Review Article

Minimally invasive gastrointestinal surgery
Current status and future perspective: an evidence based review

Abdelrahman A Nimeri, MD, FACS
Assistant Clinical Professor of Surgery University of California, San Francisco, Department of Surgery, UCSF Fresno Medical Education Program

Abstract

The history of laparoscopy started as a primitive diagnostic procedure and it took close to a century before it became an effective therapeutic tool in the management of surgical problems. In this review, we examine the history of laparoscopy, methods of access, and the current application of minimally invasive surgery for the management of common gastrointestinal surgical problems. An evidence based review was utilized with emphasis on systematic reviews published from 1987 to 2009. Following the wide spread use of laparoscopic techniques for gall bladder removal, the benefits of laparoscopic surgery was established in the management of common gastrointestinal surgical problems. Laparoscopic management of colorectal cancer, morbid obesity, and gastroesophageal reflux diseases (GERD) are examined in this review based on the current review of the literature.

I. History of laparoscopy

The history of laparoscopy dates back to the beginning of the last century. The first 3 primitive laparoscopic examinations of the abdomen were performed by George Kelling in 1901, Dimitri Ott in 1901, and Hans Christian Jakobew in 1910. Initially, Kelling described an examination of the peritoneal cavity of an anesthetized dog. That same year, Ott examined the abdomen of a pregnant woman. Nine years later, Jacobeus performed several laparoscopic examinations of the abdomen in humans and human cadavers (1,2). However, it took over 80 years for the first video laparoscopic cholecystectomy to be performed by Philippe Mouret in 1987 for several reasons. The reasons why laparoscopy never improved from a diagnostic modality to therapeutic surgery for this long time were mainly due to the primitive optics, lack of an adequate light source, and poor instrumentation allowing for a very poor image of the peritoneal cavity projected at the end of the laparoscope. The images of

Correspondent author:
Abdelrahman A Nimeri
E-mail: nimeri@yahoo.com
the initial laparoscopic examinations were seen through the shaft of the laparoscope allowing only one person to evaluate the abdomen. The person looking through the laparoscope had to hold the laparoscope with one hand, which left only his other hand to manipulate intra-abdominal viscera. The assistant had no image to look at, which prevented the assistant from helping the surgeon in performing the laparoscopic examination. The introduction of the rod-lens optical system, cold light fiber glass illumination, and computer chip television camera allowed for projection the images on a screen for the entire surgical team to evaluate the abdomen. Projecting the images on a television screen, allowed the assistant to hold the camera, assist in the surgical procedures, and the surgeon had both hands free to manipulate intra-abdominal viscera. Initially, oxygen was used to inflate the abdomen, and create the space needed to facilitate the laparoscopic examination. However, the use of oxygen was changed to Carbon Dioxide (CO₂), for better absorption capacity, and lower risk of combustion associated with CO₂ use.

Laparoscopic surgery was performed in the 1960 and 1970s mainly for gynecologic reasons. So, it is no surprise that a French gynecologist, Philippe Mouret, performed the first video laparoscopic cholecystectomy. Today, laparoscopic cholecystectomy is considered the “gold standard” for patients with gall stone disease. The body habitus of the patient affects the method of access to the abdomen as well. Closed Veress needle access, the hybrid optical access may be easier than open entry, and even safer in obese patients. Conversely, closed and hybrid optical access may be more dangerous in very thin patients because of the short distance between the posterior fascia and the retroperitoneum.

II. Laparoscopic access to abdomen
Safe access to the peritoneal cavity is a key component of any laparoscopic procedure. Avoiding injury to intra-abdominal viscera and vascular structures must be kept in mind when choosing a method of access to the peritoneal cavity. Initially, Hans Christian Jacobus in 1910 attempted access to the peritoneal cavity in patients with ascitis to minimize the risk of injury to intra-abdominal viscera. Currently, three methods of access to the peritoneal cavity are used: closed, open and the hybrid visual method of access. Closed access is done using the spring loaded needle developed by Veress in 1938. This Veress needle is commonly used today and remains essentially unchanged from its initial design. The open access is done using direct cut down to the fascia followed by trocar placement under direct visualization. This technique was developed by Hasson. The hybrid visual access is done using an optical trocar mounted on a zero degree laparoscope with or without pneumoperitoneum to gain access to the abdomen under direct vision.

The location chosen for access depends on the method of access chosen. The best place for hybrid visual access is below the costal margin on either side of the abdomen, preferably on the left side, far away from large vessels and abdominal viscera after decompressing the stomach with an orogastric tube. This is our preferred technique of access to the peritoneal cavity unless there is a previous surgical scar at this location.

