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ORIGINAL CONTRIBUTIONS

Robot-Assisted Versus Laparoscopic Gastric Bypass: Comparison of Short-Term Outcomes

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Abstract
Background Roux-en-Y gastric bypass is an effective treatment for severe obesity and obesity-related comorbidities. Presently, gastric bypass is performed most often laparoscopically, although a robotic-assisted procedure is the preferred approach for an increasing number of bariatric surgeons.
Methods This retrospective study compared the results of 100 Roux-en-Y gastric bypass operations using the da Vinci robot and 100 laparoscopic Roux-en-Y gastric bypasses performed laparoscopically. Short-term outcomes were determined by evaluating mortality, length of stay, length of operation, return to the operating room within 90 days of operation, conversions to open procedure, leaks, strictures, transfusions, and hospital readmissions.
Results There was no mortality, pulmonary embolus, or conversion to open procedure in either group. Both the laparoscopic and robotic operative times decreased progressively, although the robotic operation time was longer (mean, 144 versus 87 min, $P<0.001$). The length of stay was shorter for the robotic-assisted group (37 versus 52 h, $P<0.001$), and 60 % of these patients were discharged after one night's stay ($P<0.001$). There were fewer transfusions ($P=0.005$) and readmissions ($P=.560$) in the robotic group. The stricture rate was higher in the first 50 robotic procedures (17 mm gastrotomy) but resolved in the second 50 procedures (21 mm gastrotomy). There was no difference in the rate of leak and return to the operating room between groups (both $P>0.05$).
Conclusions These results indicate that Roux-en-Y gastric bypass can be performed safely with robotic assistance, even during the first 100 cases.

Keywords Gastric bypass · Obesity · Roux-en-Y · Laparoscopic · Robotic-assisted

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Introduction

Bariatric surgery is an effective treatment for morbid obesity [1]. The gastric bypass operation has been especially effective in facilitating weight loss and resolving obesity-related comorbidities, such as diabetes mellitus, hypertension, obstructive sleep apnea, and gastroesophageal reflux disease [2]. Mason and Ito [3] originally performed the gastric bypass operation through an open incision. In 1994, Wittgrove et al. reported the first gastric bypass performed via a laparoscopic approach [4]. Since that report, the laparoscopic approach has been adopted widely. With experience using the laparoscopic approach and additional advancements in the field of bariatric surgery, the morbidity and mortality of this operation have decreased to the present very low levels. Following the first report describing robotic bariatric surgery [5], several bariatric surgeons have reported the results of gastric bypass operations performed with the assistance of the da Vinci surgical robot (da Vinci® Surgical System, Intuitive Surgical®, Inc., Sunnyvale, CA, USA). The present study compares the early perioperative outcomes in 100 laparoscopic Roux-en-Y gastric bypass operations and 100 robotic-assisted, Roux-en-Y gastric bypass operations.

Methods

Study Design

The study was approved by the Investigational Review Board, and patients undergoing the robotically assisted operation

provided written, informed consent for the robotic approach. Data were collected prospectively and evaluated retrospectively. Confidentiality was maintained by using a numerical sequence to conceal identifying patient information.

The study consists of 200 consecutive gastric bypass operations performed between October 2009 and September 2011 by a single experienced surgeon in a 1,300-bed community hospital with a stable, robust Center of Excellence-verified bariatric surgery program. The study reviewed the results of 100 laparoscopic Roux-en-Y gastric bypass operations performed from September 2009 to September 2010 immediately prior to beginning the series of robotic-assisted gastric bypass operations. The laparoscopic operations were the last 100 of a series of 800 laparoscopic gastric bypasses performed by the surgeon. These were selected for comparison with the first 100 robot-assisted gastric bypass operations performed by the same surgeon from September 2010 to September 2011.

Each patient met National Institutes of Health criteria for a bariatric operation and completed the standardized program that included thorough medical and psychological evaluations and a minimum of 3 h of one-on-one dietary educational instruction sessions prior to the operation. There were consistent protocols and procedures and mid-level and hospital care throughout the study. There was no difference in discharge support, insurance requirements, operating days, or operating room start times that would influence the length of stay. To determine whether these two groups were similar, we collected the following patient demographic information: age, sex, body mass index (BMI), and obesity-related comorbidities including diabetes mellitus, hypertension, obstructive sleep apnea, and coronary artery disease.

