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ORIGINAL CONTRIBUTIONS

Outcomes of Robot-Assisted Roux-en-Y Gastric Bypass as a Reoperative Bariatric Procedure

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Abstract
Background We evaluate the outcomes of robot-assisted Roux-en-Y gastric bypass (RRYGB) as a reoperative bariatric procedure (RBP).
Methods A retrospective analysis was done from 2007 to 2014, and all the patients who underwent RRYGB as a RBP at a teaching university hospital were included.
Results A total of 32 patients underwent RRYGB as a reoperation from adjustable gastric band (AGB n=16) or sleeve gastrectomy (SG n=11) or previous gastric bypass (n=5). Twenty patients underwent conversion to RRYGB due to weight loss failure, either after AGB (n=13) or SG (n=7). Twelve patients underwent reoperation because of complications of index procedure. Mean preoperative weight was 109.7±29.5 kg, and BMI was 40±10.6 kg/m^2. The mean operative time for RRYGB was 226±45.3 min with a blood loss of 20±15.9 ml. Average length of stay was 3 days. In two cases, pin point leaks were detected intraoperatively during check gastroscopy, and they were repaired with sutures. There were no postoperative anastomotic leaks or hemorrhage or gastrojejunostomy strictures. None of the patients required a blood transfusion or reoperation within perioperative period. In the patients who underwent RRYGB for weight loss failure (n=20), the mean excess weight loss (EWL) was 39.2 % at 6 months (n=11), 53.8 % at 1 year (n=13), and 60.7 % at 2 years (n=6).
Conclusions RRYGB is safe and effective to be used as a revisional bariatric procedure. The weight loss outcomes and complication rates compare favorably with the published results of laparoscopic technique, although the small sample size may not be enough to reach definite conclusions.

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Keywords Robot · Revisional · Gastric bypass · Reoperation · Bariatric surgery · Gastric band

Introduction

Morbid obesity is a chronic disease requiring lifelong treatment. Bariatric surgery is currently the most effective and consistent treatment modality for morbidly obese patients to achieve weight loss, decreasing obesity-related comorbidities, and improving overall quality of life and survival [1]. However, there are some patients who do not loose enough weight or have persistent complications after a bariatric procedure [2]. These may be candidates for a reoperative bariatric procedure to address their issues. Due to the rise in number of primary bariatric procedures, surgeons have started to encounter a significant number of these patients.

The commonly performed bariatric procedures in order of increasing complexity are adjustable gastric banding (AGB), sleeve gastrectomy (SG), Roux-en-Y gastric bypass (RYGB), and biliopancreatic diversion with or without duodenal switch (BPD ± DS). The restrictive procedures like AGB and SG have a higher failure rate in terms of weight loss as compared to RYGB and BPD ± DS which are both restrictive and malabsorptive [3]. There may be complications of primary procedures like band erosion, band slippage, severe reflux, stricture, marginal ulceration, internal hernia etc. requiring a reoperation. The weight loss expectations after a revision may not be the same as with the index bariatric procedure.

Reoperations pose significant technical difficulty and challenge to the bariatric surgeons. It carries a higher risk of complications, and a possibility that it may have to be done in a staged fashion rather than a single intervention. This is due to the presence of scarring, adhesions and inflammation, which increase the risk of bleeding and anastomotic complications. It also increases the chances of conversion to open from a

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minimally invasive procedure. Some of these challenges are related to the limitations of conventional laparoscopy like rigid instruments, two-dimensional vision, and tremor amplification. Robotic surgery provides the potential advantages of three-dimensional vision, increased dexterity and precision by downscaling surgeon movements, and obliteration of tremors enabling a fine tissue dissection [4]. It overcomes the restraint of torque on ports from thick abdominal wall and minimizes port site trauma by remote center technology. Selected case series have shown better outcomes with robot-assisted RYGB (RRYGB) as compared to laparoscopic RYGB (LRYGB); however, further studies are required to demonstrate the benefits of robotic surgery vs standard laparoscopic techniques [5, 6]. Also, there are limitations of this technique like lack of haptic feedback, need of trained bedside assistant, and added cost.

