscopically, and all the gastrojejunostomies were completed robotically without a need for conversion to open or traditional laparoscopic surgery. Simultaneously with the Roux-en-Y gastric bypass, we performed a cholecystectomy in seven cases, a gastric band removal in nine cases, and a gastric pacemaker removal in one case. The total operative time was 247.5 min (range, 90–405 min). The mean robotic portion of the surgery time was 54.5 min (range, 30–125 min), and the mean time required to complete the robotic system setup was 10.1 min (range, 7–17 min) (Table 2).

Table 2

Operative times and hospital lengths of stay

	Robotic RYGBP	**Laparoscopic RYGBP**	**p Value**
Total operative time: min (range)	247.5 (90.0–405.0)	187.0 (75.0–360.0)	<0.001
Robotic operative time: min (range)	54.5 (30.0–125.0)	–	–
Setup time: min (range)	10.1 (7.0–17.0)	–	–
Hospital stay: days (range)	7.8 (3–65)	8.3 (3–99)	NS

RYGBP Roux-en-Y gastric bypass, NS not statistically significant

Five intraoperative complications (4.5%) occurred. Two cases involved bleeding from a superficial spleen tear, which resolved with hemostasis. In the remaining three cases, the methylene blue test results were positive for leakage, which was repaired intraoperatively by additional stitches and caused no postoperative sequelae.

The early postoperative complications (i.e., complications occurring until postoperative day 30) were classified as minor if they could be managed conservatively and did not significantly prolong the hospital stay. There were 14 minor postoperative early complications (12.7%) including melena from anastomotic ulcer treated medically (n = 2), anastomotic stricture treated with endoscopic dilation followed by complete symptomatic resolution (n = 2), anemia with no need for transfusion (n = 3), respiratory distress needing intensive care unit admission (n = 5), pulmonary thromboembolism (n = 1), and wound infection (n = 1).

Four major postoperative complications (3.6%) occurred. Two anastomotic leaks identified at a standard gastrografin swallow 3 days postoperatively were treated conservatively with prolonged total parenteral nutrition (TPN) and antibiotic therapy until a complete radiologic resolution. For one patient, we performed an exploratory laparoscopy on postoperative day 5 for fever and tachycardia, with evidence of a tear in the alimentary loop. The tear was repaired laparoscopically, with subsequent recovery and a prolonged hospital stay (65 days). The remaining patient was submitted to laparoscopy on postoperative day 14 due to clinical signs of intestinal occlusion. An internal hernia was found and repaired. There were no mortalities (Table 3). The mean hospital stay was 7.8 days (range 3–65 days; median, 6.5 days).

Table 3

Early (<30 days) and late (>30 days) postoperative complications

	Robotic RYGBP n (%)	**Laparoscopic RYGBP n (%)**	**p Value**
Postoperative mortality	0/110 (0)	1/423 (0.2)	NS
Early major complications	4/110 (3.6)	9/423 (2.1)	NS
Late major complications	7/110 (6.4)	23/423 (5.4)	NS
Gastrojejunal anastomotic leak rate	2/110 (1.8)	8/423 (1.9)	NS
Gastrojejunal anastomotic stricture rate	3/110 (2.7)	33/423 (7.8)	NS

RYGBP Roux-en-Y gastric bypass, NS not statistically significant

The patients were followed up at 1, 3, 6, and 12 months, then annually thereafter. The follow-up period ranged from 6 to 38 months (average, 23.4 months). The follow-up rates were 100% at 6 months, 91.1% at 12 months, 86.5% at 24 months, and 100% at 36 months. The mean excess weight loss was 33.6% (range, 10–76.2%) at 3 months, 50.9% (range, 24.5–102.4%) at 6 months, 62.1% (range, 21.9–87.3%) at 1 year, 64.5% (range, 33.3–88.5%) at 2 years, and 64.4% (range, 41.5–85.1%) at 3 years (Fig. 1).

