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A Review of the Role of Robotics in Bariatric Surgery

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The epidemic of obesity continues to be a major health issue. It is now almost uniform that surgical procedures for weight loss are performed with minimally invasive techniques. This article reviews the literature regarding obesity-related health issues, in particular risk of malignancy, and the application of robotic technology in weight loss surgical procedures. With increasing literature and technology in surgical robotics, its application in the field of bariatric surgery continues to evolve.
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INTRODUCTION

The number of obese children, adolescents, and adults continues to rise exponentially and represents a major health issue. Even more alarming is the increase in patients who are considered morbidly obese (body mass index [BMI] over 40) [1]. Today, roughly two out of every three adults in the US are overweight and one out of every three adults are considered obese. Globally, it is estimated that 500 million adults are obese and 43 million preschool children are overweight or obese [2]. The adverse consequences of obesity have been recognized for decades. There are multiple studies showing the correlation between obesity and cardiovascular disease, diabetes, metabolic syndrome, arthritis, and even increased risk of cancer [2–4]. In June 2013, the American Medical Association formally adopted a policy designating obesity as a chronic disease [5].

OBESITY AND CANCER

The association of obesity and increased risk of cancer has been shown in several studies. This association has best been demonstrated in what has traditionally been thought of as high BMI-related cancers, such as esophageal (adenocarcinoma), colon, rectal, kidney, pancreas, gallbladder, and postmenopausal breast and ovarian cancer [4]. Lim et al. [6] estimated that 3.9% of cancer mortality in 2010 could be attributed to high BMI. Arnold et al. evaluated worldwide cancer incidence and its association to BMI. Interestingly, they found that 481,000 (3.6%) of all new cancers cases and 12.8% of all high BMI-related cancers in adults were attributable to obesity. The majority of cases attributed to obesity in this study included uterine, colon, and breast cancer. The relation of obesity to new cancer cases was significantly higher in developed as compared to developing countries. Interestingly, but not surprisingly, this mirrors global obesity statistics [3,4].

BARIATRIC SURGERY AND CANCER RISK

Recently, there have been several studies looking at the effect of bariatric surgery on cancer incidence and oncologic outcomes [7,8]. The data are mostly observational studies; however, conclusions favoring bariatric surgery can be drawn. Two meta-analyses of the published data concluded that patients undergoing bariatric surgery when compared to obese individuals who had not undergone surgery had an overall reduced risk of developing cancer. In some studies, it was suggested that the relative risk was reduced to that of the general nonobese population [8]. The mechanisms behind obesity and weight loss surgery and its effects on cancer incidence, treatment, prognosis, and mortality continue to be an evolving field of research.

ROBOTICS AND BARIATRIC SURGERY

With the growing epidemic of obesity and related health issues, surgery for the treatment of morbid obesity has exploded. The development and maturation of surgical approaches has steadily improved over the past several decades as our understanding of the complex pathophysiology of obesity has evolved. Some of the first techniques were less than ideal, and included wiring the jaw shut [9]. Modern weight loss surgery started with bypass of the majority of the distal small bowel (jejunoileal bypass) and portions of the colon (jejunocolic bypass) [9]. As the science of obesity has been advancing, we have seen an evolution in the procedures being performed and now include from adjustable gastric banding to biliopancreatic diversion with duodenal switch. Newer endoscopic options, including balloons, are starting to gain traction.

An understanding of the metabolic effects of bariatric surgery has additionally led to the refinement of its indications. For instance, we are now seeing promising results in patients with lower BMI's and difficult to control diabetes [10]. In an evidence-based practice climate, the growth of bariatric surgery has repeatedly been substantiated in the literature as an effective, economic, and safe solution for durable weight

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loss and as a treatment option for diabetes and other obesity-related comorbid conditions including cancer risk reduction [7,8,11,12].

In the last 100 years, we have seen a number of technological advancements in surgery. In 1911, Dr. Hans Christian Jacobaeus performed the first diagnostic laparoscopy on humans. In 1985, Dr. Erich Muhe (Germany) performed the first laparoscopic cholecystectomy [13]. The field of minimally invasive surgery was born. Laparoscopy was used for placement of a fixed gastric band in 1992, followed by descriptions of laparoscopy for adjustable gastric band placement, vertical banded gastroplasty, and gastric bypass [14]. Today, minimally invasive approaches to bariatric surgery has become the standard of care and has allowed for better outcomes, decreased rates of complications, faster recovery, and decreased overall cost making bariatric surgery an optimal long-term treatment modality for obesity.