Outcomes

The length of stay was measured from the time a patient left the operating room until the time he/she left the hospital. Short-term outcomes of the two patient groups were assessed by comparing the following adverse events: mortality, return to the operating room within 90 days of operation, conversions to open procedure, and 90-day complications such as leaks, strictures, transfusions, hospital readmissions, pulmonary embolus, stroke, and myocardial infarction.

Laparoscopic Surgical Technique

The laparoscopic gastric bypass procedure is performed in a standardized fashion using four 12 mm ports, one of which was enlarged to 3 cm for passage of the circular stapler. After any adhesions are divided and the omentum is divided vertically, a 15–20 cc pouch is formed with a 60 mm Echelon Flex™ Endopath® linear stapler (Ethicon Endo-Surgery, Inc., Cincinnati, OH, USA) reinforced with Peri-Strips (Peri-Strips Dry®, Synovis® Surgical Innovations, St. Paul, MN, USA). Prior to completing the gastric pouch, a Peri-Strip-reinforced anvil of the 25 mm proximate circular stapler (PROXIMATE® Circular Stapler, Ethicon Endo-Surgery, Inc., Cincinnati, OH, USA) was placed along the horizontal staple line through a transgastric approach closing the gastrotomy with a single firing of the 60 mm Echelon Flex linear stapler stapling device. The small intestine is divided, creating a biliopancreatic limb 40 cm in length and a Roux limb 150 cm in length. The jejunojejunostomy is completed with a single application of the 60 mm Echelon Flex linear stapler reinforced with Peri-Strips for hemostasis; the closure of the common opening is completed with the same stapling device. The mesenteric defect is closed with a running suture. The Roux limb is brought to the gastric pouch in an antegastric, antecolic position. One 12 cm port site is extended to 3 cm to allow for passage of the 25 mm PROXIMATE® circular stapler reinforced with Synovis buttressing material. The circular stapler is passed into the end of the Roux limb, and the post is advanced through the antimesenteric wall of the Roux limb and connected to the anvil. The gastrojejunostomy is completed by firing the circular stapling device at the mid-location on the tissue compression dial. The circular stapler is removed, and the end of the Roux limb is closed with the linear stapler. Peterson's space and the mesentery defect are closed with 2–0 Vicryl suture.

Robotic Surgical Technique

In the fully robotic-assisted gastric bypass, two 12 mm ports are placed, one for the camera and one for the stapling device, and two 8 mm ports are placed for the robotic instruments. Adhesions are divided laparoscopically, and the omentum is divided vertically. After the robot is docked, the surgeon performs the remainder of the operation at the console. All staple lines are accomplished by the Certified Registered Nurse First Assistant (CRNFA) at the direction of the surgeon. The jejunojejunostomy and the gastric pouch are completed as described previously in the laparoscopic operation with the surgeon at the console. The mesenteric defect is closed with a running suture. The robot is docked only once, and the surgeon does not return to the operating table once at the console.

The Roux limb is positioned in an antegastric, antecolic position adjacent to the transverse staple line of the pouch, and the openings in the gastric pouch and Roux limb are created with the robotic-controlled Harmonic Scalpel (Ethicon Endo-Surgery, Cincinnati, OH). The gastrojejunostomy is completed using the robot as a two-layered sutured anastomosis using a running 2–0 Vicryl for the full-thickness circumferential inner row and another running seromuscular row of 2–0 Vicryl instead of using the circular stapling device.

The 100 robotic-assisted gastric bypass operations were performed in a stepwise sequence: (1) performing the first 50 operations by completing the pouch and jejunojejunostomy laparoscopically before docking the robot to complete the robot-assisted, hand-sewn gastrojejunostomy; (2) performing the next 30 operations by completing the gastric pouch laparoscopically before docking the robot to perform both the jejunojejunostomy and the gastrojejunostomy, while the CRNFA deployed the 60 mm Echelon linear stapling device; and (3) performing all three components of the last 20 robotic-assisted gastric bypass operations at the console, including the formation of the gastric pouch, the jejunojejunostomy, and the gastrojejunostomy. This sequence is depicted in Fig. 1a. The first 50 operations utilized a 17 mm gastrotomy, and the second 50 operations utilized a 21 mm gastrotomy.