The body habitus of the patient affects the method of access to the abdomen as well. Closed Veress needle access, the hybrid optical access may be easier than open entry, and even safer in obese patients. Conversely, closed and hybrid optical access may be more dangerous in very thin patients because of the short distance between the posterior fascia and the retroperitoneum. The commonest area for closed and open access to the peritoneal cavity is the peri-umbilical region because it is the thinnest area of the abdomen. However, inadvertent injury to major vessels or viscera immediately below this area can happen with any method of access to the abdomen.
These injuries are classified according to the location of the injured organ into two types. Type I injury, when the vessel or viscera are in their normal location; and Type II injury, when the vessel or viscera are adherent to the anterior abdominal wall(5).

There is no consensus to the optimal method of entry to the peritoneal cavity(5). In a recent review published in the Cochrane data base regarding randomized controlled trials comparing different laparoscopic entry techniques(6). The total number of patients undergoing laparoscopy evaluated in the meta-analysis were 3040 patients. Overall, there was no advantage in terms of preventing major complications when different ways of entry to the peritoneal cavity are compared. However, the studies evaluated in this meta-analysis were small and could not be used to establish safety of any technique(6).

III. Laparoscopic colorectal surgery

The first laparoscopic sigmoid colon resection was performed by Jacobs in 1991(7). Today, laparoscopic colon resection is not only considered an acceptable alternative to standard open colon resection for the treatment of colon cancer, but in some cases it may be more effective(8,9). The effectiveness of Laparoscopic colectomy for colon cancer was evaluated recently; in the largest long term randomized controlled trial from a single institution comparing laparoscopic assisted versus open colectomy for colon cancer. This trial concluded that laparoscopic assisted colectomy is more effective than open colectomy for non-metastatic colon cancer(9).

In this study, also known as the Barcelona trial, 219 patients with colon cancer were randomized to laparoscopic assisted or open resection from 1993 to 1998(9). The median follow was 95 months (77-133). There was a trend towards higher cancer related survival (P=0.07, NS) and overall survival (P=0.06, NS) with no statistical significance. In addition, the probability of cancer related survival was higher in the laparoscopic assisted when compared to open colectomy (P=0.02). The regression analysis showed that laparoscopic assisted colectomy was associated with a lower risk of tumor relapse (hazard ratio 0.47, 95% CI 0.23-0.94), cancer related death (hazard ratio 0.44, 95% CI 0.21-0.92), and death from any cause (hazard ratio 0.59, 95% CI 0.35-0.98)(9).

The trial concluded that laparoscopic assisted colectomy is more effective than open colectomy for colon cancer. One of the criticisms of the Barcelona trial is that it is from a single institution with a large experience and the results may not be generalized in other centers.

The largest multi-institutional randomized controlled trial in North America comparing laparoscopic assisted to open colectomy for non-metastatic colon cancer is also known as the COST trial(10). This trial was a non-inferiority trial done across 48 institutions in the United States and Canada. Because of the design of the COST trial, it concluded that laparoscopic assisted colon resection is an acceptable alternative to open resection for colon cancer. 872 patients were randomized excluding patients with transverse, bulky, metastatic or rectal cancer patients. The median follow was 4.4 years, with the primary end point being the time to recurrence. The recurrence rate was similar at 3 years, 16% in the laparoscopic group compared to 18% in the open group (hazard ratio 0.86, 95% CI 0.63 to 1.17). The wound recurrence rate was similar as well, less than 1% in both groups. The overall survival was similar at 3 years, 86% in the laparoscopic group compared to 85% in the open group (hazard ratio 0.91, 95% CI 0.68 to 1.21). The time to recurrence and overall survival were similar in both groups.
when all stages of colon cancer were compared. Peri-operative recovery was faster in the laparoscopic group when compared to the open group. The hospital stay (5 Vs 6 days, \(P<0.001\)), use of parenteral narcotics (3 V 4 days, \(P<0.001\)), and oral analgesic use (1 Vs 2 days, \(P=0.02\)) were lower in the laparoscopic group when compared to the open group. The rates of intra-operative complications, 30 day mortality, re admission rate to the hospital, complication rate at discharge and 60 days, and re-operation were similar between both groups\(^{10}\).