In the 1980s, when laparoscopy was still in its infancy, scientists from NASA and the Stanford Research Institute combined technologies and the first surgical robot was created. We have seen this technology flourish in the field of minimally invasive surgery. The adoption of robotics in general and gastrointestinal surgery is increasing. We have already witnessed how robotic technology has enhanced surgical visualization and increased instrument degrees of freedom. In addition, there has been incorporation of other technologies such as fluorescence-based imaging on robotic platforms.

The initial report of the use of robotics in weight loss surgery was described in 1999. Since that time, there has been increasing use of this technology in bariatric surgery [15]. However, there is limited published data comparing the advantages and disadvantages of robotics as compared to traditional laparoscopy in weight loss surgery. Similar to the growth of early laparoscopy, the growth of robotics has been driven primarily by surgeons who have recognized its benefits and adopted it as part of their practice. We review the published literature of the application of robotics in weight loss surgery with a particular focus on outcomes.

ROBOTICS AND ADJUSTABLE GASTRIC BANDS

There is a relatively small amount of literature published on the application of robotics in adjustable gastric band placement. This is likely due to several factors, including the generally outpatient nature of these cases, the lack of significant tissue manipulation and dissection or large amounts of suturing during these cases, and the rapid decrease in the number of adjustable gastric band being placed [16,17]. The key advantage of robotics in this patient population is likely when revising patients with previous adjustable gastric banding to another operation. There is evidence that in patients with a BMI >50, the robotic platform may provide a time of operation advantage in primary placement of an adjustable gastric band [18].

ROBOTICS AND LONGITUDINAL SLEEVE GASTRECTOMY

With the decrease in number of adjustable gastric bands being placed, we have seen an almost exponential increase in surgeons performing longitudinal sleeve gastrectomy as an initial weight loss operation [16]. The literature is varied and outcomes related to robotics frequently centers on operative time. Diamantis et al. reported one of the few studies documenting equivalent operative time robotic-assisted sleeve gastrectomy as compared to laparoscopic sleeve gastrectomy. Of importance, this was a small study of 19 patients [19]. In a small series comparing patients with a BMI over 55, the robotic technique was noted to be 21 min longer with no other difference in outcomes or complications. The time difference may have been in part secondary to that fact that patients undergoing robotic sleeve gastrectomy had routine oversewing of the staple line [20]. The increased time with robotic sleeve gastrectomy has been noted in other series [21]. In regard to other outcome variables, Romero et al. [21] noted in a retrospective study shorter hospital length of stay with the robotic approach.

In almost all reports, the robotic technique is accomplished with an assistant port and bedside assistant for operation of the gastrointestinal stapler. With advent of robotic staplers, it is feasible that the entire operation can be performed without the placement of an assistant port. The learning curve for operative efficiency and time for robotic assisted sleeve gastrectomy is estimated to be about 20 cases, with some studies demonstrating this to be as low as 10 cases [22–24].

The limitations of the studies describing robotic-assisted laparoscopic sleeve gastrectomy are that they are primarily non-randomized clinical trials. The benefits of robotic-assisted laparoscopic sleeve gastrectomy are open for debate. Some reasons in favor of using robotics for laparoscopic sleeve gastrectomy include increasing surgeon experience with robotics with a relatively straightforward operation, as well in situations requiring suturing. This may include those surgeons who routinely oversew their staple lines or patients with hiatal hernias requiring repair during sleeve gastrectomy.

ROBOTICS AND Roux-en-y GASTRIC BYPASS AND BILIOPANCREATIC DIVERSION/ DUODENAL SWITCH

For those who perform robotic bariatric surgery and/or robotic surgery in general, one of the most apparent benefits of this technology is when an extensive amount of suturing is involved (such as hand sewn anastomoses during gastric bypass). Mohr et al. [25] compared 10 robotic to 10 laparoscopic gastric bypass procedures, and noted a decrease in operative times when robotics was utilized. There have been several other studies that show similar outcomes; however, most report increased operative times with the robotic platform. Importantly, however, similar to other types of cases, most also show that operative time decreases with increased institution and surgeon experience [26–29].