Statistical Analysis

Minitab 16 (Minitab, Inc., State College, PA, USA) was used for the statistical analysis. Differences for age, body mass index, operation length, and length of stay were determined using Student's *t* test. Differences for gender, comorbidities, and perioperative outcomes were determined using Fisher's exact test. The values reported in the "Results" section are mean±standard deviation.

Results

Patient Characteristics

One hundred patients underwent gastric bypass surgery using a laparoscopic approach, and 100 patients underwent a robotic-assisted operation. The characteristics of the two groups are shown in Table 1. The mean BMI and age were similar in both groups, and there were slightly more men in the robotic group. The comorbidities were also similar, although sleep apnea was more frequent in the robotic group ($P=0.006$). All patients in the laparoscopic group had a stapled gastrojejunostomy performed with a 25 mm PROXIMATE® circular stapler, whereas all patients in the robotic-assisted group had a two-layered, robot-assisted, hand-sewn gastrojejunostomy.

The perioperative data for the two groups are shown in Table 2. There was no mortality, pulmonary embolus, stroke, myocardial infarction, or conversion to open procedure in either group. The operative time was longer in the robotic group by an average of 57 min. However, the operating time decreased progressively (Fig. 1b).

There was a significant decrease in the length of stay of patients undergoing the robotic-assisted gastric bypass; 60 % of the robotic-assisted gastric bypass patients left the hospital after only a one-night stay compared with 4 % of the laparoscopic patients ($P<0.001$).

There were eight patients in the laparoscopic group readmitted to the hospital and three in the robotic-assisted group ($P=0.213$). Two patients in the robotic-assisted group returned to the operating room within 90 days for release of a small bowel obstruction because of fresh adhesions, and one patient in the laparoscopic group returned to the operating room for a cholecystectomy for acute cholecystitis (Table 2).

Adverse events are listed in Table 3. Overall, the complication rate in both groups was low with no mortality in either group. However, more patients required transfusions in the laparoscopic group ($P=0.005$), and more strictures occurred in patients in the robotic-assisted group during the first half of the robotic-assisted series. Although one patient from the robotic group required transfusion, this patient did not have evidence of gastrointestinal bleeding and only received one unit of blood. Five patients from the laparoscopic group received a total of 11 units of blood. Three of these patients had evidence of gastrointestinal bleeding. One patient from the laparoscopic group was readmitted 9 days after her operation with hematemesis; this patient was admitted to the ICU and received 4 units of blood. She was discharged to home after 7 days in the hospital. Three other patients each received 2 units of blood, and one patient received 1 unit of blood. No patient in either group required endoscopic or operative intervention for hemostasis.

Six patients who were treated in the first 50 robotic-assisted operations required dilation procedures for anastomotic stricture. In this group, we utilized a 17 mm gastrotomy. For the second 50 robotic-assisted procedures, we utilized a larger, 21 mm gastrotomy for the gastrojejunostomy, and there were no anastomotic strictures. There were two strictures in the laparoscopic group (Table 3).

Discussion

Since the first report of a robotic-assisted gastric bypass was published by Horgan and Vanuno in 2001 [5], several surgeons have adopted the robotic approach. Advantages include the enhanced movement of the robot's articulating instruments, three-dimensional vision controlled by the surgeon, a more stable platform for the laparoscope and the instruments, better ergonomics that relieve the surgeon of the torque and pressure inherent in passing instruments through the obese abdominal wall, and comfortable seating for the surgeon during much of the operation.

Although the author was generally satisfied with the laparoscopic approach, he was bothered by the occasional and seemingly unpredictable episode of upper gastrointestinal bleeding and complaints of pain at the 3 cm incision site for entrance of the 25 mm stapling device and, therefore,