The only randomized controlled trial that included rectal cancer patients, in addition to colon cancer patients undergoing laparoscopic assisted versus open resection was done in the United Kingdom\(^{11}\). This trial is also known as the CLASSIC trial, done between 1996 and 2002. 794 patients with non metastatic colon and rectal cancer were randomized 2:1 to laparoscopic assisted or open resection. The 3 year overall survival was similar in both groups (68.4% for laparoscopy and 66.7% for open resection), without a difference between colon and rectal cancer overall survival for any stage. There was a trend towards improved overall survival for laparoscopic rectal cancer patients with Duke Stage I (\(P=0.07\)). The 3 year disease free survival (time to local, distant, and port/wound site recurrence) was similar in both groups (66.3% for laparoscopy and 67.7% for open resection), without a difference between colon and rectal cancer overall survival for any stage. The same trend towards improved overall survival for laparoscopic rectal cancer patients with Duke Stage I (\(P=0.08\)) was seen in 3 year disease free survival\(^{11}\).

A recent meta-analysis evaluated all randomized controlled trials of colon and rectal cancer patients randomized to laparoscopic assisted versus open resection concluded that laparoscopic assisted colectomy is oncologically safe\(^{12}\). All trials included in the meta-analysis had 3 years of long term follow up and patients had curative intent surgery prior to March of 2000. All the trials mentioned above were included in this in addition to the COLOR trial, totaling 1765 patients. The 3 year disease free survival rate was similar in the laparoscopic assisted 75.8% versus open resection 75.3% (95% CI -5% to 4%). The 3 year overall survival rate was similar in the laparoscopic assisted 82.2 % versus open resection 83.5 % (95% CI -3% to 5%). There was no difference in disease free or overall survival for any stage of cancer\(^{12}\).

Another meta-analysis published in the Cochrane database evaluated randomized controlled trials with long term outcomes of laparoscopic resection of colon or rectal cancer were found to be no different than that of open resection\(^{13}\). In this 13 randomized controlled trials were identified comparing laparoscopic assisted versus open resection for colon cancer, totaling 3346 patients. Tumor recurrence was similar for colon cancer resection (5.2% for laparoscopic and 5.6% for open resection, 95% CI 0.47 to 1.52, \(P=0.57\)). Similarly, rectal cancer resection tumor recurrence was no different (7.2% laparoscopic and 7.7% open resection, 95% CI 0.45 to 1.43, \(P=0.46\)).

Cancer related death was similar for colon cancer resection (5.2% for laparoscopic and 5.6% for open resection, 95% CI 0.47 to 1.52, \(P=0.57\)). Similarly, rectal cancer related death was no different (7.2% for laparoscopic and 7.7% for open resection, 95% CI 0.45 to 1.43, \(P=0.46\)). Wound/port site recurrence was no different between laparoscopic and open resection patients for colon and rectal cancer, \(P=0.16\)\(^{13}\). Today, level I evidence shows that laparoscopic
assisted colectomy for colon cancer is not inferior to open resection oncologically. There is clear adoption to laparoscopic techniques for the management of colon cancer in the United States\textsuperscript{(14)}. Furthermore, a recent study from Barcelona\textsuperscript{(9)} concluded that laparoscopic assisted colectomy is more effective than open colectomy for colon cancer. However, the same is not true for laparoscopic resection for rectal cancer; since few of the randomized controlled trials done included patients with rectal cancer. Currently, there are randomized controlled trials underway to evaluate the long term outcomes of laparoscopic resection of rectal cancer (COLOR and COST trials)\textsuperscript{(8)}. Laparoscopic resection of rectal cancer holds great promise because of the anatomy of the pelvis being a confined space. The great visualization that laparoscopy provides, better definition of anatomic landmarks, and absence of the hand to obscure the visual field may aid in managing patients like obese males considered now difficult cases for open rectal resection. In the future, Natural Orifice Trans-luminal Endoscopic Surgery NOTES with the adoption of laparoscopic techniques in the management of rectal cancer may allow for the development of a hybrid operation because of the proximity rectal cancer to the natural orifice\textsuperscript{(8)}.  