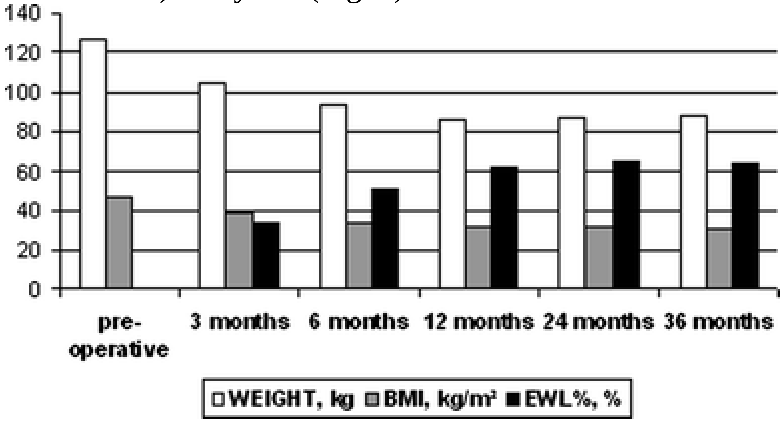

Fig. 1
Weight loss results for robot-assisted Roux-en-Y gastric bypass (RYGBP)

The late postoperative complications (i.e., occurring after postoperative day 30) included seven minor complications (6.4%) (6 perianastomotic ulcers treated medically with proton pump inhibitors and 1 anastomotic stricture improved with endoscopic dilation) and seven major complications (6.4%), each needing a reintervention. Four patients were submitted for surgery due to bowel occlusion caused by internal hernia (n = 3) and generalized peritoneal adhesions (n = 1). Two patients underwent surgery due to a perforated perianastomotic ulcer.

A patient was submitted to exploratory laparoscopy 1 year after the procedure due to intermittent abdominal pain, with evidence of vascular damage to the alimentary loop. This patient underwent construction of a new anastomosis (Table 3).

The 423 laparoscopic RYGBP procedures performed during the same period presented comparable demographic data (Table 1). Comparisons between the robot-assisted and laparascopic RYGBP data are presented in Tables 2 and 3. Comparative cost evaluations, showing a significant increase for robotic patients ($p < 0.001$), are presented in Table 4.

Table 4
Cost evaluation for robotic and laparoscopic Roux-en-Y gastric bypass (RYGBP)[a]

	Robotic RYGBP (€)	**Laparoscopic RYGBP (€)**	**p Value**
Surgical devices	1,581.51	765.78	
Operating room (450 €/h)	1,856.25	1,402.50	
Hospital stay (300 €/day)	2,340.00	2,490.00	
Total cost	5777.76	4658.28	<0.001

NS not statistically significant
[a]The surgical devices costs account only for the tools needed to perform the gastrojejunostomy

Discussion

Since RYGBP was first described by Mason and Ito [*13*] in 1967, it has become one of the most applied procedures for the surgical treatment of morbid obesity [*14*]. With the development of minimally invasive surgical techniques, the laparoscopic approach to RYGBP has been one of the most important advances in modern bariatric surgery.

Advanced laparoscopic skills such as intracorporeal knot tying, effective use of angled laparoscopes, and two-handed tissue manipulation are required for laparoscopic RYGBP, making it a challenging procedure. Moreover, the application of laparoscopic techniques to morbidly obese patients adds some obstacles, such as increased abdominal wall torque on the ports and awkward surgeon posture.

In laparoscopic RYGBP, construction of the gastrojejunal anastomosis is the most controversial part of the procedure [*15*] because severe complications occur at this point, causing an increase in morbidity and mortality.

With traditional laparoscopic RYGBP, three commonly accepted techniques are used to create the gastrojejunostomy. Two of the procedures involve a stapled anastomosis with either circular or linear staplers, potentially reducing technical complexity and the duration of the procedure. The reported rates for complications after stapled gastrojejunostomy are 1.1 to 6% for leaks, 2.9 to 27.1% for strictures, and 1.6% for intraluminal bleeding [*16–23*]. The third accepted technique is the hand-sewn gastrojejunostomy originally promoted by Higa et al. [*24*]. Although hand-sewn anastomoses may take longer to perform, they result in a lower hospital cost, less anastomotic bleeding, fewer stricture complications, and a lower incidence of wound infection [*24–26*]. In addition, the use of absorbable suture to create the gastrojejunostomy reduces the risk of gastrogastric fistula and marginal ulceration [*27*]. Nevertheless, the laparoscopic hand-sewn anastomosis is a challenging technique, and the learning curve can be very long.