Independent of the indication, RYGB is the most commonly performed reoperative procedure [7]. Our division has an extensive experience in robot-assisted bariatric procedures, both primary and reoperations. In this study, we look at our outcomes of RRYGB as a reoperative procedure, performed either after AGB, SG, or RYGB as the index operation.

Methods

With an institutional review board approved protocol, the prospectively collected database at University of Illinois Medical Center in Chicago was reviewed retrospectively from May 2007 to Feb 2014. A total of 32 patients were included who underwent robot-assisted RYGB as a reoperative bariatric procedure. Patients who underwent a robot-assisted reoperative procedure other than RYGB were excluded, as were those who had a different index procedure apart from AGB, SG, or RYGB. The indications varied from weight loss failure, weight regain, and complications of primary bariatric procedure. Informed consent was obtained after explaining all the risks and benefits involved. All patients eligible for a reoperation were offered robotic surgery for performing the procedure. A preoperative upper gastrointestinal endoscopy or a contrast study was performed in all cases to delineate the anatomy and rule out complications like band erosion, stricture, marginal ulceration etc.

The American Society of Metabolic and Bariatric Surgery task force has classified reoperative bariatric procedures into conversion (changing an index procedure to a different type of procedure), corrective (to address complications or incomplete treatment of a previous bariatric procedure), or reversal (to restore the normal anatomy) [8]. For the purposes of this manuscript, the first operation was considered the index operation, and the second operation was considered the reoperation (either corrective or conversion).

Variables and Statistics

Patient demographics, clinical characteristics, obesity-related comorbidities, index operation, indication for reoperation, operative parameters, conversions, complications, reoperations (within 30 days of surgery), excess weight loss (EWL), and mortality were recorded and analyzed. Operative time was defined as time between the first skin incision and the last skin closure. Length of hospital stay denoted time between surgical procedure and discharge of the patient. Conversion was considered when there was a need to convert to laparoscopic or open approach in order to complete the procedure. An assessment of the percentage EWL was obtained at 6 months, 1 year, and 2 year after reoperation. The ideal body weight was calculated equivalent to a BMI of 25 kg/m^2, and the EWL was calculated from pre-revision weight. The results of parametric and nonparametric data were expressed as mean±standard deviation (SD) and median (range), respectively. Statistical analysis was done using IBM® SPSS® Statistics software version 19.0. Confidence intervals were set at 95 %.

Surgical Technique

All the procedures were performed using da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA)®. We prefer to conduct conversion as a one-stage procedure whenever possible, because it decreases the number of sittings and overall cost. The detailed surgical procedure was dependent on the index operation and the indication for reoperation. The end point in all cases was to create RYGB by either converting previous AGB/SG or correcting previous RYGB. To accomplish this, patients were placed in 15–20° reverse Trendelenberg position with a urinary catheter in situ. The abdomen was entered with optical trocar in the left upper quadrant and camera port was placed. Overall, five ports were placed including three da Vinci trocars. Nathanson liver retractor was placed in epigastrium for liver retraction whenever possible; else the liver was retracted dynamically using the third robotic arm. The patient cart was docked from the head end of the patient. The first step in all cases was dissecting the adhesions. This was preferred to be done using the robot with the help of monopolar hook and ultrasonic scalpel.

Band removal is one of the most important steps in revisional surgery for failed AGB. The gastric band produces a fibrotic ring (capsule) around the stomach, and it has to be meticulously excised, as a misfiring of stapler can occur otherwise. A check intraoperative gastroscopy was performed after band removal before proceeding with RYGB. This was important as the revision may have to be deferred to a second stage because of an intraoperative complication such as significant hemorrhage or an inadvertent gastric perforation. In cases of previous SG, adhesiolysis was done and anatomy defined.

