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ORIGINAL CONTRIBUTIONS

Technique Evolution, Learning Curve, and Outcomes of 200 Robot-Assisted Gastric Bypass Procedures: a 5-Year Experience

Vivek Bindal · Raquel Gonzalez-Heredia · Mario Masrur · Enrique F. Elli

Abstract
Background We evaluate our 5-year experience, evolution of technique, and clinical outcomes with robot-assisted RYGB.
Methods Two hundred consecutive patients who underwent robot-assisted RYGB at our center were included. Among them, 118 patients underwent a hybrid robot-assisted laparoscopic RYGB (LRRYGB), and 82 patients underwent a totally robotic RYGB (TRRYGB). Patient demographics, clinical characteristics, comorbidities, operative parameters, conversions, morbidity, mortality, and excess weight loss were analyzed.
Results Most of the patients (88 %) were female with a mean age of 41.9 years and mean BMI of 46.6 kg/m^2. The outcomes of patients who underwent LRRYGB (n=118) were compared to those who underwent TRRYGB (n=82). The mean operative time in TRRYGB group was 170.9±51.4 min which was significantly lower than LRRYGB group (216±54.1 min). The mean operative time for the last 100 patients was significantly lower than that for the first 100 patients. The excess weight loss (EWL) was 58.3 % at 6 months, 67.7 % at 1 year, 71.6 % at 2 years, and 65 % at 3 years. There were three conversions to open, three reoperations and four readmissions. There were no anastomotic leak, major bleed, gastrojejunostomy stricture, or mortality seen in our series.
Conclusions Use of robot assistance to perform RYGB is safe and may reduce the associated complications, namely, anastomotic leak, gastrojejunostomy (GJ) stricture, and hemorrhage. Excess weight loss at 2 years after RRYGB is comparable to laparoscopic RYGB.

Keywords Robotic bariatric surgery · Robotic gastric bypass · Robotic surgery outcomes · Robotic surgery learning curve · Robotic surgery · Roux-en-y gastric bypass

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Introduction

Use of Robotics in Bariatric surgery has been evolving since Cadiere et al. reported the first such case in 1999 [1]. Bariatric surgery can be challenging in many situations because of large patients, large livers, thick abdominal walls with torque on rigid instruments, and substantial visceral fat making exposure, dissection, and reconstruction difficult [2]. Robotic surgery has provided the surgeons with the advantage of three-dimensional vision, increased dexterity, and precision by downscaling surgeon's movements enabling a fine tissue dissection [3, 4]. It overcomes the restraint of torque on ports from thick abdominal wall and minimizes port site trauma by remote center technology [5]. The main limitation with robotic surgery is the perceived higher cost and setup time compared to laparoscopy. But with increased experience, it is seen that setup times reduce and costs may also come down as material prices reduce [6].

Roux-en-Y Gastric Bypass (RYGB) is considered as the gold standard surgical procedure for morbid obesity by many specialists [7, 8]. The overall results are good in terms of both weight loss and comorbidity resolution [9]. Robotic surgery is currently considered as an attractive technology that could help to perform RYGB [10]. We evaluate our 5-year

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experience, evolution of technique, and clinical outcomes with robot-assisted RYGB.

Materials and Methods

Two hundred consecutive patients who underwent robot-assisted RYGB in the multidisciplinary unit at University of Illinois medical center at Chicago between June 2008 and January 2014 were included in the study. Among these 200 patients who had robot-assisted RYGB as an initial bariatric procedure, 118 patients underwent a hybrid robot-assisted laparoscopic RYGB (LRRYGB), and as the technique developed, 82 patients underwent a totally robotic RYGB (TRRYGB). Two different board-certified surgeons performed all RYGBs.

A retrospective review of prospectively collected data from electronic patient medical records was performed as part of an Institutional Review Board (IRB)-approved protocol. Patients included in the bariatric program met the requirements laid down in the National Institute of Health guidelines [11]. All patients underwent medically supervised weight loss, psychological, and anesthesia clearance before the procedure. Informed consent was obtained after explaining the risks and benefits involved in the procedure. All the patients who were posted for RYGB underwent the robotic approach. There were no exclusion criteria for using a robotic approach to RYGB. However, patients with body mass index (BMI) greater than 55 kg/m^2 were counseled in favor of sleeve gastrectomy for risk reduction. Initially, a hybrid approach was performed which evolved into a totally robotic approach with growing experience of the surgeons and the team.

