Review Article

Bariatric and revisional robotic surgery

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Abstract: The use of robots to assist in performing surgical tasks has been developed over the last decade. Robotic digital platforms provide potential benefits such as three-dimensional visualization, wristed instruments which lead to enhanced dexterity, and blocking the transmission of torque on ports. These advantages become remarkable when the robot system is employed in bariatric surgery. This review explores the literature and examines the surgical outcomes and complications in robot bariatric surgeries. Robotic adjustable gastric banding (AGB), Roux-en-Y gastric bypass (RYGB), sleeve gastrectomy (SG), biliopancreatic diversion (BPD) with duodenal switch (BPDDS), and revisional bariatric surgery (RBS) are assessed. The review showed that robot bariatric surgeries generally led to comparable or better outcomes and shorter learning curve than conventional laparoscopic surgeries. However, most upper gastrointestinal (UGI) and bariatric surgeons in East Asia are commonly exposed to laparoscopic gastrectomy because of high incidence of gastric cancer in this area and they are already well-trained laparoscopic surgeons. Therefore, most of them still prefer laparoscopic techniques because it has proven clinical benefits, does not require complex setups, and super obese patients are not as common as Western countries. More research is needed to elucidate accurate conclusion in East Asia.

Keywords: Bariatric; gastric bypass; revisional surgery; robotic surgery; sleeve gastrectomy (SG)

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Introduction

The prevalence of obesity has been constantly increasing worldwide. Obesity, defined as a body mass index (BMI) of 30 kg/m^2 or greater, already affected more than 35% of American adults according to National Health and Nutritional Examination Surgery (NHANES) from 2009–2010 (1). As a disease entity, overweight and obesity has not received the attention in Asia until recently, however, westernized eating habits and sedentary lifestyles have increased rapidly numbers of obesity patients. Obesity is generally defined as a BMI of 25 kg/m^2 or greater in Asian countries. The rate of obesity in South Korea was reported at 32.8% according to the National Health and Nutrition Survey in 2012 (2) , and the number of obese Chinese accounted for more than 38% of the total Chinese population in 2011 (3).

With this rise in the prevalence of obesity, the field of bariatric surgery witnessed an increasing demand. Furthermore, an employment of the minimally invasive surgical techniques in bariatric surgery has contributed to sudden increase in popularity of bariatric surgery since Wittgrove *et al*. (4) introduced laparoscopic gastric bypass in 1994. Although laparoscopic approaches are impressive in terms of less wound complications, shorter hospital stay, similar postoperative mortality rate comparing with open surgery (5,6), surgeons still encounter difficulties during laparoscopic bariatric surgery; ergonomically awkward positions, restraint of torque on ports from thick subcutaneous fat, two-dimensional vision, and rigid instruments (7,8). These challenges related to the limitations of conventional laparoscopy made bariatric surgeons seek other options.

Use of robotics in bariatric surgery has been evolving since Cadiere *et al*. (9) reported the first such case in 1999. Robotic digital platforms provide several advantages of ergonomically comfortable position, increased precision by downscaling surgeon's movements enabling a fine tissue dissection, blocking the transmission of torque on ports, three-dimensional vision with a stable camera that surgeons handle themselves, articulated wrists of instruments yielding three additional degrees of freedom, and the availability of an accessory arm allowing surgeons to operate without any assistants (7,8). These advantages of robotic system can be more definitely notable in complex procedures like re-operations of bariatric surgery. Here, we review the published literature of the application of a robotic system in bariatric surgery with a particular focus on outcomes.

Robotic adjustable gastric banding (AGB)

The cases of AGB peaked in 2008 (42.3% of total number of bariatric surgeries), then had a significant and continuous decrease in 2011 (–24.5%) and in 2013 (–7.8%) according to the global survey of the International Federation for the Surgery of Obesity and Metabolic Disease (IFSO) (10). Hence, there have been few studies published in the literature looking at outcomes of robotic assistance in AGB, although the first robot bariatric surgery was AGB (9).

Edelson *et al*. (11) reported the largest retrospective comparative study of robotic (n=287) and laparoscopic AGB (n=120). No significant differences were found in the operating time, hospital stay, complication rates, or excess weight loss. However, for super-obese patients with a preoperative BMI $\geq$50 kg/m^2 (n=89, 64 robotic and 25 conventional), they did find a significantly shorter operative time by about 10 min in the robotic arm. One of the main problems of operating on obese individuals is the increased thickness of the abdominal wall. The increased torque on conventional laparoscopic instruments in super-obese patients with a BMI above 50 kg/m^2 makes a precise operative technique more difficult. Robot AGB has a certain advantage to overcome the above problems of super-obese patients, but now, the robot system is usually used for not inserting gastric band itself, but managing complications and revising gastric band to other procedures.