Table 1 Indication of converting or correcting index procedure to robot-assisted Roux-en-Y gastric bypass (RYGB)

Indication	Index procedure (number of patients with percentage in their subgroup)		
	AGB	SG	RYGB
Insufficient weight loss/significant weight regain	13 (81.3 %)	7 (63.6 %)	0
Band prolapse	2 (12.5 %)	0	0
Severe reflux	0	3 (27.3 %)	0
Intolerance/dysphagia	1 (6.2 %)	1 (9.1 %)	0
Marginal ulcer	0	0	4 (80 %)
Candy cane with hiatal hernia	0	0	1 (20 %)
Total	16	11	5

AGB adjustable gastric band, *SG* sleeve gastrectomy

A small gastric pouch was created using perigastric technique with 2–3 firings of endoscopic staplers. Jejunum was transected at 50 cm from the ligament of Treitz and 120 cm of Roux limb was measured. Jejunojejunostomy (JJ) was done using a 60-mm stapler, and enterotomy closed using PDS 3-0 running suture. The Roux limb was taken to the gastric pouch in an antecolic antegastric fashion, after dividing the omentum if necessary. A hand-sewn gastrojejunostomy (GJ) in two layers with PDS 3–0 was performed. We used the fourth robotic arm from the right side of the patient which decreased the dependence on the assistant and allowed the surgeon to retract by himself.

In cases when corrective procedure was required for a previous RYGB, the gastric pouch, GJ, JJ, and Roux limb were defined. Most of these were done for a marginal ulcer or candy cane. In case of marginal ulcer, the GJ was excised and redone with hand-sewn two-layered technique using PDS 3–0. In case of candy cane, the redundant Roux limb was excised using endoscopic stapler. After the reoperation was complete, an intraoperative esophagogastroscopy was done with air leak test in all the cases.

Results

The index procedure and indication of reoperation in all 32 patients who underwent RRYGB are listed in Table 1. Twenty patients underwent conversion to RRYGB due to inadequate weight loss or weight regain, either after AGB or SG. Twelve patients underwent either correction of RYGB or conversion from AGB/SG because of complications of index procedure.

The patient demographics and clinical data are summarized in Table 2. All the patients in the series were females. There was no significant difference in any of demographic parameters among various groups.

Table 3 lists the operative parameters and outcomes after surgery. There was no significant difference in the operative time, blood loss, or length of stay between diverse groups. An anastomotic leak at GJ was identified intraoperatively in two patients who underwent conversion from AGB to RYGB. Both the leaks were detected during check endoscopy from the jejunal side of anastomosis and were repaired using PDS 3–0 suture. The patients did well postoperatively. There was no conversion to open, postoperative leak or hemorrhage, GJ stricture, reoperation within 30 days or mortality in the entire series.

Twenty patients who underwent conversion from a restrictive procedure to RYGB for weight loss failure or weight regain were analyzed separately. Out of those, 13 patients underwent conversion from AGB and 7 patients from SG. There was no significant difference in the two groups in any of demographic parameters, operative time, blood loss, or length of stay. The weight loss outcomes were studied at 6, 12, and 24 months with a percentage follow up of 55, 65, and

Table 2 Patient demographics and preoperative parameters

	Total (n=32)	AGB to RYGB (n=16)	SG to RYGB (n=11)	Correction of RYGB (n=5)
Mean age (years)	43±9.4	39.9±10.9	45.9±8.3	43.6±3.5
BMI (kg/m^2)	40±10.6	43±6.9	40.5±13.3	30.3±9.9
Weight (kg)	109±29.5	116.7±18.8	107.7±38.9	88.4±29.6
ASA score	2±0.5	2.4±0.5	2.5±0.5	2.2±0.4
No. of patients with HTN (percentage of patients in each subgroup)	13 (40.6 %)	9 (56.2 %)	4 (36.4 %)	0
No. of patients with T2DM (percentage of patients in each subgroup)	10 (31.3 %)	6 (37.5 %)	2 (18.2 %)	2 (40 %)
No. of patients with dyslipidemia (percentage of patients in each subgroup)	7 (21.9 %)	5 (31.2 %)	2 (18.2 %)	0

AGB adjustable gastric band, *SG* sleeve gastrectomy, *RYGB* Roux-en-Y gastric bypass, *BMI* body mass index, *ASA* American Society of Anesthesiologists, *T2DM* type 2 diabetes mellitus, *HTN* hypertension