Variables

Patient demographics, clinical characteristics, obesity-related comorbidities, operative parameters, conversions, early morbidity (within 30 days of surgery), late morbidity (after 30 days of procedure), and mortality were recorded and analyzed. Operative time was defined as time between first skin incision and 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. Finally, the median follow-up was calculated in all patients at the study endpoint, and an assessment of the percentage of weight loss was obtained at 6-month, 1-year, 2-year, and 3-year intervals.

Surgical Technique

In the hybrid approach, robot was used only for performing gastrojejunostomy after other steps of the procedure were completed laparoscopically [12]. A small gastric pouch was created using endoscopic staplers. Jejunum was transected at 50 cm from ligament of treitz, and 120 cm of roux limb was measured. Jejunojejunostomy 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, and da Vinci® surgical system was docked from the head end of the patient. A two-layer hand-sewn gastrojejunostomy was performed with either Prolene 3–0 or PDS 3–0 using the robotic instruments. Third arm of robot was not used.

In TRRYGB, the entire procedure was performed with the robotic system using all three instrument arms. Both infracolic and supracolic portions of RYGB were completed in a single docking fashion. To accomplish this, patients were placed in 15°–20° reverse Trendelenburg position, and the trocars are placed in a caudal position as compared to hybrid technique (Fig. 1). The abdomen was entered with optiview 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. For creation of the gastric pouch, dissection was started at the level of second vessel on the lesser curvature from gastroesophageal junction. A small gastric pouch was created using perigastric technique with two to three firings of endoscopic staplers, without using any calibrating device. Roux limb of jejunum was prepared as in hybrid procedure and brought up to gastric pouch after dividing omentum, if necessary. A 2-cm gastrostomy is made using monopolar hook (the flat portion of da Vinci® monopolar hook measures 5 mm, so we use four lengths of the hook to measure the gastrostomy). A hand-sewn antecolic antegastric gastrojejunostomy in two layers with PDS 3–0 was performed without using any bougie. We use the fourth robotic arm from the right side of the patient which decreases the dependence on the assistant and allows the surgeon to retract by himself.

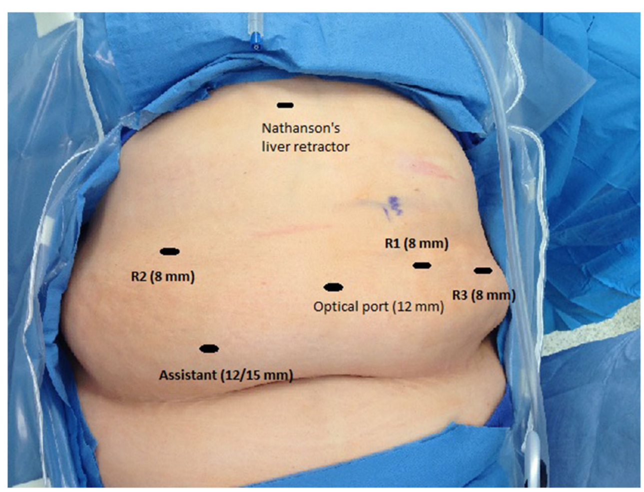

Fig. 1 Port position for totally robotic RYGB. *R1*, *R2*, and *R3*: da Vinci® trocar for robotic arm 1, 2, and 3, respectively

In both techniques, an intraoperative esophagogastroscopy was done with air leak test in all the cases at the end of the procedure.

Statistics

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 %. A two-sided P value ≤0.05 was considered statistically significant. Comparisons between the two groups were carried out with Fisher's exact test for discrete variables and Student's t test for continuous variables.

Results

The outcomes of patients who underwent LRRYGB (n=118) were compared those who underwent TRRYGB (n=82) in order to look for any significant difference in operative parameters and complications as the technique and experience of the bariatric team evolved. Patient demographics are summarized in Table 1. Most of the patients (88 %) were females with a mean age of 41.9 years and mean BMI of 46.6 kg/m^2. There was no significant difference in any of demographic parameters amongst the two groups.