In 2000, the Food and Drug Administration approved the da Vinci Surgical System for applications in general laparoscopic surgery. As robotic techniques were introduced into the surgical armamentarium, an attempt was made to combine the advantages of minimally invasive surgery (less trauma to the patient, quicker recovery, less postoperative morbidity) with the easier performance of open surgery (three-dimensional vision, more precise tissue handling, more degrees of freedom in manipulating instruments, and better ergonomics for the surgeon).

A robotic gastrojejunostomy offers several advantages to the bariatric surgeon [*9*, *10*]. The most important advantage is the added degrees of freedom that the needledriver allows for precise, ambidextrous forehand and backhand suture placement. Another advantage of robotics is the clear, three-dimensional view of the operative field. In addition, the robot allows work in tighter spaces as well as a very steady and magnified operative view [*28–32*]. A final advantage offered by robotics is the improved ergonomics afforded to the surgeon during the procedure, with minimized musculoskeletal discomfort [*33*].

A survey conducted by Jacobsen et al. [*10*] in 2003, found that 6 of 11 U.S. surgeons using the da Vinci system for bariatric surgery had experience with robot-assisted RYGBP. They all found the robotically assisted hand-sewn gastrojejunostomy superior to any standard laparoscopic technique and technically easier to perform. The greatest advantages reported by these surgeons included articulating wrists, three-dimensional view, motion scaling for precise hand movement, and mechanical forces to counteract the abdominal wall torque.

Altogether, these advantages not only could improve clinical results of the RYGBP but also could shorten the learning curve for this procedure [*12*]. In the 2003 survey by Jacobsen et al. [*10*], surgeons who had experience with more than 20 cases reported that the setup and operative times were inversely proportional to the number of operative cases performed.

In the recent literature, several reports of robot-assisted RYGBP have been published [*9*, *10*, *28–32*, *34*]. Most of these report robotic assistance used only in the creation of the gastrojejunostomy, whereas only a few authors have described a totally robotic RYGBP [*12*, *35–37*].

The current study was conducted in two surgical units devoted largely to laparoscopic and bariatric surgery. Furthermore, both units were significantly experienced in robotic surgery before application of robotic assistance to bariatric surgery [*29*, *38*, *39*]. Thus we did not need to manage a learning curve for the robotic system nor for the Roux-en-Y gastric bypass.

From a technical point of view, our experience shows use of the robotic system to be safe, as demonstrated by the fact that we had no need for conversion to open or traditional laparoscopic surgery. Furthermore, we had five intraoperative complications easily managed laparoscopically with no significant prolongation of the operative time or the hospital stay.

Despite this, the da Vinci system has demonstrated certain disadvantages. First, the lack of tensile feedback is a major limitation of the device. Second, the range of robotic instruments now available is somewhat limited because this system was designed specifically for use in cardiac surgery rather than for laparoscopic procedures. The loss of tactile sensation together with the fact that the actual robotic instruments for grasping and handling delicate tissue still are less than optimal increases the risk for bowel lesions in our opinion.

In a series of 45 cases, Hubens et al. [*37*] reported that five patients (11%) had to undergo conversion to open surgery because of intestinal laceration during manipulation of the intestines with the robotic instruments. Our experience included a case of bowel tear in the robotic group, whereas this complication did not occur in the standard laparoscopic patients.

Concerning operative times, Hubens et al. [*37*] reported a shorter total operating time for the laparoscopic cases than for the robotic cases (127 vs 212 min; $p < 0.05$). Most authors have noted a significant and rapid learning curve. Deng and Lourié [*32*] reported a trend for a shorter operative time toward the latter part of their patient series. The mean operative time was 200 min for the first 30 cases versus 184 min for the second 30 cases ($p = 0.03$). In the series by Hubens et al. [*37*], the total operative time decreased from 231 min for cases 1 to 15 to 136 min for cases 36 to 45 ($p < 0.05$).