Table 3 Perioperative results and outcomes of reoperation

	Total (*n*=32)	AGB to RYGB (*n*=16)	SG to RYGB (*n*=11)	Correction of RYGB (*n*=5)
Operative time (min)	226±45.3	230±52	221.3±42.6	226.4±32.9
Blood loss (ml)	20±15.9	15.6±14.4	23.6±18	24±15.2
Length of stay (days)	3±2.6	3±1.5	2.9±0.7	6.2±5.8
Conversion	0	0	0	0
Reoperation (within 30 days) of reoperative bariatric procedure	0	0	0	0
Intraoperative detection of anastomotic leak	2 (6.25 %)	2 (12.5 %)	0	0
Postoperative detection of anastomotic leak	0	0	0	0
Postoperative hemorrhage	0	0	0	0
GJ stricture	0	0	0	0
Mortality	0	0	0	0

AGB adjustable gastric band, *SG* sleeve gastrectomy, *RYGB* Roux-en-Y gastric bypass

30 %, respectively. Figure 1 reveals the percentage EWL at these time intervals in various groups.

Discussion

To the best of our knowledge, there are only two published studies reporting outcomes of robot-assisted reoperative bariatric surgery [9, 10]. Our study refers in particular to the outcomes of reoperative robot-assisted RYGB, which has not been addressed adequately.

Most of the published series report that the complication rate of revisional RYGB is higher than primary RYGB [11–13]. A recent systematic review of 15 studies (588 patients) evaluated conversion from AGB to laparoscopic RYGB and reported an overall complication rate (major and minor) of 8.5 % with bleeding and anastomotic leak rates of 1.8 and 0.9 %, respectively. The rate of converting to open was 2.4 % and the mean incidence of reoperation was 6.5 % [14]. In the light of these results, although our series is small, the fact that it had no postoperative leaks or hemorrhage, no strictures, no conversions to open and no reoperation deserves attention and further evaluation in larger studies. The two cases in which a leak was detected intraoperatively occurred fairly early in the series, and may be attributed to learning curve of reoperative surgery. Interestingly, the two previously published studies on outcomes of robot-assisted revisional RYGB also reported no anastomotic leak or hemorrhage [9, 10]. One of the potential reasons of a low rate of anastomotic complications in RRYGB can be a hand sewn GJ rather than stapled GJ as done in most of the laparoscopic series [15, 16]. This becomes more important in the case of reoperations due to scarring and fibrosis, thus increasing the chances of misfiring of a mechanical stapler, or improper approximation of tissues. An intraoperative check endoscopy is a very useful tool in these cases to detect a leak due to technical reasons on

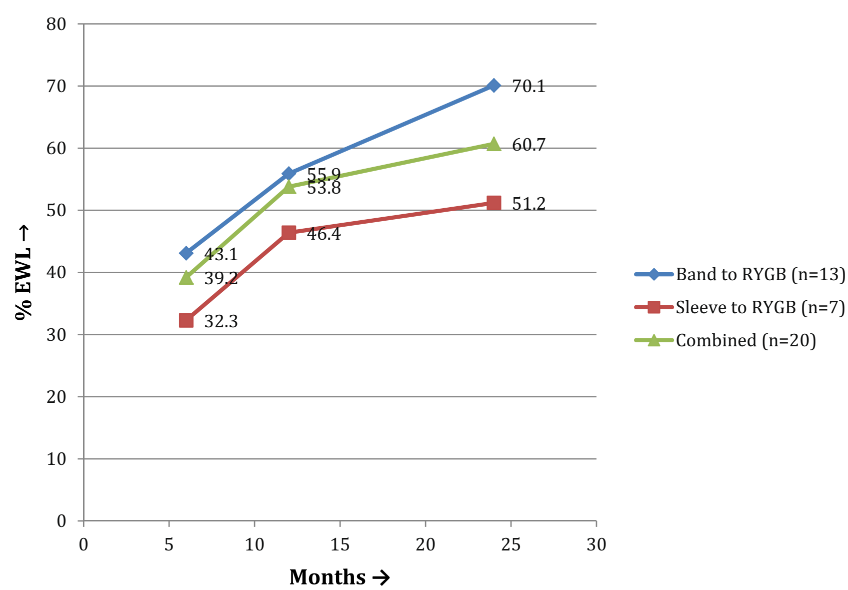

Fig. 1 Weight loss outcomes after conversion of a restrictive procedure to robot-assisted Roux-en-Y gastric bypass due to weight regain/weight loss failure. Percentage follow-up at 6 months was 55 %, at 12 months was 65 %, and at 2 years was 30 %. *EWL* excess weight loss, *RYGB* Roux-en-Y gastric bypass

the table itself. As mentioned, it helped us take care of such leak in two cases, thus avoiding potentially disastrous consequences in the postoperative period.