**IV. Laparoscopic bariatric surgery**

Obesity is a disease defined by the National Institute of Health (NIH), and the surgical treatment for morbid obesity is the most effective long term therapy. Today, the vast majority of bariatric surgery is done laparoscopically in the United States\textsuperscript{(14,16)}. Furthermore, in a recent survey from the American Society of Metabolic and Bariatric Surgery 98% of the bariatric procedures performed were done laparoscopically\textsuperscript{(17)}. The first laparoscopic gastric bypass was done in the United States by Wittgrove et al in 1994\textsuperscript{(18)}. Obesity is approaching tobacco use as the number 1 preventable cause of death in the United States\textsuperscript{(19)}. Furthermore, the association between higher Body Mass Index (BMI) and increased mortality was established in a prospective cohort study of 1 million United States adults after over 14 years of follow up\textsuperscript{(20)}. The effect of bariatric surgery on mortality was established in a recent prospective trial published in 2007; bariatric surgery led to long term weight loss, and decreased mortality in obese Swedish subjects\textsuperscript{(21)}. In this trial, also known as the Swedish Obesity Study, 4047 obese subjects were prospectively matched to bariatric surgery 2010 subjects or conventional treatment 2037 subjects from 1987 to 2001\textsuperscript{(21)}. The bariatric surgeries performed included the now abandoned vertical banded gastroplasty (stomach stapling). During the 15 year period of the study, the average weight change for the conventional treatment group was ±2%. The maximum weight loss for the surgery group occurred 1-2 years after surgery: gastric bypass 32%, vertical banded gastroplasty 25%, and gastric banding 20%. After 10 years of follow the weight loss for the surgery group stabilized at gastric bypass 25%, vertical banded gastroplasty 16%, and gastric banding 14%. The primary outcome measured was overall mortality; this was known for 99.9% of the subjects enrolled. Of the surgery group 101 patients died, while 129 patients died in the conventional treatment group. The unadjusted overall hazard ratio was 0.76 in the surgery group (P=0.04) as compared to the conventional treatment group. The hazard ratio adjusted for sex, age, and risk factors was 0.71 (P=0.01). The most common cause of death were myocardial infarction (surgery group 13, and conventional treatment group 25.
Review Article
Gastrointestinal surgery Abdelrahman Nimeri

...subjects) and cancer (surgery group 29, and conventional treatment group 47 subjects)\(^{21}\).

Furthermore, a recent systematic review and meta-analysis of the literature concluded that morbidly obese patients achieved effective weight loss after bariatric surgery\(^{22}\). In addition, a substantial majority of morbidly obese patients with diabetes, hyperlipidemia, hypertension and obstructive sleep apnea had complete resolution of these medical problems or improvement\(^{22}\). The meta-analysis included 136 studies, and a total of 22,094 patients who had surgery between 1990 and 2003. Women represented 72.6% of patients, with a mean age of 39 years (16-64), and a mean body mass index (BMI) of 46.9 kg/m\(^2\) (32.3-68.8). The mean (95% confidence interval) percentage of excess weight loss was 61.2% (95% CI, 58.1%-64.4%) for all patients; for patients who underwent biliopancreatic diversion or duodenal switch it was 70.1% (95% CI, 66.3%-73.9%), for patients who underwent vertical banded gastroplasty it was 68.2% (95% CI, 61.5%-74.8%), for patients who underwent gastric bypass it was 61.6% (95% CI, 56.7.1%-66.5%), and for patients who underwent gastric banding it was 47.5% (95% CI, 40.7%-54.2%). The resolution of diabetes occurred in 76.8% of patients, and improved or resolved in 86%, hyperlipidemia improved in 70% of patient, hypertension resolved in 61.7% of patients, and improved or resolved in 78.5%, and obstructive sleep apnea improved in 85.7% of patients, and improved or resolved in 83.6%. The overall 30 day operative mortality was 0.1%.

Currently, several endoscopic techniques are developed to create a small gastric pouch endoscopically, or place an endoscopic sleeve across the duodenojejunual area to act as an endoscopic malabsorptive procedure. No published data with long term effective weight loss have been published yet.

V. Laparoscopic anti-reflux surgery

The first laparoscopic Nissen fundoplication for the treatment of gastroesophageal reflux disease (GERD) was reported by Dallemagne et al in 1991\(^{23}\). Today, there is level I evidence to show that laparoscopic nissen fundoplication is more effective than proton pump inhibitors in the control of reflux related symptoms\(^{24}\). However, this effectiveness depends on the experience and the quality of the surgeon. Conversely, there is level I evidence to show that no gold standard exists for the treatment of GERD, and that there is no consensus on a single effective therapy for patient with GERD\(^{25}\). Before considering surgical treatment for GERD, one needs to ascertain the presence of objective evidence for GERD\(^{24}\). While treating subjective GERD with medication is acceptable practice, the same does not hold true for the surgical treatment of GERD. Furthermore, GERD patients with subjective symptoms and normal preoperative 24hr pH study have significantly worse symptomatic outcome when compared to patients with abnormal 24hr pH study following laparoscopic Nissen fundoplication\(^{26}\). In addition, not all patients complaining of heartburn following antireflux surgery have objective evidence of GERD\(^{27}\).