The operative data is summarized in Table 2. There was a highly significant decrease in the operative time in last 100 patients (158.3±39.2 min) from initial 100 procedures (236.7 ±44.4 min) (P<0.001) (Fig. 2). This reflects the increased experience of the entire bariatric team. The mean operative time in TRRYGB group was 170.9±51.4 min which was significantly lower than that in LRRYGB group (216± 54.1 min). This can also be explained by the fact that most of totally robotic procedures were performed in the later stage when the surgeon and entire team were comfortable with the use of robotic platform in bariatrics.

The outcomes of surgeon A were also compared to surgeon B. There was a significant decrease in the operative time from 221.2±43.4 (A) to 185.3±59.9 min (B). There was no difference in %EWL, conversions, or complications. The time difference may be explained in part by the learning curve of the operating room team which got used to performing the robotic RYGB with surgeon A before surgeon B started doing the cases.

There were three conversions to open in the entire series, and all occurred relatively early in the series, in the initial 100 cases. The reason for conversion in the first patient was an inadvertent enterotomy by the stapler while doing jejunojejunostomy, for which the whole anastomosis had to be resected and redone. In other two patients, there were extensive adhesions in the lower abdomen thus not allowing for jejunojejunostomy to be performed. In all three patients, gastrojejunostomy was performed by using robotic platform only, and all of them did well in the postoperative period. There were three reoperations in the series, the reason being internal hernia with volvulus, incarcerated incisional hernia, and bowel obstruction at jejunojejunostomy site, respectively. Four patients had to be readmitted within 30 days for rhabdomyolysis, deep venous thrombosis, vomiting, and nausea, respectively. There was no incidence of any major postoperative bleed, and transfusions were not required. There was no report of anastomotic leak, gastrojejunostomy stricture, or mortality in our series. There was no significant difference found in complication rate among the two groups.

We had 89 patients (44.5 %) followed up at 6 months whose mean BMI decreased to 35.4±6.1 kg/m^2 (58.3 % excess weight loss). Seventy-three patients (36.5 %) were followed up at 1 year and had a mean BMI of 32.6±6.4 kg/

Table 1 Patient demographics and clinical data

	All pts (n=200)	LRRYGB group (n=118)	TRRYGB group (n=82)	P value
Age (years)	41.9±9.9	41.6±8.5	42.4±11.7	0.56
Male	24 (12 %)	16 (13.6 %)	8 (9.8 %)	0.42
Female	176 (88 %)	102 (86.4 %)	74 (90.2 %)	
Initial wt (kg)	129±22.4	132.4±24.0	124.0±18.7	0.008
Initial BMI (kg/m^2)	46.6±6.9	47.3±7.2	45.5±6.2	0.07
ASA score	2.6±0.5	2.6±0.5	2.7±0.5	0.57
DM	73 (36.5 %)	44 (37.3 %)	29 (35.4 %)	0.88
HTN	99 (49.5 %)	58 (49.2 %)	41 (50 %)	0.77
OSA	74 (37 %)	46 (39 %)	28 (34.1 %)	0.57
Dyslipidemia	56 (28 %)	32 (27.1 %)	24 (29.3 %)	0.66

LRRYGB hybrid robot-assisted laparoscopic roux-en-y gastric bypass, *TRRYGB* totally robotic roux-en-y gastric bypass, *BMI* body mass index, *ASA* American Society of Anesthesiologists, *DM* diabetes mellitus, *HTN* hypertension, *OSA* obstructive sleep apnea

Table 2 Perioperative results and outcomes in two groups

	All pts (n=200)	LRRYGB group (n=118)	TRRYGB group (n=82)	P value
Operative time (min)	197.5±57.4	216±54.1	170.9±51.4	0.00001
Blood loss (ml)	20.7±23.7	23.6±28.7	16.4±12.7	0.03
Length of stay (days)	2.6±1.0	2.7±1.1	2.4±0.8	0.02
Conversion	3 (1.5 %)	2 (1.7 %)	1 (1.2 %)	0.79
Reoperation (within 30 days)	3 (1.5 %)	2 (1.7 %)	1 (1.2 %)	0.76
Readmission (within 30 days)	4 (2 %)	3 (2.5 %)	1 (1.2 %)	
Blood transfusions	0	0	0	0
Mortality	0	0	0	0
GJ stricture	0	0	0	0
Anastomotic leak	0	0	0	0

LRRYGB hybrid robot-assisted laparoscopic roux-en-y gastric bypass, *TRRYGB* totally robotic roux-en-y gastric bypass

m^2 (67.7 % EWL). Thirty-eight patients (19 %) were followed up at 2 years and decreased their BMI to 32.3±6.6 kg/m^2 (71.6 % EWL). Ten patients (5 %) were followed up at 3 years who had a mean BMI of 34.7±8.1 kg/m^2 (65 % EWL). Only four patients (2 %) were followed up at 4 years and had a BMI of 37.1±8.7 kg/m^2 (59.6 % EWL). This is depicted in Fig. 3. There was no significant difference in percentage EWL amongst the first 100 and the last 100 patients.