The EWL after revisional RYGB has been demonstrated to be lower than that for primary RYGB in many published studies [13, 17, 18]. A systematic review evaluated conversion of 514 AGB patients to laparoscopic RYGB and reported EWL to be 46.3 % (6–12 months), 57.8 % (12–24 months), and 48.2 % (24–48 months) [19]. In our series, the EWL after conversion of AGB to RRYGB was 43.1 % (6 months), 55.9 % (12 months), and 70.1 % (24 months). Another article reviewed 6 studies (n=114) evaluating conversion from SG to laparoscopic gastric bypass, and reported EWL of 37 % (6 months), 60 % (12 months), and 48 % (24 months) [20]. In our series, the EWL after conversion from SG to RRYGB was 32.3 % (6 months), 46.4 % (12 months) and 51.2 % (24 months). In both these groups, the weight loss outcomes after revisional RRYGB at our institution seem to be in accordance with the published literature, or even better.

The operative times in revisional RYGB cases has been shown to be longer as compared to primary RYGB. For performing a laparoscopic revisional RYGB, Zhang et al. [21] reported mean operative time of 272.5 min (n=172), while Delko et al. [17] reported it to be 201 min (n=48). There is only one paper that reports the operative time for a robotic revisional RYGB (353 min, n=11) [10]. The mean operative time in our series, which was performed in a teaching hospital with fellows and residents, was 226 min (n=32), which is better than most studies, either laparoscopic or robotic. One of the perceived disadvantages of using a robotic system is a longer operative time. It appears to be a matter of getting over the learning curve for the surgeon as well as the operating room (OR) team, in order to reach the acceptable operative time.

Use of robotic platform in complex cases like reoperative bariatric surgery provides an attractive option, considering the amount of challenge faced by surgeons while performing these procedures [22]. However, it should be ventured into only after the surgeon and the OR team have gained sufficient experience with use of robotic platform in performing primary bariatric procedures. This is a guiding principle for any type of reoperative bariatric procedure, whether open, laparoscopic or robotic [8].

Even though it brings in new data, this study has some limitations which deserve comment. First, it is a retrospective review of data already collected. Secondly, it does not compare laparoscopic technique to robotic technique. Although a prospective randomized controlled trial may be ideal, but it may not be practically possible, considering the relatively small number of patients requiring reoperation and the influence of patient choice as well as insurance reimbursements on the type of reoperative procedure chosen. Finally, the cost has not been assessed as it was beyond the scope of this retrospective analysis. There has been a concern about cost every time use of robotic system is considered, as the direct costs are generally higher for the robotic approach in bariatric procedures like RYGB [23, 24]. However, Hagen et al. took into consideration the total costs including the complications and readmissions [16]. They found that cost of robotic RYGB was lower as compared to laparoscopic RYGB when all the factors were counted for. There is also a saving due to decrease in number of laparoscopic staplers used in robotic procedures, by doing a hand sewn anastomosis.

Conclusions

Robot-assisted RYGB is safe and effective as a revisional bariatric procedure in experienced hands. The weight loss outcomes and complication rates compare favorably with the published results of laparoscopic technique, although the small sample size may not be enough to reach definite conclusions. Using robotic platform may provide subtle advantages to the surgeon, enabling him or her to reduce complications and improve the clinical outcomes of this technically complex and challenging procedure.

Conflict of Interest Vivek Bindal declared no conflict of interest.
Raquel Gonzalez-Heredia declared no conflict of interest.
Enrique F. Elli declared no conflict of interest.

Statement of Informed Consent Informed consent for surgery was obtained from all individual participants included in the study before they underwent the procedure. As this is a retrospective analysis, formal consent is not required, and an exempt application was approved by the Institutional Review Board.

Statement of Human Rights For this type of retrospective study, formal consent is not required, and an exempt application was approved by the Institutional Review Board.

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