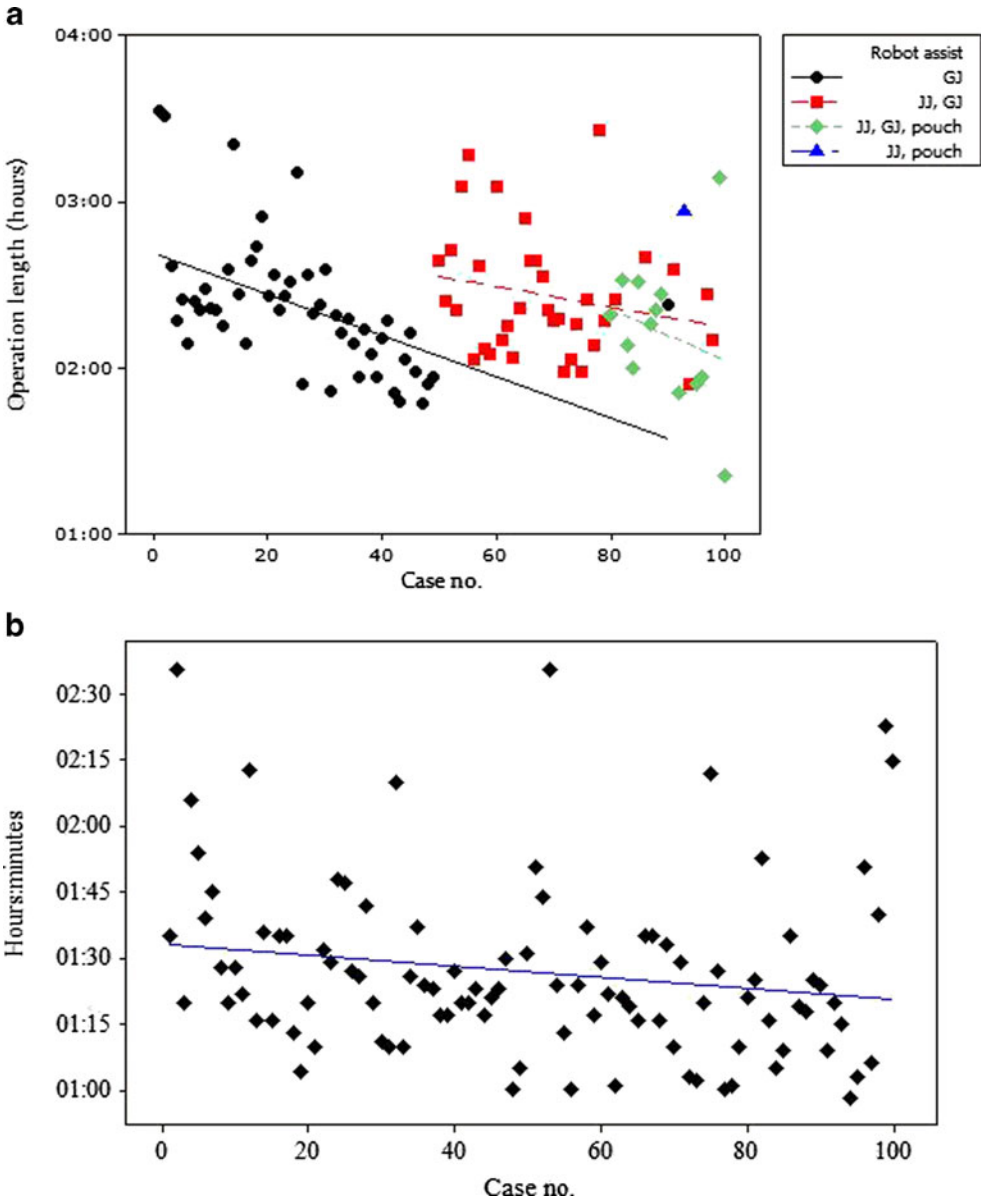

Fig. 1 **a** Operative time according to procedure phase using robotic assistance (n=100). *GJ*=gastrojejunostomy; *JJ*=jejunojejunostomy. **b** Operative time for laparoscopic procedure by case (n=100). *GJ* =gastrojejunostomy; *JJ*= jejunojejunostomy

Table 1 Patient characteristics at baseline

Characteristic	Robotic-assisted, n =100	Laparoscopic, n =100	P value
Male	24	17	0.219
Female	76	83	0.293
Age (years)	45.7 (9.95)	47.0 (10.83)	0.404
BMI (kg/m^2)	45.7 (6.31)	44.6 (5.69)	0.174
Comorbidities			
Sleep apnea	83	65	0.006
Hypertension	72	60	0.100
Diabetes mellitus	41	40	1.000
Coronary artery disease	6	8	0.783

BMI body mass index

was willing to consider the robotic-assisted approach to potentially reduce these issues.