Discussion

It has been shown that routine use of robotics in bariatric surgery is a safe option [13]. Our initial experience and hybrid technique of robot-assisted RYGB were published few years back [12]. There have been very few published studies with more than 200 patients of robot-assisted RYGB and with a medium to long-term follow-up [12, 14]. In our experience, we graduated from hybrid technique to totally robotic RYGB, and we have tried to compare and ascertain any difference in outcomes of initial 100 versus last 100 cases.

With regard to the literature on operative time with respect to learning curve, Schauer et al. reported a learning curve of 100 cases for laparoscopic RYGB with a mean operative time of 269 min [15]. In the published studies for the initial 100 cases, the average time to complete a robot-assisted RYGB varies from 186 min in a community hospital series by a single surgeon [16] to 254 min in a fellowship training program [17]. We had a mean operative time of 236.7 min in the first 100 cases which significantly reduced to 158.3 min in the last 100 cases. Considering that ours is a fellowship training center, we are in accordance with the published studies.

Looking at the complication rate, there was no anastomotic leak, no hemorrhage requiring transfusion, or gastrojejunostomy (GJ) strictures in the entire series. This is an important finding as previously reported complication rates in robot-assisted RYGB series vary from 0 to 7 % GJ strictures, 0 to 2 % GJ leaks, and 0 to 9 % anastomotic bleeds [13, 14, 16–19]. These rates are considerably lower than most of published laparoscopic RYGB series [17, 20, 21]. In a systematic review, Markar et al. demonstrated a significantly reduced incidence of anastomotic stricture with robotic approach as compared to laparoscopy for