Robotic Roux-en-Y gastric bypass (RYGB)

Previous studies have shown that one of the most common complications of laparoscopic RYGB is stricture at the anastomotic site (12,13). Therefore, several modified laparoscopic anastomotic techniques have been proposed in an effort to reduce the incidence of associated complications: a handsewn (HS) technique as advocated by Higa *et al*. (14), a circular-stapled (CS) technique as recommended by Wittgrove and Clark (15), and a linear-stapled (LS) technique as advocated by Williams and Champion (16). These techniques result in a variety of initial sizes of anastomosis and have been also implicated in a variable incidence of postoperative anastomotic stricture requiring endoscopic dilation, or rarely even requiring operative revision. Several articles comparing the outcomes of these anastomosis techniques have been published (17-21), but there is conflicting evidence regarding which techniques is superior and results in fewer complications. Gonzalez *et al*. (17) showed a statistically significant difference between HS, 30-mm LS, and 21-mm CS. CS had 31% (4/13) stricture rate and HS and LS each had 3.5% (3/87) and 0% (0/8) (P<0.01), respectively, and there was no difference in anastomotic bleeding, leakage. Lois *et al*. (20) presented the superiority of the HS technique to the CS technique. In this study, anastomotic stenosis and postoperative bleeding occurred more frequently with the 25-mm CS technique: 16.4% (9/55) CS versus 3% (4/135, P<0.01) HS of stenosis and 10.9% (6/55) CS versus 1.5% (2/135, P<0.01) HS of bleeding. Kravetz *et al*. (19) suggested that the incidence of anastomotic stricture tends to be lower with a HS technique (4.1%, 5/123) compared to an 18-mm LS technique (10.1%, 10/99, P=0.076). On the other hand, some reports have raised a question whether HS is a safer anastomotic technique (18,21). Qureshi *et al*. (21) reported the lower stricture rate of 25-mm CS (1.2%, 3/254) compared to HS (2.8%, 5/177) and 1.5-mm LS (4.4%, 19/429, P=0.016). Bendewald *et al*. (18) showed no differences among three techniques in the rates of stricture (LS, 6.0%, HS, 6.1%, CS, 4.3%, P=0.657), leak (LS, 1.0%, HS, 1.1%, CS, 0.0%, P=0.480), and marginal ulcer (LS, 8.0%, HS, 7.7%, CS, 3.6%, P=0.180). Interestingly, the stricture rates of HS were relatively stable (2.8–6.8%) in previous literatures while the other techniques had wide ranges dependent on types of stapling devices. Although laparoscopic HS anastomosis is a time-consuming and challenging technique in severely obese patients, the stable and low anastomosis-related complication rates can give confidence to surgeons.

Initially, a robotic system was involved in anastomosis procedures during RYGB and other procedures such as gastric pouch formation were performed laparoscopically (robot-assisted gastric bypass). Although the totally robotic gastric bypass has become more popular nowadays than the hybrid procedure due to improved instruments and techniques (8), as the history suggests, a robot system offers several advantages to the bariatric surgeon especially when performing HS anastomosis of gastrojejunostomy (G-J stomy). Hagen *et al.* (22) reported significantly lower anastomosis leak (0%, 0/143) and stricture rates (0%) in robotic HS G-J stomy compared with the laparoscopic circular stapling method [4% (13/323) of leak, P=0.035 and 6.8% (22/323) of stricture, P<0.001], and Buchs *et al.* (23) also revealed favorable results for the robotic gastric bypass. In their study, the robotic HS G-J stomy had significantly less gastrointestinal leaks than the laparoscopic linear stapling method [0.3% (1/388) in robot *vs.* 3.6% (14/389) in laparoscope, P<0.001], and robotic bypass showed also less early reoperation than laparoscopic bypass [1% (4/388) *vs.* 3.3% (13/389), P=0.05].

However, some studies have shown conflicting results. Scozzari *et al.* (24) reported no differences between two approaches in terms of the intra- or postoperative complication rates including anastomosis leak and stricture rates, hospital length of stay, and revisional surgery, but the operative time was significantly longer in the robot group (247.5 *vs.* 187 min, P<0.001). Benizri *et al.* (25) showed even higher postoperative surgical complication rate [13% (13/100) *vs.* 1% (1/100), P=0.001] and longer hospital stay (9.3 *vs.* 6.7 days, P<0001) in the robotic bypass group, but in this study, there were two different surgeons in each group and this bias could make the different surgical outcomes.