In terms of other measures of morbidity and mortality, most series report similar outcomes to the laparoscopic approach. Certain series have noted a lower leak rate with robotic-assisted laparoscopic roux-en-y gastric bypass [30–32] and a recent review of over 1,500 patients demonstrated a significant reduction in anastomotic strictures with robotic gastric bypass [33]. Some studies have demonstrated shorter hospital length of stay with robotic gastric bypass; however, this is not uniformly reported [34]. It is important to also note that some studies note increased complication rates after robotic gastric bypass [35].

There is little published on the role of robotics in biliopancreatic diversion and duodenal switch. This is likely reflective of the overall small number of these operations that are performed yearly. A series of 47 patients undergoing robotic-assisted biliopancreatic diversion with duodenal switch demonstrated an 8% leak rate [36].

An advantage of the robotic approach for gastric bypass and biliopancreatic diversion is that the learning curve may be significantly less than the traditional laparoscopic approach. Some have reported the number of cases to be less than 20 cases for gastric bypass [37–39]. In surgeons starting to perform gastric bypasses, the robotic approach is associated with a shorter operative time [40]. The robotic platform has been shown to allow for a low rate of complications during the learning curve. This has been reproduced in a number of series. In comparison, complications reported during the learning curve for laparoscopic roux-en-y gastric bypass have been reported as high as 10% [36,41–43]. Not surprisingly, the learning curve for robotic-assisted biliopancreatic diversion is significantly higher (approximately 50 cases) [44].

A topic of intense discussion whenever the utility of robotics in surgery is discussed centers around the cost of the robotic platform.

Indeed, a review of over 2,500 patients noted that robotic-assisted gastric bypass was about $3,500 more expensive than the straight laparoscopic approach [45,46]. As with any technology, this is likely to continue to decrease with increased competition. Other factors to be considered while evaluating cost data include the decreased learning curve as well as learning curve-related complication and some suggest that the decreased rate of complications actually creates a cost advantage with robotic gastric bypass [47].

ROBOTICS AND REVISIONAL BARIATRIC SURGERY

With the continued increase in number of primary bariatric procedures, it is not surprising that the number and complexity of revisional cases continues to increase. Reasons for pursuing revisional surgery include converting an older failed procedure such as vertical banded gastroplasty, fixed or adjustable gastric bands, treating a complication of a previous weight loss surgery, and/or adding a component of malabsorption (as in conversions to gastric bypass or biliopancreatic diversion). There is limited, but promising, literature on the role of robotics in revisional weight loss surgery.

A recently published series of almost 100 patients undergoing robotic revisional bariatric surgery demonstrated no conversion or anastomotic leaks [48]. Buchs [49] reported in a smaller series of revisional patients that the robotic approach was associated with no operative conversions as opposed to a 14.3% conversion rate with the laparoscopic approach. These small series suggest that the robotic approach is associated with a significantly lower rate of conversion. In other series, conversion rates to an open procedure with revisional bariatric surgery is approximately 10.4% [50]. Other small series have demonstrated an extremely low morbidity rate with robotic-assisted revisional weight loss surgery [51]. More studies are required to fully elucidate any potential advantages of the robotic approach in revisional bariatric surgery.

ROBOTICS AND TRAINING

With any new technology, it is crucial that surgeons and operating room teams who adopt robotics are appropriately trained in its safe execution. There are a number of established curriculums for training and there are several avenues for surgeons and other team members to obtain this training in the form of skills labs to introduce the robotic platform, surgical simulators, case observations, mini-fellowships, and wet labs. The first cases performed by novice robotic surgeons should be proctored by an experienced surgeon, and it is imperative that surgeons continue to use robotics regularly in their practice. This enables them and the surgical team to improve their skills and efficiency [52]. In today's climate of efficiency, hybrid approaches or staged introduction can be a way to introduce robotics without significantly increasing operative times during the learning curve.

ADOPTION OF ROBOTICS

There is little written in the literature regarding practical tips toward starting or adopting robotics as part of an advanced laparoscopic surgery practice. Much is learned from the errors and successes of early adopters of this technology. There are several points to consider when starting a robotics program that we have learned over the years of using this technology.