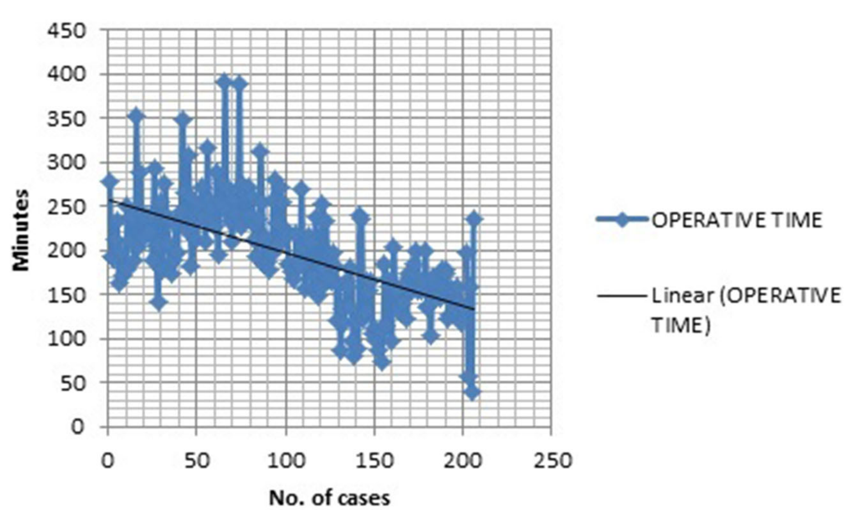

Fig. 2 Variation of operative time with number of cases

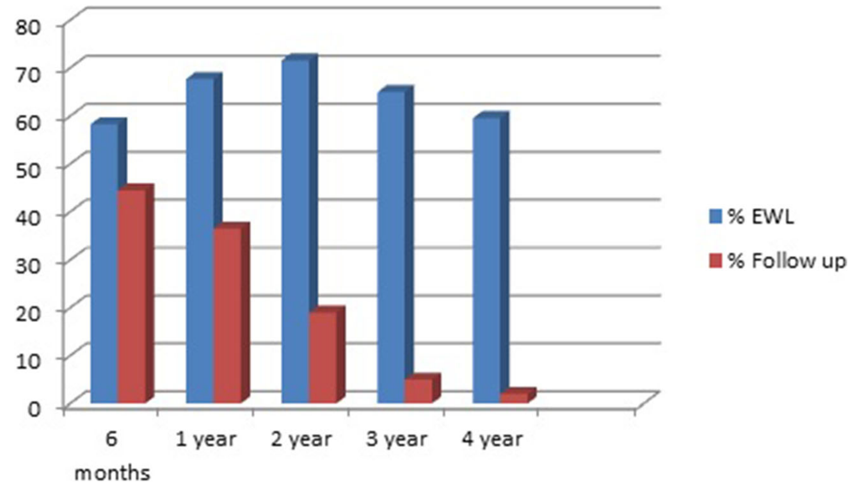

Fig. 3 Percentage excess weight loss and percentage follow-up of patients who underwent robot-assisted RYGB

RYGB [22]. This may be a result of hand-sewn GJ anastomosis which is precise because of the use of robotic platform as compared to stapled anastomosis in laparoscopic RYGB. We created a gastrostomy with endowristed hook approximately four times the length of the flat portion of the hook. This makes the opening around 20 mm and prevents formation of GJ strictures. An EGD is always done at the end of the procedure to rule out a leak or a bleed and goes a long way in fixing any problem on the table itself.

Conversion to open procedure had to be done in 1.5 % (n= 3) cases, all in the first 100 procedures. But, there was no statistically significant difference in the conversion/complication rate or long-term outcomes among the first 100 and last 100 cases. This may be partly explained by the fact that surgeons were already experienced in laparoscopic bariatric techniques and that robotic technology may help overcome certain limitations in surgical skills by virtue of its unique advantages.

The learning curve of robot-assisted RYGB is not only for the surgeon but also for the entire operative team as total time in a robot-assisted procedure depends a lot on the skill level of the assistant surgeon, scrubbed nurse, and ancillary staff. If the team members are constant, the operative times decrease much faster and learning curve may be shorter as compared to a setting in which assistants or staff keeps on changing. This is one of the reasons that overall time is higher in a teaching hospital versus a community hospital setting [18]. We had a constantly changing team of bedside assistants and scrub technicians, as these procedures were done in a teaching hospital. But due to high volume of robotic procedures performed at the center, assistants usually had a prior exposure of handling surgical robot. We switched to a totally robotic procedure with a single docking technique later in the series which helped to decrease the operative time. The mean BMI and comorbidities of patients do not differ in the first or last hundred patients, thus implying that the complexity of cases taken up for RYGB remained similar as the experience increased. This may be explained by the fact that the institutional criteria for RYGB was not changed when use of robotic platform was introduced in bariatric procedures.

The weight loss achieved in our series is comparable to large laparoscopic series which have been published [23, 24]. This may point to the fact that use of robotic platform for RYGB may allow us to achieve similar results as laparoscopic approach, with a lower rate of perioperative complications. This study had a high attrition rate in terms of follow-up with just 5 % of patients following up at 3 years. Thus, it provides acceptable 2-year outcome data but may not provide any useful insight into medium- and long-term follow-up.

The other issue which crops up with the use of robotic technology is the cost. It has been studied by various authors most of whom come to a conclusion that robot assistance increases the cost of the procedure [25–27]. But, Hagen et al. found that overall cost of robot-assisted RYGB was less as compared to laparoscopy [20]. We did not study the cost in our series, but we do believe that cost is a relative and temporary factor. A parallel study comparing laparoscopic and robotic RYGB will be a better study to reach at a conclusion with regard to the cost.

This study has several limitations which deserve comment. First, this is not a comparative study in between laparoscopic and robot-assisted RYGB procedures, which is a big question that needs to be answered yet. Second, it is a retrospective analysis, and there is a high attrition in the follow-up. Third, the cost issues have not been studied. However, it is one of the largest single center series of robot-assisted RYGB procedures, with arguably the least complication rate.

Conclusions

Use of robot assistance to perform RYGB is safe and may reduce the associated complications, viz., anastomotic leak, GJ stricture, and hemorrhage. Excess weight loss at 2 years after RRYGB is comparable to laparoscopic RYGB. Further studies are required to ascertain the best way to perform RYGB, especially in terms of cost advantage.

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