Surgeons can make the best results when their fully adopted devices are provided, so that it is difficult to conclude which technique is superior until a multicenter prospective randomized controlled trial comparing laparoscopic and robotic gastric bypass is performed. Nevertheless, it is obvious that the robotic platform can offer favorable conditions, such as three-dimensional vision and wristed instrument, for suturing performance to all surgeons (26,27), and these positive effects could make robotic HS G-J stomy have stably lower anastomosis-related morbidity as above.

Laparoscopic gastric bypass showed a steep learning curve, reported to require 75–100 cases (28-30), however, Buchs *et al.* (31) reported that, in a series of 64 patients undergoing robotic gastric bypass, the learning curve was 14 patients. Yu *et al.* (32) also examined the first 100 cases of a surgeon who had only 12 laparoscopic gastric bypass experiences, and reported that the use of robotic assistance in creating HS G-J stomy has resulted in no leaks and no deaths. As the previous literature suggested, the robot platform could be beneficial for inexperienced surgeons in terms of lowering the entry barrier to minimally invasive surgery (33), so that the learning curve for robot gastric bypass is shorter than laparoscopic technique.

Robotic sleeve gastrectomy (RSG)

Sleeve gastrectomy (SG) has quickly gained popularity because of its low morbidity, excellent outcome and perceived technical simplicity. It also permits routine accessibility of the gastric sleeve by endoscopy in the postoperative setting, which is important especially in areas of high gastric cancer incidence such as Korea, Japan, and China. Laparoscopic sleeve gastrectomy (LSG) is technically simple because it does not involve gastrointestinal anastomosis or mesenteric defect repair. Hence, it is true that the merits of robot system are difficult to be highlighted in SG. Although some surgeons suggested robotic sleeve gastrectomy (RSG) facilitates the visualization and mobilization of the fundus and makes it possible safe and precise dissection near the gastroesophageal junction and left crus, there has been not enough evidence to prove their arguments. Also, stapling line reinforcement suture may be performed easily using the robotic platform, however, whether the reinforcement in LSG is beneficial or not has been remained a controversial issue until now (34,35).

There are three comparative studies of LSG and RSG (36-38). All of three studies showed similar results, which represented no significant difference in postoperative complication rates, such as leak, stricture, bleeding, and longer operating time for RSG.

Recently, some surgeons approached the positive effects of RSG from different viewpoints. Bhatia *et al.* (39) performed a comparative study of RSG in morbidly obese (n=24) versus super obese (BMI ≥50 kg/m^2, n=11) patients. There was no significant difference in all of perioperative outcomes including operative time, blood loss, and perioperative complications. Thus, they concluded that the robot system might help overcome the operative difficulties encountered in super obese patients.

Ecker *et al.* (40) suggested residency training programs using robotic platforms. The residents participating this study showed a short learning period (five cases) to develop facility with robot arm and camera manipulation, and operating times and perioperative outcomes were comparable with historical controls of LSG. They also reported no difference in operative times of RSG between the cohorts of BMI 50 to 59 kg/m^2 and those with BMI 30 to 49 kg/m^2. Consequently, RSG can be instituted as a safe model for resident education and overcome the manual difficulty of working against the weight of the abdominal wall of the super obese patients.

Robotic biliopancreatic diversion with duodenal switch (BPDDS)

There is little published on the role of robotics in biliopancreatic diversion (BPD) and duodenal switch. This is likely reflective of the overall small number of these operations that are performed yearly because of greater malabsorption, longer operative duration, and higher technical complication rates. The robotic BPDDS procedure was first performed in 2000 and was initially reported by Sudan *et al*. (41). In this study, a series of 47 patients undergoing robotic BPDDS demonstrated an 8% (4/47) leak rate and 6.3% (3/47, 2 due to iatrogenic bowel injury and 1 bleeding around the gastroduodenal artery) open conversion rate. They used the hybrid technique in which only the duodeno-ileal HS anastomosis was conducted using the robot system and the other majority of the operation was performed laparoscopically. However, they recently reported totally robot-assisted BPDDS through anchoring bowel to anterior abdominal wall (42). The learning curve was found to be around 50 cases after which the complications and operating time normalized (43). This is longer than the learning curve for robotic gastric bypass at closer to 15 cases and reflects the complexity of this operation.

Robotic revisional bariatric surgery (RBS)

Reoperations have significant technical difficulty and challenge to the bariatric surgeons. It carries a higher risk of complications, and this was attributed to the complexity of the revisional cases, which included adhesions from the primary procedure, inflammation, tissue changes and metabolic derangements. The intra- and postoperative complication risk with RBS depends on which procedure was the primary surgery and which procedure will be performed as a second surgery (44). It also may be affected by the causes of reoperation such as simple patient's dissatisfaction, or weight regain, or various complications of the first operation.