Perhaps, the most important aspect of robotic surgery is training. It is important to keep in mind that the use of robotics does not alter the basic principles of surgery or the operation in question. We believe that the best robotic surgeons are those with strong advanced laparoscopic skills, and that improved laparoscopic skills lead to better robotic skills and vice versa. When introducing robotics, it is important to completely understand the technology, not only from a console standpoint but also in operation of the patient side cart. Perhaps, the most frustrating and time consuming part early in the robotics learning curve is port placement, positioning of the robotic side cart, docking, and troubleshooting issues with any of the above. Oftentimes, critics of robotics will point to the significant increase in case length caused by docking of the patient side cart. With practice, we routinely will complete docking of the patient side cart in under 1 min (even with participation of fellows). Even after performing robotic surgery for a number of years, attending surgeons almost uniformly participate in docking of the patient side cart. This not only keeps surgeon skills current, but also continues to improve operating room efficiency. Wet labs, offered through many simulation labs at large academic and tertiary care medical centers, can be immensely useful. Minimizing system-related frustration plays a key role in continued use and adoption of robotic technology in practice.

When introducing robotics in complex laparoscopic operations, we have found it immensely useful to introduce the technology in stages. This can significantly decrease operative times. For example, when our group started performing robotic gastric bypasses, we would perform the jejunojejunostomy laparoscopically, and complete the gastrojejunostomy with robotic assistance. As experience with the robotic platform grows, more of the operation can be performed robotically. In keeping with this point, although it may seem counterintuitive, doing basic laparoscopic cases with the robot may increase overall efficiency and time. For example, robotic-assisted multi-port laparoscopic cholecystectomy or inguinal hernia repair can increase surgeon and operative team experience and familiarity with the robotics platform as well as decrease the time involved with docking the patient side cart given increased repetition. This must, however, be balanced with operative costs. By carefully selecting instruments and disposables, it is possible to perform robotic cases at a similar cost to traditional laparoscopy. Specific to adoption of robotics in bariatric surgery, using robotics to perform sleeve gastrectomy can function in a similar manner to that described above.

We have found the most use of robotics in operations that require large amounts of laparoscopic suturing, particularly in completing gastrointestinal anastomoses or suturing with odd angles (such as suturing mesh to the anterior abdominal wall during ventral hernia repair). Our technique of laparoscopic gastric bypass and duodenal switch relies on a completely hand sewn two layer gastric or duodenal anastomosis. While possible to do laparoscopically, it requires a large amount of practice and a steep learning curve. Most will agree that it is of vital importance to prevent anastomotic complications. This is especially true with surgeons starting practice or early in their operative experience. The learning curve to achieve proficiency in robotic suturing is significantly lower than that of pure laparoscopic suturing. We (as others have) demonstrated in our own early experience that it was possible to perform robotic gastrointestinal anastomoses with an extremely low complication rate. It has been the anecdotal experience of the authors that robotic suturing also improves proficiency of laparoscopic suturing.

In addition, robotics has been a significant asset in revisional cases. In our published series (described earlier), we have demonstrated one of the lowest published conversion rates in the literature. We believe the value of robotics in revision has to do with visualization, precision of dissection, and the relative ease of suturing.

BARIATRIC SURGERY IN PATIENTS WITH MALIGNANCY

Understandably, there are few studies evaluating the role of preoperative weight loss surgery in patients with newly diagnosed malignancy. One of the only published studies reported four patients who underwent sleeve gastrectomy prior to definitive surgery for malignancy (small bowel carcinoid, renal hypernephroma, and prostate cancer). After a mean of about 3 months, these patients underwent definitive surgery for their malignancy. No adverse events were noted in this small group of patients. In carefully selected patients with early stage malignancy, preoperative weight loss surgery may be considered [53].

It is also important to note that the rate of gastric cancer following weight loss surgery (especially in gastric bypass in which an excluded portion of the stomach remains) is extremely low; less than 20 cases have been reported [54].

CONCLUSIONS

Since initially described, there has been a steady increase in the number of surgeons using robotics to perform weight loss surgical procedures [15]. Despite the increase in its use, the literature surrounding this topic is still relative limited. This offers a host of opportunities for development, research, and innovation. The current as well as future proposed robotic platforms offer potential in the advancement of decreased incision, single incision, and incision-less (endoscopic and natural orifice) surgery. The continued integration of radiologic imaging and other adjuncts for augmented visualization to allow for creation of a real time operative map may be especially useful in complex revisional cases, as has been utilized in other complex gastrointestinal and oncological surgeries [55]. The robotic platform provides superior visualization, increased degrees of movement, technological promise, and ergonomic advantages, and with future innovations and research, we are likely to see even more widespread adoption of this tool in bariatric surgical procedures. Despite the advantages purported by industry and surgeons who have adopted robotics into their practice, use of robotic platform is still relatively small in elective weight loss surgery [56]. It is crucial that we objectively evaluate the data and evaluate it with large comparative trials.

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