The treatment of GERD was evaluated in a randomized controlled trial comparing open antireflux surgery (144 patients) to medical treatment with omeprazole (154 patients) with 7 years of follow up\(^{28}\). The primary outcome measure was treatment failure. More patients in the omeprazole group 66% failed, when compared to the open antireflux surgery group 46%, (P =0.002). However, more patients in the open antireflux surgery group complained of dysphagia, inability to...
Review Article
Gastrointestinal surgery Abdelrahman Nimeri

belch/vomit, and rectal flatulence as compared to the omeprazole group. Another study randomized GERD patients, in 11 European centers, to laparoscopic antireflux surgery (288 patients), and esomprazole (266 patients) with 3 years of follow up\(^{(29)}\). In this study, the proportion of patients having effective control of GERD symptoms were similar in the laparoscopic antireflux surgery group 90%, and the esomprazole group 93% (P=0.25). Both treatments were well tolerated, and were associated with low complication rates. However, mild dysphagia, and flatulence was more common in the laparoscopic antireflux surgery group than in the esomprazole group (P<0.001).

The experience and quality of the surgeon performing antireflux surgery is important for the effective treatment of GERD. It is established that GERD patients with abnormal 24hr pH study have excellent results following primary antireflux surgery\(^{(24)}\). However, reoperative laparoscopic antireflux surgery is associated with inferior results when compared to the excellent results following primary laparoscopic antireflux surgery for the treatment of GERD\(^{(24)}\). This fact was evaluated in a retrospective review of a large series of reoperative antireflux surgery totaling 176 patients between 1993 and 2006\(^{(30)}\). Failure of the primary antireflux surgery was defined by a symptoms score of > 2 or an abnormal 24hr pH study (Demeester score of >14.7). After median follow up of 9.2 months, with 82.4% of patients evaluated, a successful symptomatic outcome was achieved in 74.5% of patients (P=0.001). Odds of failure were higher in patients presenting with dysphagia as a presenting symptom (OR 3.38; 95% CI 1.35-8.40, P=0.0009) or needing an oesophageal lengthening procedure (OR 5.77; 95% CI 1.38-24.11, P=0.02).

The issue of tailoring the type of fundoplication (Nissen Vs Toupet) for patients with weak oesophageal peristalsis to prevent dysphagia postoperatively has been debated\(^{(31)}\). Recently, several studies have shown that this tailored approach is not necessary\(^{(31-33)}\). First, Patti et al retrospectively evaluated two groups of patients, totaling 357, following a selective (1992-1999) then non selective approach (1999-2002) based on the quality of oesophageal peristalsis\(^{(31)}\). All patients studied underwent laparoscopic fundoplication over the ten year period. In the selective group, there were 141 partial (Toupet), and 94 total (Nissen) fundoplication, while the non selective group contained 122 total (Nissen) fundoplication regardless of the oesophageal peristalsis. In the selective group, an abnormal 24hr pH study was found in 19% of patients after partial fundoplication and 4% after full fundoplication. In the nonselective group, an abnormal 24hr pH study was found in 4% of patients after full fundoplication. The incidence of postoperative dysphagia was similar in the selective and nonselective group. This study concluded that a Nissen fundoplication is the procedure of choice to treat GERD regardless of the oesophageal peristalsis.

Second, Booth et al randomized 127 patients (75 effective oesophageal peristalsis, and 52 with ineffective oesophageal peristalsis) into a Nissen (64 patients) or a Toupet fundoplication (63 patients)\(^{(32)}\). At one year, there was no difference in heartburn, regurgitation, or reflux symptoms in between the two groups; dysphagia of any degree (27% Vs 9%, P=0.18), and chest pain on eating (22% Vs 5%, P=0.18) was more common in the full fundoplication group. Treatment failure occurred in 8 patients (3 Nissen, and 5 Toupet fundoplication). This study concluded, there is no difference to
tailor the approach to a Nissen or Toupet fundoplication based on preoperative oesophageal peristalsis. Finally, Novitsky et al reported on a multicenter retrospective review of 48 consecutive patients with severe oesophageal dysmotility who underwent laparoscopic Nissen fundoplication. In this study, persistent dysphagia occurred in 2 patients (4.2%), while oesophageal dysmotility improved in most patients. The study concluded that severe oesophageal dysmotility should not be a contraindication to a Nissen fundoplication.

Currently, endoscopic management of GERD includes radiofrequency ablation, injection of biopolymer, and creating an endoscopic fundoplication. None of these techniques have been shown to reach the gold standard of laparoscopic Nissen fundoplication. However, they hold promise to be a part of the therapies available for treat GERD patients.

References