The robotic platform offers superior ergonomics and three-dimensional vision, which has the potential to make a difference in the outcomes of these complex procedures. Also, another robotic arm results in less dependence on the first assistant.

Snyder *et al*. (45) reviewed 99 cases of robotic revisional surgeries which included AGB/vertical banded gastroplasty (VBG) to RYGB/SG, RYGB to biliopancreatic diversion (BPD), RYGB to RYGB. The reasons for revisional surgeries varied from abdominal pain, dysphagia, insufficient weight loss or weight regain to complications such as hiatal hernia or malfunctioned band. The overall complication rate was 17% with a 90 days readmission rate of 24%. However, there was no leak, hemorrhage or mortality. Buchs *et al*. (46) compared three techniques (28 cases of open, 21 laparoscopic 11 robotics) to perform revisional RYGB. The robotic group had fewer complications (0% *vs*. 14.3% for laparoscopy, *vs*. 10.7% for open, P>0.05), less reoperation (9.1% *vs*. 19% *vs*. 25% respectively, P>0.05), although it took longer than the other approaches (352 *vs*. 270 *vs*. 250 min respectively, P<0.05). Bindal *et al*. (7) reported their experiences of 32 cases of robotic revisional RYGB from AGC (n=16) or SG (n=11) or previous gastric bypass (n=5). The causes of reoperation of 20 patients were weight loss failure and the others were complications of the primary procedure. The safety and feasibility of revisional surgeries was acceptable because there were no leaks or strictures or hemorrhage, and no open conversion. As mentioned above, one of the potential reasons of a low rate of anastomotic complications in robotic RYGB can be a HS G-J stomy rather than stapling. This can be more important in reoperations due to scarring and fibrosis, thus increasing the chances of misfiring of staplers, or inappropriate approximation of tissues.

Discussion

It is obvious that the robot bariatric surgery is a safe and feasible option. The outstanding advantages of the robot bariatric surgery are three-dimensional visualization, enhanced degrees of freedom, and mechanical power overcoming the increased torque of thick abdominal wall. These advantages allow precise dissection, easy HS bowel anastomosis, less strenuous operations for surgeons, and several literatures have shown a lower complication rate with the robot system including leak, stricture and bleeding.

However, we have to consider the regional difference of surgeons' experiences. In Korea, Japan, and China, where the incidence of gastric cancer is high, most upper gastrointestinal (UGI) surgeons perform laparoscopic gastrectomy for gastric cancer frequently. In other words, since most bariatric and UGI surgeons are commonly exposed to laparoscopic gastrectomy and they are already well-trained laparoscopic surgeons in these countries. Recently, some Korean UGI surgeons reported multicenter prospective study comparing robot and laparoscopic gastrectomy for gastric cancer (47). The results showed similar outcomes between two groups in terms of postoperative complication rates, blood loss, and open conversion rates. The operating time was even significantly longer and the cost was higher in the robot arm. Moreover, it is possible to perform laparoscopic procedure with high-quality three-dimensional vision systems, and some investigators suggested that well-trained laparoscopic surgeons may not really benefit from robot system if three-dimensional laparoscopy is available (33). Gastric cancer patients are not morbidly obese, but the primary bariatric surgery is not as technically demanding as gastric cancer surgery. Therefore, if further research of robot bariatric surgery is being carried out in East Asian countries, interesting results are expected to be delivered.

There has always been a concern about the high cost of the robot system because the direct costs are generally higher in the robotic approach. But the situations vary by countries. In Korea, the National Health Insurance Corporation does not cover the reimbursement of bariatric surgery, so that patients pay similar costs regardless of types of surgery. Another view is that because the fewer anastomotic complications and readmission occurred in the robotic arm, total costs of robotic RYGB was lower compared to laparoscopic RYGB when all factors were counted for. Therefore, the cost effectiveness of robot bariatric surgery is difficult to judge because it depends on the situation of each institution or each country and it varies with the range of its involvement into the total cost.

It is an absolute truth that the robotic system improves surgeons' ergonomics and causes lesser operator fatigue. The digital interface of robot has enormous potential to combine other newest technologies such as near-infrared image, virtual reality, or single incisional surgery. These latest technologies also can be reproducible in laparoscopic surgery; however, current laparoscopic devices may be going to evolve into robotic devices eventually. Robot platform in the future will differ from the current one and develop more than we can imagine, but we believe it will provide a potent surgical system to future surgeons.

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Footnote

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