There have been several reported series of at least 100 robotic-assisted Roux-en-Y gastric bypass procedures [6–10]. All were hybrid operations with varying amounts of the operation performed laparoscopically, although each procedure involved a robotically assisted, hand-sewn gastrojejunostomy. During the first 100 cases reported by a fellowship-training program, the average time to complete the robotic-assisted gastric bypass from incision to skin closure was 254 min [6], as compared with 186 min reported by a single surgeon in a community hospital [8]. These findings are comparable to other studies and the laparoscopic "learning curve" reported by Schauer et al. of 269 min [11]. In series that compared times with the laparoscopic approach within the same institution, the robotically assisted operation took

Table 2 Perioperative outcomes

Outcome	Robotic-assisted, $n=100$	Laparoscopic, $n=100$	P value
Operative time (min)	144	87	<0.001
ICU stay (patients)	0	1	0.315
Length of stay (h)	37.2	52.0	<0.001
One-night stay (%)	60	4	<0.001
30-day readmission (patients)	3	8	0.560

ICU intensive care unit

longer, especially during the "learning curve" period [6]. However, the operative time to perform the robotic-assisted operation decreased over the first 100 cases in each series, including ours. Snyder and colleagues reported continued improvement from 259 min during the first 100 cases to 192 min during a longer series [7]. Our average time compares favorably at 144 min. Of course, extensive experience with the laparoscopic gastric bypass such as in this study may decrease the robotic learning curve as compared with the learning curve of a fellow without significant prior experience with the laparoscopic gastric bypass.

Reported complications in the robotic-assisted gastric bypass series have been low [6–8, 10, 12, 13], with leaks ranging from 0 % to 1 %, strictures from 0 % to 4 %, obstructions from 0 % to 3 %, and transfusions from 0 % to 3 %. These complications are considerably lower than in most laparoscopic series, as also noted in the larger series of robotic-assisted operations at the University of Texas [6]. The low complication rate in these studies is remarkable, since each study represents the "learning curve" for the respective institution. The low complication rate in our study is especially remarkable, although not statistically significant, since our robotic series had a higher percentage of male patients, a known independent risk factor.

Table 3 Adverse event

Adverse event	Robotic-assisted, $n=100$	Laparoscopic, $n=100$	P value
Blood transfusion (n patients)	1	5	0.005
Units transfused	1	11	0.003
GI bleeding	0	3	NS
Non-GI bleeding	1	2	NS
Anastomotic leak	1	1	NS
Strictures	6	2	NS
Intra-abdominal abscess	0	1	NS
Intestinal obstruction	2	1	NS

GI gastrointestinal, *NS* not significant

It is of interest that strictures were more frequent in the first 50 robotic operations in our series. We believe this is partly due to the superior three-dimensional visualization provided by the da Vinci robot, thus possibly making the opening in the gastric pouch appear much larger than it would appear in the two-dimensional environment of the standard laparoscopic operation. In our first 50 robotic operations, the surgeon opened the gastric pouch slightly larger than the length of the cutting blade of the harmonic scalpel, approximately 17 mm. In the second 50 operations, the surgeon increased the gastrotomy to 21 mm, and no strictures occurred. This is similar to the decrease in stricture rates found by increasing the diameter of the circular stapling device from 21 to 25 mm.

Early postoperative bleeding following a gastric bypass operation is a known complication and has been reported in several series [14–16]. Although often self-limited, bleeding can lead to the need for transfusion, significant morbidity, and even mortality [17]. The frequency of early gastrointestinal bleeding with laparoscopic gastric bypass operations has been reported to range from 1 % to 4 % [14, 18–22]. It occurs more frequently in diabetic patients [23] and in older patients [24]. Although postoperative bleeding can be related to intraperitoneal or abdominal wall bleeding, approximately half of postoperative bleeding originates in the gastrointestinal tract and nearly always from a staple line [25], with the gastrojejunostomy appearing to be the single most frequent site.