A learning curve effect is reported also for setup time. In the series reported by Ali et al. [*40*], the setup time decreased from 22.3 min for the first 10 cases to 14.4 min for the second 10 cases and then remained relatively stable ($p < 0.05$).

Although we found the use of the robot in RYGBP to be safe and easy to learn, the operative time was significantly longer for the robotic procedure than for the laparoscopic procedure (247.5 vs 187 min; $p < 0.001$). Because operative time is a reasonable parameter for clinicians to evaluate when determining the efficacy of a new technology designed to improve a preexisting operation, we can conclude that the robotic approach did not lead to a technical improvement. In particular, the time required to perform a robotic anastomosis in the current series was extremely variable, ranging from 30 to 125 min, and strongly dependent on the operative surgeon and his level of laparoscopic and robotic experience. Concerning the system setup time, with increasing familiarity, our operative team significantly reduced the time, which currently adds approximately 10 min to each case.

In our series, robot-assisted surgery was comparable with standard laparoscopy in terms of postoperative morbidity. No mortality occurred in our 110 cases. The major postoperative complication rate was 3.6% for early complications and 6.4% for late complications, with a rate of 1.8% for anastomotic leaks and a rate of 2.7% for anastomotic strictures. In our laparoscopic experience, we had a rate of 1.9% for anastomotic leak and a rate of 7.8% for anastomotic strictures.

The rates for anastomotic leakage and stenosis registered in the robotic experience were comparable with those in the literature and with the reported averages of 2% for leaks and 4.3% for stricture in large established programs involving more than 100 cases [*41*]. Nevertheless, no statistical difference in the rates for postoperative complications and revisional surgery were noted between the patients who had surgery with the da Vinci system and those who underwent standard laparoscopic surgery.

In a recently published series of 249 robotic RYGBP procedures, Snyder et al. [*31*] retrospectively compared their results with those for 356 laparoscopic RYGBP procedures. The overall major complication rate was similar, but a significant difference was identified in the anastomotic leak rate. Six leaks occurred the laparoscopic group and none in the robotic group, for a 1.7% difference in leak rate ($p = 0.04$). In a series of 75 totally robotic RYGBP procedures [*35*], the authors reported two gastrojejunostomy strictures. These two strictures were associated with the use of nonabsorbable suture for the inner layer of the gastrojejunostomy, and after the second stricture, a change was made to Vicryl for the inner layer, with no subsequent strictures. We used absorbable

suture in all cases and experienced a stricture rate of 2.7%. Although this is lower than the stricture rate observed in the laparoscopic experience (7.8%), the difference is not statistically significant.
Concerning costs, Hubens et al. [*37*] showed a mean total cost of 2,761 € for robotic gastric bypass versus a mean cost of 1,766 € for laparoscopic cases, including only the material. In our experience, the robotic devices used for the gastrojejunostomy determined a global cost of 1,581.51 €, whereas the surgical tools needed for a circular stapled laparoscopic gastrojejunostomy had a cost of 765.78 €. These costs include only the devices for the anastomosis and do not include the initial purchase cost of the da Vinci System. Nevertheless, the increased expense for the robotic approach was due to the use of semidisposable robotic instruments. Adding the cost for the use of the operating room and for the hospitalization, the difference becomes 5,777.76 € vs 4,658.28 € ($p < 0.001$).
In addition to the greater cost for surgical devices and the increased operative time, the robotic group did not benefit from the use of fewer trocars or a shorter postoperative hospital stay. We can conclude that the robot-assisted approach is burdened by a major economic expense, although a multidisciplinary use of the system would result in a faster realization of return on the initial investment. Concerning weight loss results, the robotic patients showed a mean excess weight loss comparable with that of the laparoscopic RYGBP patients and with that reported in the literature [*42*].
In conclusion, although safe and intuitive, the robotic approach was burdened by greater operative time and equipment costs and did not seem to provide a real advantage over standard laparoscopy in terms of hospital length of stay and complication rates.

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