The original operation described by Mason and Ito in 1969 completed the gastrojejunostomy using a hand-sewn technique [3]. The advent of the laparoscopic approach led to increased use of stapling devices. Several reports have identified an increase in gastrointestinal bleeding with the laparoscopic approach [11, 15, 16, 24, 26, 27]. The stapled gastrojejunostomy can be performed using either a circular or a linear stapler. A recent article by Nguyen et al. showed that the incidence of bleeding could be reduced by half by changing from the 4.8 mm nonadjustable device to the 3.5 mm device by Covidien (Endo GIA™ Ultra Universal Stapler, Covidien, Mansfield, MA, USA) [25]. Others use an adjustable circular stapling device by Ethicon as used in the present study. Although technically challenging to perform with long, straight laparoscopic instruments, some surgeons have performed the gastrojejunostomy laparoscopically by suturing, as reported by Higa and others [27]. The da Vinci surgical robot can enable the surgeon to create a hand-sewn anastomosis with precision using articulating instruments that mitigate the complexity of using long, straight, nonarticulating instruments required with standard laparoscopic surgery. With the robot, the surgeon can perform a very precise operation with stable surgeon-controlled, three-dimensional visualization and "wristed" instruments. However, the fact that none of our patients

who had a robotic-assisted sutured gastrojejunostomy had gastrointestinal bleeding requiring transfusion is cause for speculation. It is possible that using the robotic harmonic scalpel to create the openings in the gastric pouch and Roux limb for the anastomosis contributes to hemostasis. In addition, the fact that the full-thickness, two-layered, running-sutured anastomosis is a very hemostatic construction might also contribute to the decrease in gastrointestinal bleeding with the robotic approach. However, our data show that the risk of early gastrointestinal bleeding can be reduced or even eliminated by the robotic approach.

Early discharge from the hospital is noted in most robotic-assisted series. Yu et al. reported 3 days [6], Moser and Horgan reported 2.1 days [10], and Deng and Lourié reported 1.5 days [8]. It was surprising to the authors how much earlier patients in our robotic-assisted group were able to leave the hospital. Usually, by the afternoon of the second postoperative day, our robotic-assisted patients were meeting criteria for discharge and requesting to leave the hospital. Our standards for discharge include normal vital signs, blood count, glucose, and pulse oximetry, the ability to ambulate comfortably with oral pain medications without assistance, and a BMI$<$50 kg/m^2. Although we did not observe a difference in narcotic use in the first 24 h, it appeared that, by the second 24 h, patients in the robotic-assisted group were more comfortable. Unfortunately, the narcotic use could not be documented after the first 24 h since the patients frequently left the hospital before the second 24-h period concluded. Earlier discharge in the robotic-assisted group may have been related to having only two 12-mm ports and two 8-mm ports in the robotic operations compared with three 12-mm ports and a 3-cm incision to insert the circular stapling device through the abdominal wall that required fascial closure. In addition, the ability of the robot to pivot each instrument at the location of passage through the abdominal wall is likely to decrease the usual abdominal wall trauma inherent in the standard laparoscopic approach.

These two patient groups are not equivalent. The laparoscopic series is a reflection of 7 years of laparoscopic experience and nearly 800 laparoscopic gastric bypass operations. In contrast, the robotic-assisted series reports the first 100 robotic-assisted cases performed by the surgeon and constitutes the surgeon's "learning curve" for robotic surgery. Of course, this makes the findings even more important in light of the time difference in experience. Although a higher complication rate might be expected during a "learning curve," this was not seen in our study and in most other studies.

Other study limitations include the sequential nature of the two patient groups instead of a randomized trial, and a single surgeon/single medical center instead of a multicenter study. Finally, we did not confirm the gastrointestinal bleeding endoscopically and relied on hematemesis or hematochezia for confirmation, nor did we evaluate patients with computed tomographic scans to identify the source of non-gastrointestinal bleeding (i.e., intraperitoneal or abdominal wall).

Cost comparisons were not done, since the two groups were not similar in levels of experience and the learning curve by nature would be longer and, therefore, likely be biased toward higher costs.

Conclusion

The results of this study show that the Roux-en-Y gastric bypass can be performed safely with robotic assistance, even during the first 100 cases with significant improvement in short-term outcomes over the standard laparoscopic approach, including decreased transfusion frequency and decreased volume of blood transfused, as well as decreased length of stay. Although the operating time is longer for robotic cases, the operating time decreases with experience. Further studies are required to confirm these findings and identify additional benefits and risks from robotic-assisted bariatric surgery.

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